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

Anna P. Smith[1], Nicholaus Brosowsky[1], Samuel Murray[1], Rebecca Daniel[2], Matt E. Meier[2], and Paul Seli[1]

[1] Department of Psychology and Neuroscience, Duke University

[2] Department of Psychology, Western Carolina University

The mind-wandering literature is long on results and short on theory. One notable exception is the *Dynamic Framework*, a theoretical framework that characterizes mind wandering as thoughts that are relatively unconstrained from deliberate and automatic sources, or "freely moving." Critically, this framework makes numerous testable predictions, including (a) a positive association between freely moving thought and ADHD, (b) negative associations between freely moving thought and depression, anxiety, and OCD, and (c) a positive association between freely moving thought and divergent thinking ability. In Study 1, to test these predictions, we measured participants' reports of freely moving thoughts during a cognitive task and assessed divergent thinking and various psychopathological symptoms. Results failed to support any of the Dynamic Framework's predictions. In Study 2, we assessed the predicted relations between freely moving thought and divergent-thinking performance by manipulating thought constraint during a creative-incubation interval that preceded a divergent-thinking task. Here, we found some evidence (albeit very weak) to support the Dynamic Framework's prediction. Finally, in Study 3, we examined the possibility that indexing freely moving thought *during* a divergent-thinking task would yield the predicted associations but failed to find support for these associations. These results, most of which are at odds with the predictions of the Dynamic Framework, suggest either the need to revise the framework and/or that current methods are inadequate to properly test these predictions.

Public Significance Statement

Although the 2016 *Nature Reviews Neuroscience* article that first proposed and delineated the Dynamic Framework has played a prominent role in recent theoretical discussions of mind wandering and thought dynamics (and has since garnered 780 citations in only 5 years), surprisingly, to date, few of its core predictions have been tested. Our results suggest the need to dramatically revise the Dynamic Framework and/or the methodological tools it has offered to mind-wandering researchers. Given the decisive influence the Dynamic Framework has had on contemporary accounts of mind wandering and thought dynamics, our article will play a critical role in guiding future theory and research in the mind-wandering literature.

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

Since it was first integrated into mainstream psychology 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 et al., 2008; Smallwood, Fishman, & Schooler, 2007; Smallwood, McSpadden, & Schooler, 2007; Smilek et al., 2010; 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 articles implicitly or explicitly characterized mind wandering in terms of TUT (Mills, Raffaeli, 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, Raffaelli, et al., 2018).

The Dynamic Framework marks a significant departure from standard views of mind wandering. Whereas most researchers operationalize mind wandering in terms of task-unrelated thoughts, the

Anna P. Smith https://orcid.org/0000-0002-1365-0809

Rebecca Daniel https://orcid.org/0000-0001-7422-3299

Matt E. Meier https://orcid.org/0000-0003-2002-191X

De-identified data from our study are available at https://osf.io/58jyt/?view_only=31decc229af248bbbae096fc7b0fc186.

Correspondence concerning this article should be addressed to Anna P. Smith, Department of Psychology and Neuroscience, Duke University, 417 Chapel Drive, Durham, NC 27708, United States. Email: anna.p.smith@duke.edu

Dynamic Framework operationalizes mind wandering in terms of "freely moving thought," where thoughts move freely when they are relatively unconstrained (Mills, Herrera-Bennett, et al., 2018). Constraint is defined in terms of sustained topical focus, and thinking can be constrained by both deliberate, top-down processes (i.e., cognitive control), and automatic, bottom-up processes (i.e., attentional capture by affective or sensory salience). Mind wandering does not consist in an absence of either kind of constraint; instead, mind wandering is *relatively* unconstrained compared with other kinds of thinking. We can get a better idea of what this means by considering contrasting states of thought that differ as a function of constraint. 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 et al., 2018, p. 958), or, as mentioned above, freely moving thoughts that are relatively unconstrained by deliberate or automatic processes. Hereafter, we use the term "unconstrained thought" to refer more specifically to the absence of automatic and deliberate constraint within the Dynamic Framework's theoretical space, and "freely moving thought" to refer to the emergent phenomenological quality of relatively unconstrained thought.

Proponents of the Dynamic Framework have proposed novel methods to measure mind wandering. Typically, researchers measure mind wandering with thought probes that are randomly interspersed throughout a task (Smallwood & Schooler, 2015). These probes ask participants to report whether, just prior to probe onset, one was paying attention to the task or not (Weinstein, 2018). Although this can serve as an adequate measure of task-unrelated thought, researchers operating within the Dynamic Framework have raised concerns about whether these probes adequately index the underlying dynamics of thought (Christoff et al., 2016; Irving, 2016; Irving & Glasser, 2020; Murray et al., 2020; Sripada, 2018). Alternative measures have been proposed. For example, Mills, Raffaelli, et al. (2018) measured thought constraint by asking participants whether their thoughts were moving about freely (see also Alperin et al., 2021; Kam et al., 2021). Recent work using these probes shows that self-reported freely moving thought and task-unrelated thought are dissociable both behaviorally (Mills, Raffaelli, et al., 2018; Smith et al., 2022) and neurally (Fox et al., 2013, 2015; Kam et al., 2021). To date, however, research on the dynamics of mind wandering has operated with this single-item probe about freely moving thought.

The Dynamic Framework makes several predictions about individual-differences correlates of relatively unconstrained thought. Only one of these predictions has been tested in previous work. Christoff et al. (2016) claimed ADHD is widely recognized as a disorder of unconstrained thought that manifests in excessive *variability* in thought movement. Hence, Christoff et al. (2016) predicted that people with ADHD ought to more frequently experience unconstrained thinking than those without ADHD. Alperin et al. (2021) tested this prediction in a clinical population of adults with ADHD and found incidence of off-task thought, as well as a greater proportion of this off-task thought being "freely-moving" compared with non-ADHD controls.

Conversely, depression and anxiety are disorders often marked by a relative *rigidity* 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 (Mathews & MacLeod, 2005; Watkins, 2008). Thus, Christoff et al. predict that people experiencing higher levels of depression and those experiencing higher levels of anxiety ought to experience less unconstrained thinking relative to people experiencing lower levels of depression/anxiety. Per Christoff et al., those whose thoughts manifest as obsessive (fixed) patterns presenting as OCD should also exhibit lower rates of unconstrained thinking relative to those with fewer obsessive thoughts.

In addition to predicting associations between unconstrained thought and clinical symptomatology, the Dynamic Framework makes predictions about how unconstrained thought relates to creativity.[1] According to this framework, and in line with previously proposed models of creative cognition (e.g., Beaty et al., 2014, 2015, 2016), some forms of creativity reflect dynamic alternations between two complementary processes: generation and evaluation (see also Girn et al., 2020). As Christoff et al. (2016) note,

> Creative thinking may be unique among other spontaneous-thought processes because it may involve dynamic shifts between the two ends of the spectrum of constraints. The creative process tends to alternate between the generation of new ideas, which would be highly spontaneous (i.e., freely moving), and critical evaluation of these ideas, which could be as constrained as goal-directed thoughts (p. 720).

Thus, whereas the generative component of creative thinking is characterized by its relative lack of constraint, the evaluative component is characterized by relatively high levels of constraint. Two predictions follow from this. First, given the connection between idea generation and relatively unconstrained thought, there should be a positive association between tendency to engage in unconstrained thought and idea generation during a divergent thinking task. Second, because *creative ideas* result from alternations between constrained and unconstrained thought, then individuals who balance between unconstrained (generative) and constrained (evaluative) thinking should perform better on tasks that measure creativity. In particular, this balance between constrained and unconstrained thinking might reflect a quadratic relationship between thought constraint and creativity, wherein extreme rates of unconstrained or constrained thought might correspond to low levels of creativity, while a combination of the two might correspond to higher levels of creativity.

To date, only a handful of studies have tested the predictions of the Dynamic Framework (Alperin et al., 2021; Irving et al., 2020; Kam et al., 2021; Mills, Herrera-Bennett, et al., 2018; O'Neill et al., 2021; Smith et al., 2022). With the exception of Alperin et al. (2021), these studies focus more on the thought probe methodology itself, its relation to existing measures of mind wandering, and

[1] For related research on the association between task-unrelated thoughts and creativity, see Baird et al. (2012), Smeekens and Kane (2016), and Murray et al. (2021).

its nature as a psychological construct (Kam et al., 2021; O'Neill et al., 2021; Smith et al., 2022). The absence of studies that use these methods to directly address the predictions of the Dynamic Framework is surprising, both because the 2016 review outlining the Dynamic Framework is one of the most widely cited mind-wandering papers (with 817 citations[2]), *and* the Dynamic Framework is one of the few systematic theories of mind wandering offered to date. Across three studies, we aimed to examine some of the key predictions of the Dynamic Framework and better understand its existing associated methods. In particular, we wanted to know whether the single-item measure of freely moving thought (used by proponents of the Dynamic Framework) is sufficiently fine-grained to assess the predictions of the Framework. In particular, we test the four predictions outlined below:

1. Freely moving thought is positively associated with ADHD symptomatology (Study 1).
2. Freely moving thought is negatively associated with depressive, anxious, and obsessive thought patterns (Study 1).
3. Freely moving thought is positively associated with the number of ideas generated during a creativity task (i.e., fluency; Studies 1, 2, and 3).
4. When plotting creativity as a function of rates of freely moving thought, we should find an inverted U-shaped function (Studies 1, 2, and 3).

Study 1

In Study 1, we administered a 2-back task during which we intermittently presented thought probes that indexed rates of freely moving 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). With respect to the AUT, we assessed both fluency—the number of ideas generated—and creativity—the extent to which the ideas were rated as creative.

Additionally, we administered trait-level measures of deliberate and spontaneous mind wandering (MW-D and MW-S, respectively; Carriere et al., 2013). The rationale for including 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., 2021), we wanted to determine whether trait levels of spontaneous and deliberate mind wandering were dissociable from state-level reports of freely moving thought. Second, and more important, if we did not find the hypothesized relations between freely moving thought 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 et al., 2019; Seli et al., 2017; Seli, Smallwood, et al., 2015), we expect to again observe these previously reported patterns of results.

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, $M_{\text{age}} = 38.13$, $SD_{age} = 11.39$). With 225 participants, we were powered to detect positive correlations as small as $r = .16$ with 80% power, as calculated using the R packages *pwr* and *pwr2ppl* (Aberson, 2020; Champely, 2020). 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. We used the 2-back task because participants exhibit moderate rates of freely moving thought during it (Brosowsky et al., in press). Instructions and stimuli were displayed in the center of the screen. Stimuli consisted of the letters B, F, K, H, M, Q, R, × 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 interstimulus 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 four possible targets and participants were required to correctly respond to at least two of the four to proceed to the task. During the experimental trials the average number of possible targets was 29. Thought probes were also presented randomly throughout, except for 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: $d' = z(\text{FA}) - z(\text{H})$, 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 pseudorandomly 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 vs. unintentional TUTs; Seli, Cheyne, et al., 2015), and (c) freely moving 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: (a) Focused on the task; (b) Not focused on the task, but I

[2] Google Scholar, February 15, 2022.

was trying to focus on it; (c) Not focused on the task, but I was not trying to focus on it" (O'Neill et al., 2021). Following their response to this probe, to assess relatively unconstrained thought, participants answered either "yes" or "no" to the prompt: "The thoughts I was experiencing were moving freely" (Mills, Herrera-Bennett, et al., 2018).[3] Task-unrelated thought (TUT) was calculated as the proportion of responses indicating "not focused on the task," whereas freely moving thought was calculated as the proportion of "Yes" responses to the freely moving thought prompt.

As noted above, in addition to indexing freely moving thought, we also indexed the task-relatedness of participants' thoughts; this was done to maintain consistency with recent work examining thought constraint (Mills, Herrera-Bennett, et al., 2018; Smith et al., 2022). However, because the predictions we are testing do not concern the task-relatedness or intentionality of mind wandering, we do not analyze these data in the present article.

Short-Form of the Adult Self-Report ADHD Scale. The Adult Self-Report ADHD Scale (ASRS) comprises 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, et al., 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. The Dimensional Obsessive-Compulsive Scale (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 nonclinical populations (Eilertsen et al., 2017), and positively correlates with unintentional mind wandering (Seli et al., 2017). The total DOCS score was computed by summing each 1 (low occurrence) to 4 (high occurrence) scale.

Depression, Anxiety, and Stress Scale. The Depression, Anxiety, and Stress Scale (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; Osman et al., 2012), this instrument captures aspects of emotional health that might be expected to be positively associated with highly constrained, depressive 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 seven questions each between depression, anxiety, and stress symptoms, and total scores were summed for each category. Note that, whereas 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.

The Alternate Uses Task. 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 creative and unusual uses for two separate objects: *marble* and *balloon*. For each object, participants were allotted three minutes to list their generated uses. The exact instructions they received are copied in Appendix C.

As in previous work (e.g., Silvia et al., 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 (two females, $M_{\text{age}} = 38.13$) 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 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 similar to previous studies that use subjective ratings (Cronbach's $\alpha = .68$; Silvia et al., 2008; Smeekens & Kane, 2016).

Spontaneous and Deliberate Mind Wandering. At the end of the study, we assessed participants' trait levels of spontaneous and 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 on a 7-pt. Likert scale (1 = *rarely*, 7 = *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 characteristics of freely-moving thoughts (Mills, Herrera-Bennett, et al., 2018; see Appendix B), after which they began the 15-minute 2-back task. Intermittently, the task

[3] Notably, Mills, Herrera-Bennett, et al. (2018) used a 7-point scale to assess the extent to which participants' thoughts were (un)constrained. However, for some of their key analyses, they converted responses from the continuous scale into binary responses, such that thoughts were classified as either constrained or unconstrained. More recently, Alperin et al. (2021) likewise used a 7-point scale and, for their analyses, they converted responses into a binary measure. Given concerns surrounding researcher degrees of freedom (if we used a 7-point scale, we could have examined the continuous data as they were, created a post-hoc dichotomy, or both), and given that the binary scale performed well in Mills et al. and Alperin et al., we opted to use a dichotomous probe (which has the added benefit of data retention, as we did not have to drop "4" responses when converting the 7-point scale into a binary scale).

paused a total of ten times to probe participants to report on the task-relatedness and extent to which their thoughts moved freely. On 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.

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 freely moving thought.

We supplemented the null hypothesis significance tests with Bayes Factor analyses to quantify the evidence for a null effect (Rouder et al., 2009). Conventionally, null hypothesis testing does not allow one to quantify the evidence for a null effect (but see Lakens et al., 2018 for an alternative frequentist method). The 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). These tests are based on Jeffreys' (1961) test for linear correlation. Our Bayes Factors for correlation analyses use non-informative priors for population means and variances, and a shifted, scaled beta (1/kappa, 1/kappa) prior distribution for rho (Ly et al., 2018). For linear regression analyses, we estimated Bayes factors using the default Jeffreys prior and modeled prior beliefs using a Cauchy distribution centered around 0, with a default scale factor of .707. Bayes Factors were computed using the R package BayesFactor and Bayes Factors (BFs; 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).

Freely Moving Thought and ADHD, Depression, Anxiety, Stress, and OCD

We began by examining the relations between probe-caught rates of freely moving thought and self-report measures of clinical symptomatology (i.e., ADHD, OCD, anxiety, stress, and depression; see Figure 1). We used directional Bayesian analyses to quantify the evidence for or against the Dynamic Framework predictions Inconsistent with the prediction that people reporting higher levels of ADHD symptomatology should experience higher rates of freely moving thought, we found a nonsignificant 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 freely moving thought due to the inclusion of entrenched, ruminative thought patterns captured by those questionnaires. However, there was no statistically significant correlation between freely-moving thought and anxiety, $r = .10$, 95% CI [−.03, .22], $t(223) = 1.45$, $p = .149$, or depression, $r = .04$, 95% CI [−.09, .17], $t(223) = .57$, $p = .572$, with moderate to strong evidence in favor of the null, (depression: $BF_{0-} = 9.56$; anxiety: $BF_{0-} = 15.11$). Next, and inconsistent with the Dynamic Framework's prediction, we found a significant *positive* correlation between OCD symptoms and freely moving thought, $r = .16$, 95% CI [.03, .29], $t(223) = 2.46$, $p = .015$, with strong evidence in favor of the null, $BF_{0-} = 21.96$.

Freely Moving Thought and Divergent Thinking

The Dynamic Framework predicts that freely moving thought is associated with the generation of ideas. To assess this prediction, we measured the relationship between freely moving thought and fluency during the AUT, a widely used measure of

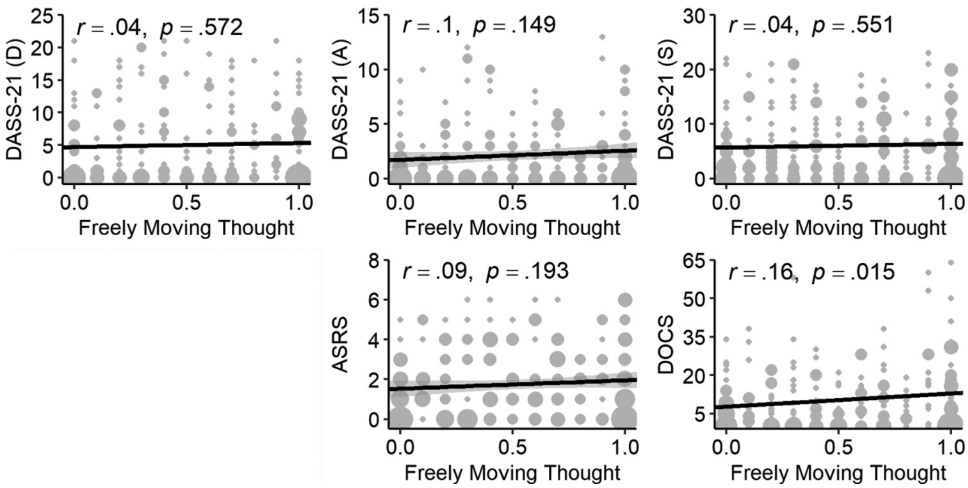
Table 1
Means, Standard Deviations, and Pearson Correlation Matrix From Study 1

Variable	*M*	*SD*	α	1	2	3	4	5	6	7	8	9	10	11
1. FMT	.52	.37												
2. Creativity	2.03	.33		−0.20*										
3. Fluency	11.05	5.23		−.16*	.08									
4. N-Back (d©)	2.21	.83		−.26**	.19*	.31**								
5. N-Back (c)	.46	.26		.05	.11	−.01	−.03							
6. MW-S	3.89	1.57	.88	.09	.08	.03	−.12	−.04						
7. MW-D	3.93	1.47	.86	.05	.07	.03	−.04	.07	.37**					
8. ASRS	1.75	1.79	.85	.09	.12	−.04	−.06	.08	.54**	.29**				
9. DASS-21-D	5.02	6.11	.95	.04	.13	−.06	−.03	−.03	.40**	.14*	.50**			
10. DASS-21-A	2.16	3.22	.90	.10	.04	−.11	−.14	−.03	.33**	.14*	.48**	.70**		
11. DASS-21-S	6.05	6.09	.91	.04	.12	−.03	−.08	−.07	.38**	.1	.55**	.75**	.78**	
12. DOCS	10.49	11.87	.96	.16*	.02	−.11	−.22	.11	.30**	.13	.45**	.61**	.71**	.67**

Note. FMT = freely moving 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. Creativity interrater reliability α = .68.
$^{*}p < .05$. $^{**}p < .001$.

Figure 1

Correlations Between Proportion Freely Moving Thought and Measures of Clinical Symptomology Including the DASS-21 Depression (D), Anxiety (A), and Stress (S), the ASRS and the DOCS



Note. DASS-21 = Depression, Anxiety, and Stress Scale – 21 items; ASRS = Adult Self-Report ADHD Scale; DOCS = Dimensional Obsessive-Compulsive Scale.

divergent thinking. We observed a significant, *negative* correlation between freely moving thoughts and fluency, $r = -.16$, 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). Likewise, the creativity ratings of AUT responses were also negatively associated with freely moving thought, $r = -.20$, 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, $BF_{-0} = 24.87$. Interrater reliability for AUT responses was calculated as Cronbach's $\alpha = .68$.

Also recall that the Dynamic Framework builds on the insight that creative ideas result from alternating between generative and evaluative thinking to predict that people who balance between freely moving (generative) and constrained (evaluative) thinking will score higher on measures of creativity. To test this prediction, we used the 'Robin Hood' method (Simonsohn, 2018): This method sets a breakpoint in the data and, using two regression lines, tests for a positive slope in the first half, and negative slope in the second half. If the two slopes have opposite signs and are individually statistically significant, then we reject the null that there is no U-shaped (or inverted U-shaped) effect (Simonsohn, 2018). At odds with this prediction, we found no evidence for a positive slope, $b = .11$, $z = .62$, $p = .534$, but did find evidence for a negative slope, $b = -.31$, $z = -2.4$, $p = .017$ (Figure 3).

Finally, we conducted a set of additional, exploratory analyses examining the rate of switching between freely moving and constrained thought. We speculated that the benefit of freely moving thought to creativity may not be evident when evaluating freely moving thought in terms of quantity (i.e., the number of freely moving thought responses reported), but in terms of oscillatory dynamics: the rate of switching between freely moving and constrained thought.[4] Balanced oscillation would indicate equitable amounts of generation and evaluation, and balanced thinking might result in higher measures of creativity relative to either completely generative or completely evaluative thinking. To that end, for every participant, we calculated the proportion of probe-to-probe sequential switches in responding, where 100% would indicate that they switched their response on every thought probe and 0% would indicate that they responded the same on every thought probe.

First, we found a small, significant, correlation between switch rate and creativity scores, $r = .14$, 95% CI [.01, .27], $t(223) = 2.18$, $p = .03$. However, there was only anecdotal evidence for the positive association over the null, $BF_{+0} = 2.99$, and strong evidence for the null over the negative association, $BF_{0-} = 20.04$. Next, we found no significant correlation between the switch rate and fluency scores, $r = -.03$, 95% CI [−.16, .11], $t(223) = -.38$, $p = .701$, with moderate evidence for the null over the positive association, $BF_{0+} = 8.51$, and moderate evidence for the null over the negative association, $BF_{0-} = 4.63$. Taking the significant, negative relationship between freely moving thought and fluency and the weak evidence for switch rate corresponding to creativity scores, we find weak to no evidence of an association between the expected profile of freely moving and constrained thought during creative thinking.

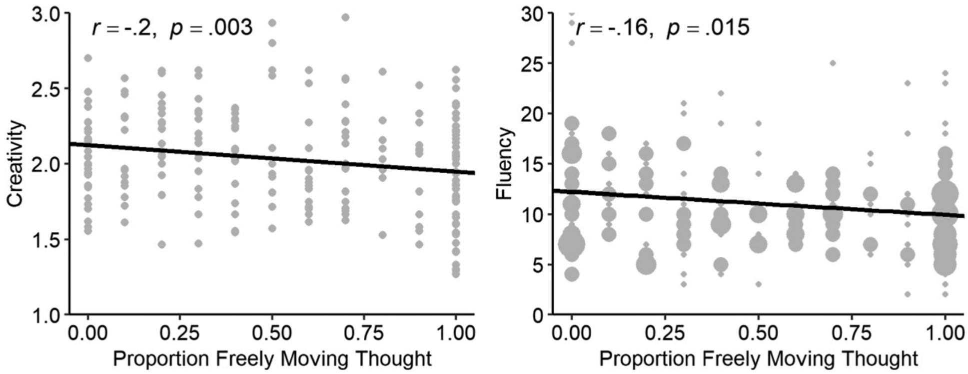
Spontaneous and Deliberate Mind Wandering and Freely Moving Thought

To determine whether state-level reports of freely moving thought are dissociable from trait-level reports of spontaneous and deliberate mind wandering, we analyzed the rates of freely moving thought using a linear regression with spontaneous (MW-S) and

[4] We thank the reviewers for this suggestion.

Figure 2

Correlation Between Alternate Uses Task (AUT) Creativity and Fluency Scores and Freely Moving Thought Proportions



deliberate (MW-D) mind wandering as explanatory variables. Previous work demonstrated high reliability for both the MW-S (α = .88) and MW-D (α = .89) scales (Seli, Cheyne, et al., 2015). Here, neither spontaneous mind wandering, $b = .02$, 95% CI [−.01, .05], $t(222) = 1.14$, $p = .254$, nor deliberate mind wandering, $b = .01$, 95% CI [−.03, .04], $t(222) = .32$, $p = .747$, predicted unique variance in freely moving thought, and the full model did not predict a statistically significant amount of variance, model fit $R^2 = .01$, 90% CI [.00, .03], $F(2, 222) = .97$, $p = .379$. Using a Bayesian analysis, we found moderate evidence favoring the intercept-only model over the full model (i.e., the model with spontaneous and deliberate mind wandering predictors), $BF_{01} = 3.44$. These findings (along with the nonsignificant bivariate correlations between MW-S, MW-D, and freely moving thought presented in Table 1) indicate, consistent with recent work (O'Neill et al., 2021), that the dynamic 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 freely moving thought and the various individual-differences measures was not the result of measurement error, we sought to determine whether we could replicate previously reported associations 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.

Adult Self-Report ADHD Scale. Replicating previous work (Seli, Smallwood, et al., 2015), we found that spontaneous mind wandering was positively associated with ADHD symptomatology (ASRS), $b = .57$, 95% CI [.44, .71], $t(222) = 8.30$, $p < .001$, and deliberate mind wandering was not, $b = .13$, 95% CI [−.02, .27], $t(222) = 1.72$, $p = .088$; model fit: $R^2 = .30$, 90% CI [.21, .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. The ASRS has been demonstrated to have high reliability in nonclinical populations (α = .80; Green et al., 2019).

Dimensional Obsessive-Compulsive Scale. Consistent with previous work (Seli et al., 2017), 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], $t(222) = .54$, $p = .591$; model fit: $R^2 = .09$, 90% CI [.03, .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. Like the ASRS, DOCS also has been shown to be a strongly reliable measure (α = .9; Abramowitz et al., 2010).

Depression, Anxiety, and Stress Scale 21. Finally, the results are the same for all three DASS-21 measures, and replicate results from recent work (Seli et al., 2019): Spontaneous mind wandering was positively associated with the measure of depression, $b = 1.56$, 95% CI [1.05, 2.07], $t(222) = 6.07$, $p < .001$, whereas deliberate mind wandering was not, $b = -.02$, 95% CI [−.57, .52], $t(222) = -.08$, $p = .934$; model fit: $R^2 = .16$, 90% CI [.09, .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. In the literature, the depression (α = .85), anxiety (α = .85), and stress (α = .87) subscales are shown to be reliable in nonclinical populations (Asghari et al., 2008).

Spontaneous mind wandering was positively associated with anxiety, $b = .66$, 95% CI [.39, .94], $t(222) = 4.76$, $p < .001$, whereas deliberate mind wandering was not, $b = .04$, 95% CI [−.26, .33], $t(222) = .26$, $p = .793$; model fit: R2 = .11, 90% CI [.05, .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], $t(222) = 5.97$, $p < .001$, whereas again, deliberate mind wandering was not, $b = -.18$, 95% CI [−.72, .37], $t(222) = -.64$, $p = .522$; model fit: $= R^2$ .15, 90% CI [.08, .22], $F(2, 222) = 19.22$, $p < .001$. Once again, the direction and significance of these relationships are in accordance with previous work that spontaneous mind wandering is significantly, positively associated with all three manifestations of affective dysfunction (Seli et al., 2019). 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 replications of previous associations suggest that our failure to observe the Dynamic Framework's predicted relations between freely moving thought and the various measures of clinical symptomatology was likely *not* a consequence of measurement error (from measures other than the thought probes assessing freely moving thought).

Freely Moving Thought and 2-Back Task Performance

Finally, for exploratory purposes, we examined the relation between rates of freely moving thoughts and performance (measured as *d* prime) on the 2-back task (see Figure 4). Consistent with recent research suggesting that freely moving thinking is resource demanding (Brosowsky et al., 2021), we found that participants who engaged in higher rates of freely moving thought 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 favoring the alternative over the null, $BF_{10} = 338.86$.

Discussion

This study aimed to test four predictions of the Dynamic Framework: namely, that freely moving thought is (a) positively associated with ADHD symptomatology and (b) negatively associated with depressive, anxious, and obsessive thought patterns. Moreover, (c) higher rates of freely moving thought are associated with greater fluency in the AUT, and (d) the relationship between performance on the AUT and freely moving thought is quadratic. We failed to find evidence in support of these predictions.

With respect to the lack of support for the predictions pertaining to freely moving thought and divergent thinking (predictions c and d), it is important to note that we tested these predictions by obtaining a measure of freely moving thought during a 2-back task, which did not permit creative incubation. Indeed, while engaging in freely moving thought during the 2-back task, participants could not generate ideas related to the AUT because they did not know about it. However, the Dynamic Framework might predict that higher rates of unconstrained thinking and balanced oscillatory dynamics are associated with greater creativity only when this unconstrained thinking occurs during a creative incubation interval. Thus, participants being unaware of the subsequent AUT cue reflects a crucial limitation on our ability to interpret the AUT results in light of the Dynamic Framework. To correct this limitation, we conducted another study.

Study 2

In Study 2, we tested whether we could experimentally manipulate the frequency of freely moving thought *during a creative-incubation interval.* Our predictions were that (a) increasing rates of freely moving thought during incubation would lead to greater fluency on the AUT, and (b) people who alternate between constrained and freely moving thinking during the creative-incubation interval would tend to perform better on the AUT. To test the first prediction, we manipulated rates of freely moving thought by using a task-difficulty manipulation that has recently been shown to effectively influence rates of freely moving thought (Brosowsky et al., 2021). In particular, participants completed either a 0-back (easy) or 2-back (difficult) task. As in Brosowsky et al., we expected to find that participants completing the easy 0-back task would engage in a higher proportion of freely moving thought than those completing the more difficult 2-back task. To test the second prediction, we explored if there was a quadratic relationship between freely moving thought and AUT creativity score.

To create an incubation interval, participants were first instructed to provide creative uses for a single object (balloon), after which they completed the n-back task (0-back or 2-back), after

Figure 3

Use of the "Robin Hood" Method Shows No Evidence for a U-Shaped Relationship Between Alternate Uses Task (AUT) Creativity Score and Proportion of Freely Moving Thought

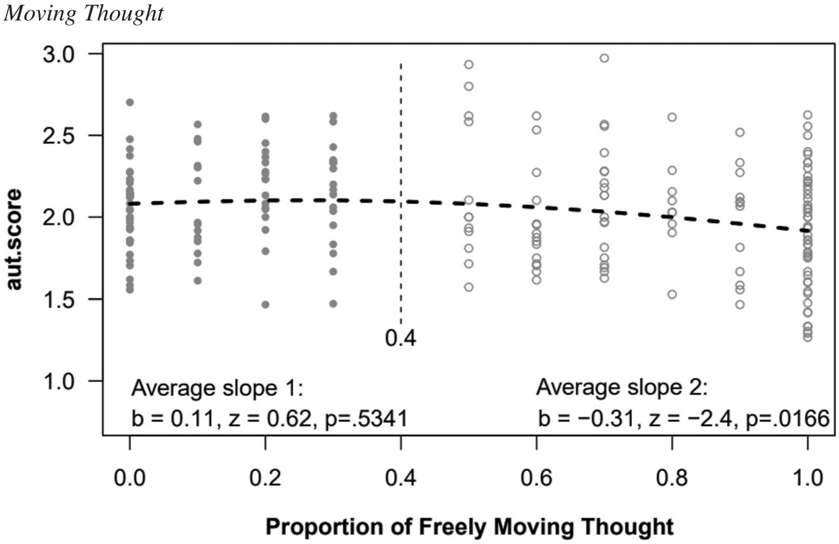
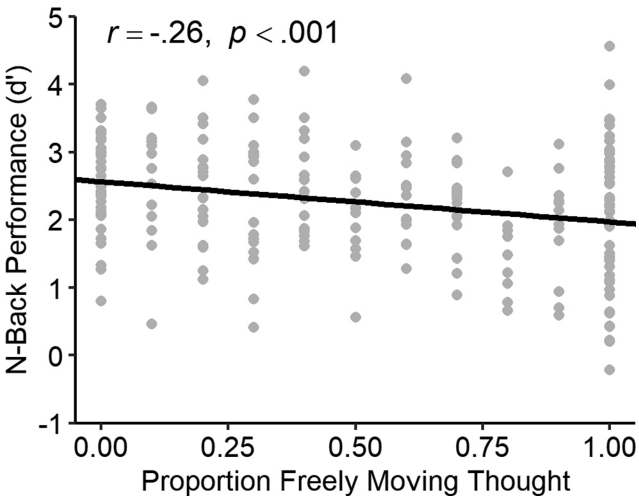


Figure 4

Correlation Between Performance on the 2-Back Task (Measured as d Prime) and Proportions of Freely Moving Thought



which they were given a surprise second round of the AUT for which they were instructed to produce new creative uses for "balloon" (i.e., they were instructed to refrain from repeating answers from the first round of the AUT; for a similar design, see Baird et al., 2012). Here, the rationale was that the n-back task would serve as an incubation interval during which participants could generate and/or evaluate new ideas for the second iteration of the AUT (using the same object cue from the first iteration: balloon). If, as predicted by the Dynamic Framework, freely moving thought facilitates idea generation, then participants engaging in higher rates of freely moving thought during the incubation interval (i.e., those completing the easy 0-back task) should, on the second iteration of the AUT, generate more uses for "balloon" than those engaging in lower rates of freely moving thought (i.e., those completing the difficult 2-back task). With respect to the second hypothesis, we tested for a quadratic relationship between freely moving thought and performance on the subsequent AUT in both the 0-back and 2-back conditions. If striking a balance between freely moving and constrained thinking facilitates greater creativity, then we should observe a significant quadratic effect in both n-back conditions.

In addition to examining differences in freely moving thought 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 perform better on the AUT (both in terms of fluency and creativity).

Finally, using a flow-state questionnaire (Marty-Dugas, 2020), 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) test the recent hypothesis (O'Neill et al., 2021) that there may be overlap between the experience of flow states (Csikszentmihalyi, 1988) and the experience of freely moving thought. In particular, O'Neill et al. found that participants sometimes reported thoughts that were both on-task *and* freely moving and suggested that this experience might reflect a flow state during which people are engaged in deep, effortless concentration (Marty-Dugas, 2020). Hence, the prediction that can be derived from O'Neill et al. is that people who more frequently report the experience of on-task *and* freely moving thoughts should also tend to be more likely to experience flow states.

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, with 150 per n-back group.[5] We estimated power using an ANCOVA with n-back as a factor and pretask AUT scores as a covariate. With 150 participants per group, we could detect a partial-eta squared as small as .027 (corresponding to a difference in AUT creativity scores between groups of .2 [e.g., $M = 2.5$ vs. $M = 2.7$]) with 83% power (assuming AUT scores had a standard deviation of .7 and a correlation between preintervention AUT scores and postintervention AUT scores of .45). Participants were restricted to US citizens with 98% HIT approval ratings and more than 5,000 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 72-px 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 (four even and four odd). Nontarget stimuli were presented in black font, and target stimuli were presented in red font. Target stimuli were randomly inserted once in every eight-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 respond only 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

[5] Owing to a coding error, we were not able to collect demographics information for Study 2.

while completing the n-back task on a scale of 1 to 5 (*never*, *rarely*, *occasionally*, *a moderate amount*, or *a great deal*).

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

The Alternate Uses Task. Participants completed two AUT tasks, one before the n-back task (i.e., preincubation) and one following the n-back task (i.e., postincubation). 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. Creativity ratings were provided by three human raters (two females, $M_{\text{age}} = 38.13$, $SD_{age} = 11.39$).

Procedure

First, participants completed the preincubation AUT—with "balloon" as the object— immediately after which they were asked to report on their level of flow during the preincubation AUT. Next, they completed the n-back task. On 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 (postincubation) with the same object (balloon) from preincubation AUT. Finally, participants reported on their level of flow during completion of the postincubation 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 whether they had used any outside resources 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 postincubation 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).

Freely Moving Thought Across n-Back Groups

First, we compared rates of freely moving thoughts across n-back groups and found that the 0-back group reported significantly more freely moving thoughts than those in the 2-back group, $M_d =$ .31, 95% CI [.23, .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 freely moving thoughts.

Next, we correlated n-back performance with freely moving thought and found a nonsignificant association in the 0-back group, $r = -.005$, 95% CI [−.17, .16], $t(133) = -.05$, $p = .958$, with strong evidence in favor of the null, $BF_{01} = 5.02$. N-back performance was, however, negatively correlated with freely moving thought in the 2-back group, $r = -.20$, 95% CI [−.35, −.03], $t(137) = -2.36$, $p = .02$, although there was only anecdotal evidence in favor of the alternative, $BF_{10} = 2.72$.

Freely Moving Thought and Divergent Thinking

Freely Moving Thought and Divergent Thinking Across N-Back Groups. Once again, interrater reliability on the AUT for this study was within the acceptable range (Cronbach's $\alpha = .74$). The primary question of interest was whether a change in task demands, via an n-back manipulation, influenced AUT scores by altering the proportion of thoughts that are freely moving. To examine this possibility, we analyzed the data using two linear regression models that accounted for participant performance in the preincubation AUT. In the first model, we analyzed postincubation AUT creativity ratings and included preincubation creativity ratings and n-back group as explanatory variables, $R^2 = .22$, 90% CI [.15, .29], $F(2, 271) = 37.84$, $p < .001$. The effect of preincubation creativity ratings was statistically significant, $b = .54$, 95% CI [.42, .66], $t(271) = 8.70$, $p < .001$, but n-back group was not, $b = -.02$, 95% CI [−.12, .08], $t(271) = -.43$, $p = .668$. Using a Bayesian analysis, the model containing only preincubation creativity ratings was preferred over the full model by a factor of 4.03.

In the second regression model, we analyzed postincubation AUT fluency scores (i.e., the number of generated responses) and

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

Variable	*M*	*SD*	α	1	2	3	4	5	6	7	8	9	10
1. FMT	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	.91	0.17*	−0.09	−0.06	−0.07	<.01	−0.03	−0.08	−0.15		
10. Flow (Pre)	0.48	0.69	.93	−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	.95	0.02	0.10	−0.17*	0.02	0.06	0.12	0.11	0.01	0.17	0.12

Note. FMT = freely moving thought; TAA = Thinking about the Alternate Uses Task (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

Variable	*M*	*SD*	α	1	2	3	4	5	6	7	8	9	10
1. FMT	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	.88	0.15	−0.03	0.04	0.06	0.06	0.12	−0.03	−0.09		
10. Flow (Pre)	0.41	0.82	.90	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	.95	0.16	−0.05	0.06	−0.17*	0.27*	<.01	0.01	0.05	0.30**	0.46**

Note. FMT = freely moving thought; TAA = Thinking about the Alternate Uses Task (AUT) during the AUT.
* $p < .05$. ** $p < .001$.

included preincubation AUT fluency scores and n-back group as explanatory variables, $R^2 = .45$, 90% CI [.37, .52], $F(2, 271) = 109.75$, $p < .001$. Here, preincubation scores, $b = .77$, 95% CI [.66, .87], $t(271) = 14.65$, $p < .001$, and n-back group, $b = .75$, 95% CI [.23, 1.26], $t(271) = 2.86$, $p = .005$, were both significant predictors of postincubation AUT fluency scores. However, the effect of n-back group differed from the prediction derived from the Dynamic Framework: participants in the 2-back group generated more AUT responses than the 0-back group (after taking into account preincubation AUT fluency scores). In the Bayesian analysis, the full model was preferred over the model containing only the preincubation scores by a factor of 7.09.

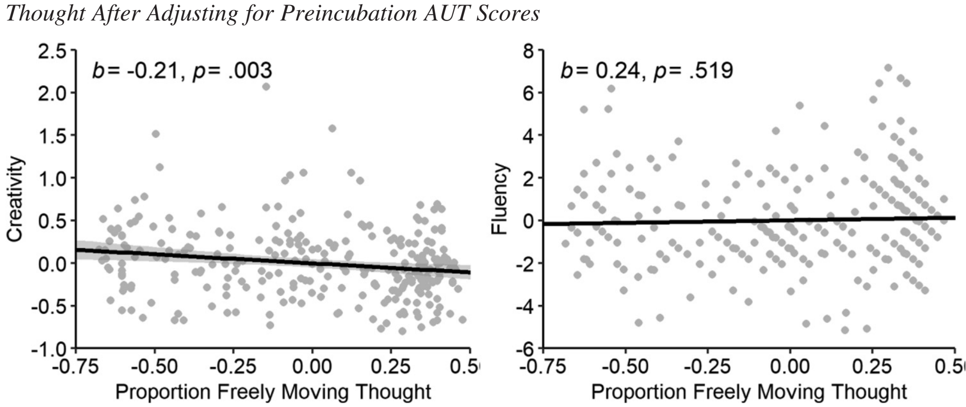
Individual Differences in Creativity and Freely Moving Thought. To determine whether there was any relationship between participant performance on the AUT and reports of freely moving thought, we examined whether individual rates of freely moving thought were predictive of creativity and fluency scores (see Figure 5).

In the first model, we analyzed postincubation AUT creativity ratings with preincubation AUT creativity ratings and freely moving thought proportion as explanatory variables, $R^2 = .24$, 90% CI [.17, .32], $F(2, 271) = 43.62$, $p < .001$. Here, as before, preincubation scores were positively associated with postincubation scores, $b = .51$, 95% CI [.39, .63], $t(271) = 8.33$, $p < .001$. However, rate of freely moving thought was *negatively* associated with postincubation creativity ratings, $b = -.21$, 95% CI [−.35, −.07], $t(271) = -3.04$, $p = .003$. Turning to the Bayesian analysis, the full model was preferred over the model only containing the preincubation scores by a factor of 9.97.

In the second regression model, we analyzed postincubation AUT fluency scores with preincubation AUT fluency scores and freely moving thought proportion as explanatory variables, $R^2 = .43$, 90% CI [.35, .50], $F(2, 271) = 102.93$, $p < .001$. Although preincubation scores were positively associated with postincubation scores, $b = .75$, 95% CI [.65, .86], $t(271) = 14.13$, $p < .001$, rate of freely moving thought was not significantly associated with postincubation scores, $b = .24$, 95% CI [−.49, .96], $t(271) = .65$, $p = .519$. In the Bayesian analysis, the model containing only the preincubation scores was preferred over the full model by a factor of 1.24.

Following our analyses in Study 1, we again tested for a quadratic relationship between creativity and freely moving thought using the Robin Hood method (Simonsohn, 2018) for each of the n-back groups. For the 0-back group, we found evidence for a U-shaped function, with a significant positive slope, $b = .64$, $z = 2.13$, $p = .03$, and a significant negative slope, $b = -.76$, $z = -2.38$, $p = .02$. However, we did not find evidence for a U-shaped

Figure 5
Partial Regression Plots Showing the Relationship Between Postincubation Alternate Uses Task (AUT) Performance (Creativity Ratings and Fluency Scores) and Proportion of Freely Moving Thought After Adjusting for Preincubation AUT Scores



function for the 2-back group. Here, we found a significant average *negative* slope for the low end of freely moving thought (where the Dynamic Framework would predict a positive slope), $b = -.29$, $z = -2.11$, $p = .035$, and no evidence for a slope in the high end of freely moving thought, $b = .37$, $z = .24$, $p = .81$ (see Figure 6).

Finally, as in Study 1, we also conducted exploratory analyses examining the frequency of alternating between freely moving and constrained thought. In the first regression model, we analyzed postincubation AUT creativity ratings with preincubation AUT creativity ratings and switch rates as explanatory variables, $R^2 = .23$, $F(2, 271) = 41.18$, $p < .001$. Here, preincubation scores were positively associated with postincubation scores, $b = .53$, 95% CI [.41, .65], $t(271) = 8.71$, $p < .001$. Similarly, switch rates were also *positively* associated with postincubation creativity ratings, $b = .29$, 95% CI [.04, .54], $t(271) = 2.33$, $p = .021$. However, this result was not corroborated by the Bayesian analysis where the full model was only preferred over the model only containing the preincubation scores by a factor of 1.63. That is, there was only anecdotal evidence supporting the inclusion of the switch rate variable.

In the second regression model, we analyzed postincubation AUT fluency scores with preincubation AUT fluency scores and switch rates as explanatory variables, $R^2 = .43$, $F(2, 271) = 104.28$, $p < .001$. Although preincubation scores were positively associated with postincubation scores, $b = .77$, 95% CI [.66, .87], $t(271) = 14.44$, $p < .001$, freely moving thought proportions were not significantly associated with postincubation scores, $b = -.92$, 95% CI [−2.20, .37], $t(271) = -1.40$, $p = .163$. In the Bayesian analysis, model containing only the preincubation scores was preferred over the full model by a factor of 5.01.

Freely Moving Thought, Divergent Thinking, and Time Spent Thinking About the AUT. 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 freely moving thought 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 who did ($N = 80$).

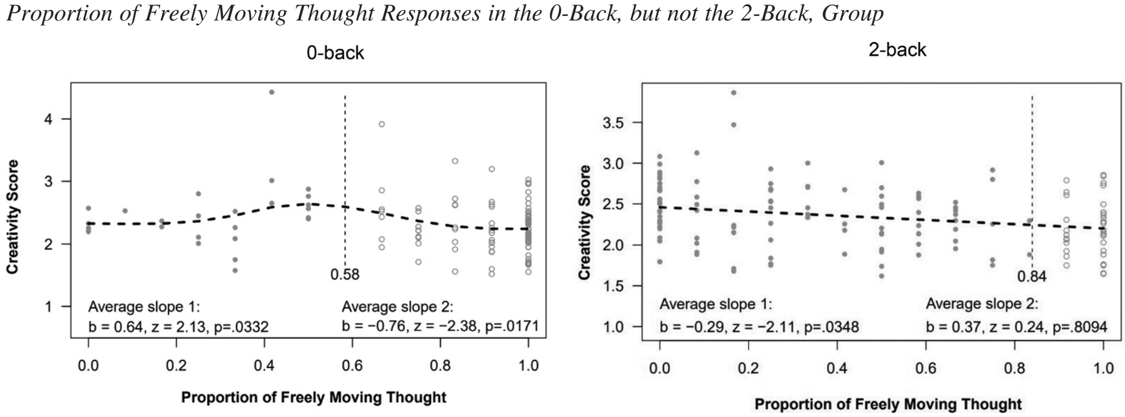
Comparing these two groups, we found lower rates of freely moving thoughts for those who reported never thinking about the AUT than those who did, $M_{\text{diff}} = -.13$, 95% CI [−.21, −.04], $t(184.05) = -2.90$, $p = .004$, with moderate evidence in favor of the alternative $BF_{10} = 3.75$. To determine whether thinking about the AUT interacted with freely moving thought to influence creative incubation, we submitted each of our postincubation AUT measures to a linear regression model with preincubation scores, proportion of freely moving thoughts, AUT thought group (did vs. did not think about the AUT), and the interaction between freely moving thoughts and AUT thought group as explanatory variables.

In the first model, analyzing creativity scores, preincubation scores were significantly associated with postincubation scores, $b = .51$, 95% CI [.39, .63], $t(269) = 8.20$, $p < .001$, and freely moving thought was *negatively* associated with postincubation creativity scores, $b = -.25$, 95% CI [−.40, −.09], $t(269) = -3.15$, $p = .002$. However, AUT thought group was not significantly associated with postincubation scores, $b = -.19$, 95% CI [−.45, .07], $t(269) = -1.46$, $p = .145$ and the interaction term was also nonsignificant, $b = .22$, 95% CI [−.13, .56], $t(269) = 1.24$, $p = .217$; model fit: $R^2 = .44$, 90% CI [.36, .51], $F(4, 269) = 52.72$, $p < .001$. Using a Bayesian analysis, the model with only preincubation scores and freely moving 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 freely moving thought.

In the second model, analyzing fluency scores, preincubation scores were positively associated with postincubation scores, $b = .76$, 95% CI [.66, .87], $t(269) = 14.26$, $p < .001$. However, both freely moving thought, $b = -.15$, 95% CI [−.97, .68], $t(269) = -.35$, $p = .723$, and AUT thought group were nonsignificant, $b = -1.00$, 95% CI [−2.36, .36], $t(269) = -1.44$, $p = .15$. Finally, the interaction between freely moving thought and AUT thought group was marginal, but also nonsignificant, $b = 1.69$, 95% CI [−.11, 3.50], $t(269) = 1.85$, $p = .066$; model fit: $R^2 = .44$, 90% CI

Figure 6

Modest Evidence for a U-Shaped Relationship Between Alternate Uses Task (AUT) Creativity Score and Proportion of Freely Moving Thought Responses in the 0-Back, but not the 2-Back, Group



[.36, .51], $F(4, 269) = 52.72$, $p < .001$. Turning to the Bayesian analysis, the model containing only the preincubation 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 freely moving 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. The flow-state questionnaire used has been shown to have high reliability ($\alpha = .95$; Marty-Dugas, 2020). Comparing responses across the three phases, we found participants reported lower flow-state scores in the n-back phase compared with both the preincubation AUT, $M_{\text{diff}} = -.31$, 95% CI [−.43, −.20], $t(273) = -5.17$, $p < .001$, $BF_{10} = 2.10 \times 10^4$, and the postincubation AUT, $M_{\text{diff}} = -.26$, 95% CI [−.39, −.14], $t(273) = -4.12$, $p < .001$, $BF_{10} = 233.91$. There was, however, no significant difference between flow state responses in pre- versus Postincubation AUT phases, $M_{\text{diff}} = .05$, 95% CI [−.05, .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 ($M = .272$) compared with the 2-back group ($M = .034$), $M_{\text{diff}} = .24$, 95% CI [.02, .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], $t(272) = -.28$, $p = .777$, $BF_{01} = 6.83$, 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 proportion of freely moving thought (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 freely moving thoughts may reflect overlapping experiential states (see also Brosowsky et al., 2021).

Discussion

In Study 2, we manipulated rates of freely moving thought via changes in task difficulty during a creative-incubation period. As predicted, we found that participants in the low-demand condition reported significantly higher rates of freely moving thought than participants in the high-demand condition. However, contrary to the prediction from the Dynamic Framework, we found that participants who engaged in the more difficult 2-back task (and hence, experienced *fewer* freely moving thoughts) generated *more* uses for the AUT prompt. This aligns with our finding from Study 1 that rates of freely moving thought are negatively correlated with average AUT fluency scores.

Second, across both the 0-back and 2-back conditions, we examined the possibility that participants who frequently oscillated between constrained and freely moving thought produced more creative responses to the AUT. To do this, we determined whether there was a quadratic relationship between creativity scores and freely moving thought in both n-back conditions. The results of these analyses were statistically significant only in the 0-back condition, where we observed a quadratic relationship (their creativity scores increased significantly as they approached the average of the distribution of freely moving thought, and then decreased significantly thereafter). In the 2-back condition, there was only a significant *negative* relationship between creativity scores and low proportion of freely moving thought. A cautious interpretation of these findings is that 0-back participants' creativity may have benefited from moderately constrained thoughts. Given that the 2-back condition begins with a negative slope in the lower end of freely moving thought, creativity scores may be maximized at a state of moderately constrained thought in the 0-back, and performance continues to decrease as a function of cognitive load. However, this interpretation conflicts with the finding that, when controlling for preincubation AUT scores, creativity scores are negatively related to freely moving thought.

Taken together, these results indicate that, during an incubation interval, (a) engaging in higher rates of freely moving thought results in the production of fewer (not more) ideas, and (b) the people who produce the most creative responses to the AUT tend to be those who infrequently engage in freely moving thought rather than those who alternate between constrained and freely moving thought. We also found no group differences in postincubation AUT creativity scores in either condition, and no interaction between reports of thinking about the AUT during the interval and freely moving thought in predicting creativity scores.

In Study 2, we failed to find evidence to support the prediction that increasing rates of freely moving thought during an incubation period leads to the generation of more ideas. Moreover, we found weak evidence to suggest that striking a balance between constrained and freely moving thought may lead to the generation of more-creative ideas (at least, in the less-demanding 0-back condition). It is, however, possible that the expected relations between freely moving thought and fluency/creativity are most likely to be observed when freely moving thought is assessed *during completion of a creativity task* (rather than during an incubation interval that precedes a creativity task). To test this possibility, we conducted another study.

Study 3

In Study 3, participants completed 10 trials of the AUT (each of which lasted one minute), with each trial consisting of a unique cue. Immediately following each trial, we presented participants with a thought probe that assessed the extent to which they had experienced freely moving thoughts during that trial of the AUT.

Method

Participants

We recruited 200 participants (100 women, $M_{\text{age}} = 38.6$, $SD_{age} = 10.59$) online via Amazon Mechanical Turk and were paid \$2.40 for the 20-minute study. With 200 participants, we could detect correlations as small as $r = .175$ with 80% power. We restricted our sample to U.S. citizens with a 98% HIT approval rating and more than 5,000 HITs completed. All participants provided informed consent and were treated in accordance with guidelines approved by the IRB at Duke University.

Materials

The Alternate Uses Task. Participants were first shown one practice trial of the AUT for the prompt "shoe." They subsequently completed ten rounds and were allotted one minute to list their generated uses for each cue. Cues included: rope, paper clip, balloon, chair, newspaper, hammer, knife, tire, brick, and box, and were presented in a randomized order. As in Studies 1 and 2, we examined two indices of divergent thinking: creativity ratings and fluency. Again, creativity ratings were provided by three human raters (two females, $M_{\text{age}} = 38.13$, $SD_{age} = 11.39$).

Thought Probes. Participants were presented 10 thought probes throughout the experiment, after each trial of the AUT. As in Studies 1 and 2, thought probes consisted of a single question gauging thought dynamics ("The thoughts I was experiencing were freely moving: YES/NO").

Procedure

After agreeing to participate, participants were provided instructions explaining the nature of the AUT and the characteristics of freely moving thought. This was followed by a single practice trial ("shoe"). The task then proceeded to the ten experimental trials. After each one-minute AUT trial, participants received the freely moving thought probe. After completing the 10 AUT trials, participants completed a demographics survey and were thanked for their participation.

Results

Data from four participants were removed because they did not complete the experiment. We also removed data from 10 participants who responded "yes" to a question asking whether they had used any outside resources to help them complete the task. Additionally, data from participants who failed to provide at least two responses in four or more AUT blocks were removed prior to all analyses (12 participants; final $N = 174$).

The first question of interest was whether rates of freely moving thought were associated with higher creativity scores ($M = 2.42$, $SD = .35$) on the AUT (see Figure 7). Using Pearson correlations, we found no significant relationship between creativity scores and proportion of freely moving thought, $r = -.13$, 95% CI "[−.28, .02], $t(172) = -1.77$, $p = .079$.

Second, we were interested in whether rates of freely moving thought were associated with higher fluency scores ($M = 4.47$, $SD = 1.40$) on the AUT (see Figure 7). We again failed to find a significant association between fluency scores and rates of freely moving thought, $r = -.02$, 95% CI [−.17, .13], $t(172) = -.27$, $p = .786$, with strong evidence against a positive association, $BF_{0+} = 6.95$.

The second question of interest was whether we would observe a quadratic relationship between creativity scores and proportion of freely moving thought, with the prediction being that those who alternate between constrained and freely moving thought should tend to perform better on the AUT Using the Robin Hood method (Simonsohn, 2018), we found no evidence for a quadratic relationship. There was no significant positive slope, $b = .41$, $z = 1.93$, $p = .053$. However, there was a negative slope, $b = -.39$, $z = -2.43$, $p = .015$ (see Figure 8).

Finally, we again examined whether creativity was associated with the rate of switching between freely moving and constrained thought (see Study 1). Here, we found no significant association between creativity scores and switch rates, $r = .13$, 95% CI [−.02, .27], $t(172) = 1.72$, $p = .088$, with only anecdotal evidence for positive association over the null, $BF_{+0} = 1.38$ and strong evidence for the null over the negative association, $BF_{0-} = 14.85$. Similarly, we found no significant association between fluency scores and switch rates, $r = .03$, 95% CI [−.12, .18], $t(172) = .41$, $p = .682$, with moderate evidence for the null over the positive association, $BF_{0+} = 3.99$, and moderate evidence for the null over the negative association, $BF_{0-} = 7.63$.

Discussion

Having failed to find the predicted associations between fluency/creativity and freely moving thought occurring (a) during an n-back task and (b) during a creative-incubation interval, in Study 3, we examined the possibility that the predicted relations may be revealed

Figure 7

Correlations Between Average Creativity and Fluency Scores and Freely Moving Thought Proportions Over the Course of 10 Alternate Uses Task (AUT) Trials

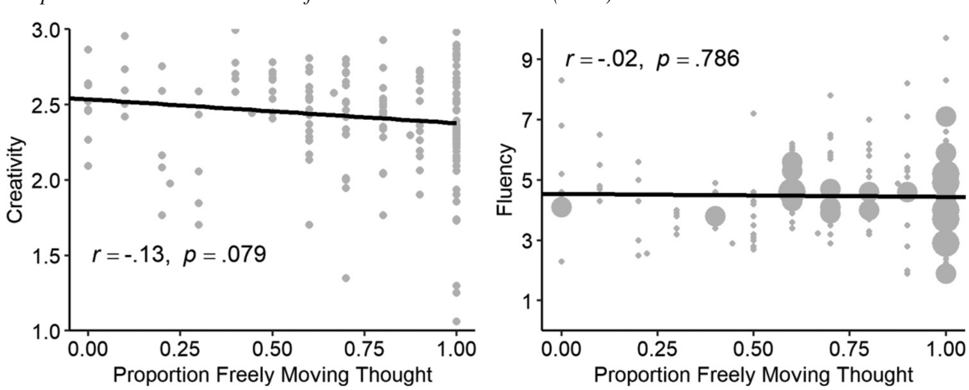
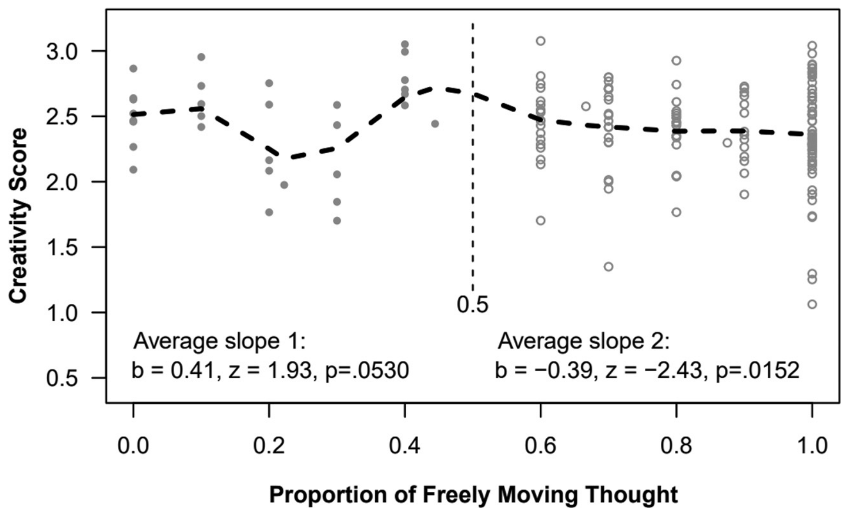


Figure 8

No Evidence for a U-Shaped Relationship Between Alternate Uses Task (AUT) Creativity Score and Proportion of Freely Moving Thought Responses



when assessing freely moving thought during a creativity task. Again, however, we did not find evidence in support of these predictions.

General Discussion

The primary aim of the studies reported here was to test four predictions of the Dynamic Framework using the methods used by proponents of the framework:

1. Freely moving thought is positively associated with ADHD symptomatology (Study 1).

2. Freely moving thought is negatively associated with depressive, anxious, and obsessive thought patterns (Study 1).

3. Freely moving thought is positively associated with the number of ideas generated during a creativity task (Studies 1, 2, and 3).

4. There is a quadratic relationship between proportion of freely moving thought and performance on a creativity task (Studies 1, 2, and 3).

Results of all three studies did not provide evidence in support of these predictions. We failed to identify predicted relationships between freely moving thought and ADHD symptomatology, OCD, depression, and anxiety, and we failed to find a positive correlation between rates of freely moving thought and the number of uses generated during the AUT (i.e., fluency). On the contrary, we found that OCD symptoms were positively associated with freely moving thought. In Study 2, we found some evidence for a quadratic relationship between proportions of freely moving thought and AUT performance during an easy task (a 0-back task), such that creativity scores were highest when the proportion of freely moving thought reports was roughly even with the proportion of constrained thought reports. However, it is also worth noting that, when running zero-order correlations, the relation between freely moving thoughts overall and creativity scores was negative for both Studies 1 and 2 in the moderately difficult 2-back task condition, as well as the same negative but nonsignificant relationship when participants reported on their thought constraint while completing the AUT. Given that this result showed some consistency in our studies, this finding is worth following up on in future work concerned with the impact of relatively unconstrained thought on divergent thinking and other creativity measures.

While we tested predictions derived from the Dynamic Framework, measurements were collected using a single-item probe that asks about the dynamic characteristics of thought in general. This measure, we think, is not fine-grained enough to test the nuanced predictions of the theory. This may also explain why, when measuring mind wandering with this probe, we failed to find evidence supporting several key predictions of the Dynamic Framework.

This does not mean that we think the single-item probe measuring freely moving thought lacks internal validity. Notably, Mills, Raffaelli, et al. (2018) reported a validation of their dynamic probe. For this 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, Herrera-Bennett, et al., 2018, p. 22). Immediately after providing these reports, participants typed out the thoughts 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. Mills et al., found a significant positive association 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, Herrera-Bennett, 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 results (Schönbrodt & Perugini, 2013). Second, the regression analysis that Mills et al., conducted to validate their thought probe resulted in what they describe as a weak and scarcely significant correlation (r = .156, $p = .046$). 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 (nonvalidation) study (the same probe used in the present study), but instead sought to validate a similar, but nevertheless different, retrospective question about freely moving thought over a protracted period of time. Indeed, the thought probe that Mills et al. used 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 freely moving thought 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 importantly, it is possible that participants' initial reports of their freely moving thought 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.

In addition to the complications above, we believe that one issue with the freely moving thought probe is that it attempts to measure multiple characteristics of freely moving thought that might be nonoverlapping. Consider the instructions that Mills, Raffaelli, et al. (2018) provide for identifying freely moving thoughts (note that we used the same instructions 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 end-directed (item 2). Yet another interpretation is that these instructions ask participants to report on the intentionality of their thoughts and whether they 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).

Although these might constitute overlapping dimensions of freely moving thought, it is unclear whether that should be assumed from the outset. Given the multiple different interpretations of these instructions, and the possibility of variability between individuals in interpreting these instructions, it is unclear what exactly the single-item probe might be measuring. This, in turn, leads to complications in testing predictions of the framework, as different dimensions of freely moving thought might relate differently to behavior. The Dynamic Framework seems to account for these different dimensions at a conceptual level by distinguishing between automatic and deliberate constraints on thinking. However, the single-item probe developed by the authors of the Dynamic Framework does not readily allow for empirical dissociations between these constraints or how individual episodes of thinking manifest differing degrees of different kinds of constraints. Thus, the single-item probe does not seem fine-grained enough to capture the various parameters underlying freely moving thought. For that reason, our results suggest that new methods are necessary for testing and refining the Dynamic Framework.

Recent work has begun to develop such nuanced probes. Notably, Kam et al. (2021) used four different probes during an attentionally demanding task that measured whether thoughts were task-related, freely moving, deliberately constrained, and/or automatically constrained. Each category was defined for participants and examples of different thought types were used to illustrate the categories. Task-unrelated thought and freely moving thought were associated with distinct ERP components. Furthermore, there was some evidence for differences in electrophysiological signals underlying reports of deliberately and automatically constrained thinking. Results reported in Kam et al., indicate that testing predictions about the neural bases or behavioral markers of freely moving, deliberately constrained, or automatically constrained thought might require three separate probes (or, depending on the prediction, one probe might be more apt than others).

Following this, predictions of the Dynamic Framework should clarify how deliberate and automatic constraints might differentially relate to various cognitive traits or behaviors (e.g., predicting a relationship between thought constraint and ADHD symptomatology). Interestingly, such a pursuit may turn out to show redundancy between (a) deliberate and automatic constraints on thought and (b) deliberate and spontaneous types of mind wandering, the latter of which has already been assessed in numerous studies in the literature (for a review see Seli et al., 2016). Put differently, the distinction between deliberate and automatic constraints may be empirically redundant with the distinction between deliberate and spontaneous mind wandering, which has been assessed in relation to variables of interest such as ADHD (Seli, Smallwood, et al., 2015), OCD (Seli et al., 2017), and anxiety, depression, and stress (Seli et al., 2019). Of course, future research is needed to assess this possibility.

Regardless of individual interpretation of the dimensions and contextual elements of freely moving thought, another key assumption that must be made to interpret responses to the dynamic thought probe is that participants are equally able to distinguish between "relatively constrained" and "relatively unconstrained" thinking. It is an open question as to whether individuals can make a binary distinction between these phenomenologies, much less distinguish in more granularity to respond to the question if it were a Likert scale. Following the efforts made by Kane et al. (2021), future research should examine whether using a continuous scale to measure freely moving thought offers any benefit compared with dichotomization.[6] Because the superiority of one measurement decision over the other has not been established, we focus on the limitations of having the dynamic thought probe as a single item, rather than the granularity of the scale itself.

That said, the single-item nature, alone, of the current method does not seem fine-grained enough to disentangle the various dimensions underlying freely moving thought. This does not imply that the single-item probe should not be used in research moving forward. Rather, we think the results reported here clarify the limitations of the single-item probe both as a tool for assessing the predictions of the Dynamic Framework and as a measure of the various cognitive dimensions of mind wandering. A single-item probe might be useful for initial research into the relationship between freely moving thought and other well-established constructs related to mind wandering. For example, the relationship between the intentionality of mind wandering and freely moving thought remains unclear (although Irving et al., 2020, suggest that folk conceptualizations of mind wandering distinguish freely moving thought from intentionality). Preliminary investigations of these relationships might rely on a single-item measure of freely moving thought and only use more complex methods when there is evidence that more fine-grained assessments are necessary.

These comments are consistent with limitations of the single-item probe identified by proponents of the Dynamic Framework. As Kam et al. (2021) explain in the supplement to their study, the Dynamic Framework predicts that the relationship between deliberate and automatic constraints varies as a function of context. Sometimes, deliberate and automatic constraints compete, such that highly automatically constrained thinking implies low levels of deliberate constraint (e.g., obsessive or ruminative thought). Other times, deliberate and automatic constraints reinforce each other, so thinking can be deliberately and automatically constrained. These contextual differences likely alter the phenomenology and behavioral correlates of freely moving thought. However, the single-item probe cannot capture these dynamic properties of constraint, thus papering over crucial components of freely moving thought.

One possibility for developing a more nuanced set of probes is 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, 2020). This method measures whether thoughts are moving outside linguistically defined semantic links, without relying on self-reports. These movement patterns can then be used to infer the degree to which thought is freely moving. Future research might look to understand how different kinds of dynamics map to the experience of topical shifting within the stream of consciousness (Zanesco, 2020). One limitation of this approach is that forcing participants to verbalize their thoughts adds additional constraints, because language is a serial process, and increased metaawareness, because 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.

Open Questions

In a recent study—published after the present studies were conducted—Alperin et al. (2021) reported results at odds with those reported for Study 1. In their study, participants were placed either in an ADHD group or a control group. Notably, unlike in our Study 1, Alperin et al. conducted diagnostic grouping in line *DSM–5* criteria (see Alperin et al., for the specific criteria used). Next, participants completed a ∼60 minute sustained-attention task, throughout which they were presented 45 thought probes indexing freely moving thought (the same probes from Mills, Raffaelli, et al., 2018). In comparing rates of freely moving thought responses across the control and ADHD groups, the authors found that those in the ADHD group reported significantly more freely moving thoughts than those in the control group; a finding that aligns with the predictions of the Dynamic Framework.

Several factors might explain the difference in results. First, as noted above, whereas Alperin et al. (2021) grouped their participants based on *DSM–5* criteria for ADHD (which included a clinical interview), in our study participants simply completed the ASRS, without undergoing a clinical interview. Perhaps, then, the relation between ADHD and freely moving thought holds only when control participants are compared with participants who are likely to receive an ADHD diagnosis (i.e., participants scoring very high on measures of ADHD).[7] Second, in our study, we administered 10 thought probes, whereas Alperin et al. administered 45. Third, whereas the probe used in our study to index freely moving thought was a binary probe, Alperin et al., initially administered a 7-point version of the same probe (although they nevertheless converted these probe responses into binary responses after data collection). It is therefore possible that this minor difference in probing procedure produced different results. Fourth, the sample sizes between the two studies were different. We analyzed data from 225 participants, whereas Alperin et al., analyzed data from 79.

[6] Notably, Kane et al. (2021) found that using a continuous measure of the perceived depth of a mind wandering episode offered negligible benefit compared with a dichotomous forced-choice response.

[7] A recent meta-analysis on clinical symptomatologies suggests that many psychopathologies—for instance, alcohol use disorder, intermittent explosive disorder, problem gambling, suicide risk, and pedophilia—are roughly five times more likely to fit a normally distributed, dimensional model than a categorical, taxonic model (Haslam et al., 2020). Although ADHD and OCD were not addressed in this meta-analysis, there is reason to suspect that they similarly vary continuously across individuals. In fact, some researchers have explicitly argued for a continuous scoring method of the ASRS scale of ADHD because ADHD symptomatology appears to fit a normally distributed model (Overbey et al., 2011; Whalen et al., 2003). Likewise, a growing literature supports the notion that OCD symptoms occur on a continuum (e.g., Tolin et al., 2006). In any case, it remains unclear whether the predicted relations between thought constraint and ADHD/OCD would obtain when collecting data from clinical samples (as in Alperin et al., 2021), and it will therefore be important for future research to explore this possibility.

Considering these differences across our studies, it is not clear what the explanation for this is. Notably, however, we found evidence for a strong, positive correlation between trait-level spontaneous mind wandering and self-reported ADHD symptomatology. Because trait-level spontaneous mind wandering has been found to correlate with clinical symptoms of ADHD, we think that the positive correlation identified in our study suggests that the measures we used to assess ADHD do not explain the differences between the two studies. Instead, in light of the issues raised with the single-item probe above, we think a simpler explanation is that reliance on a single-measure of freely moving thought is insufficient to obtain robust results. Speculatively, we think that the difference between our studies might be explained by our inability to control for underlying levels of deliberate and automatic constraints. With the current procedures, we cannot rule out that differences in underlying dynamics explain the differences between our studies.

An overarching point of this discussion is that many predictions of the Dynamic Framework are contextually bounded and sensitive to underlying constructs that haven't been measured accurately yet. For example, a valid consideration for laboratory work of any kind in this area is whether experimentally imposed constraint influences the dynamics of thought in the same ways as naturalistic constraint. To test and refine these context-specific and interactive predictions, more work is needed to develop measurement techniques that capture unique aspects of the dynamics of thought. In the case of comparing laboratory-based versus everyday thought patterns, the critical differences cannot be assessed without understanding how and when both automatic and deliberate constraints interact to produce freely moving thought. While some have already started doing this research (Kam et al., 2021), these researchers themselves admit that future work is necessary to address outstanding gaps. In the context of our studies, we, too, must assume that our cognitively constrained environment (the 2-back task) is one of many possible ways which thought might be constrained in daily life, without having the tools to compare it on both dimensions to more similar (e.g., freely moving thought while grading papers) or less similar (e.g., freely moving thought while taking the bus) ecologically valid situations.

Concluding Remarks

The present study failed to find evidence for some of the key predictions of the Dynamic Framework using the single-item measure of relatively unconstrained thought: We found no evidence that freely moving thought is associated with self-reported symptoms of ADHD, depression, or obsessive thought. Additionally, across three studies, we found little evidence that freely moving thought is associated with divergent creativity. Thus, at the very least, our studies suggest the need to refine the probing methods developed by Mills, Herrera-Bennett, et al. (2018) for measuring 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 freely moving thought and may be used to complement (or supplement) the common paradigm of measuring mind wandering with thought probes.

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(*Appendices follow*)

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 **<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.
4. I prefer not to answer.

Appendix B

Instructions for the Freely Moving Thought Probe (Mills, Herrera-Bennett, et al., 2018)

Was your mind moving about freely? Your thoughts move freely when:

- They seem to wander around, flowing from one thing to another
- There is no overarching purpose or direction to your thinking, although there may still be some connection between one thought and the next
- Images and memories seem to spontaneously come into your mind
- Your attention lands spontaneously on things in your environment
- Your mind may spontaneously drift between things in the external environment and internal images so it may go back and forth.
- Your thoughts move freely when it feels like your thoughts could land on pretty much anything
- Or that your thoughts seem to flow with ease

(*Appendices continue*)

Appendix C

Instructions for the Alternate Uses Task

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.[8]

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.

[8] The example is included to inform participants about how they are expected to complete the AUT.

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