Keeping Creativity under Control: Contributions of Attention Control and Fluid Intelligence to Divergent Thinking

By: Emily Frith, Michael J. Kane, Matthew S. Welhaf, Alexander P. Christensen, Paul J. Silvia, and Roger E. Beaty

Emily Frith, Michael J. Kane, Matthew S. Welhaf, Alexander P. Christensen, Paul J. Silvia & Roger E. Beaty (2021) Keeping Creativity under Control: Contributions of Attention Control and Fluid Intelligence to Divergent Thinking, *Creativity Research Journal*, DOI: 10.1080/10400419.2020.1855906

Abstract:

Increasing research efforts are focused on explaining the cognitive bases of creativity. However, it remains unclear when and how cognitive factors such as intelligence and executive function uniquely contribute to performance on creative thinking tasks. Although a relationship between fluid intelligence (*Gf*) and creative cognition has been well-documented, the underlying mechanism of this relation is unknown. Here, we test one possible mechanism of the Gf–creativity association – attention control (AC) – given AC's strong association with Gf and its theoretical relevance to creative cognition. We also examine the role of mind wandering (i.e., task-unrelated thought), a failure of AC that is potentially beneficial to creativity. Using latent variable and bifactor models, we investigated the unique contributions of AC to divergent thinking – above the influence of *Gf* – evaluating the specific and general contributions of AC, *Gf*, and mind wandering to divergent thinking. We found that a general executive factor (i.e., of the common variance to AC, mind wandering, and *Gf* indicators) significantly predicted divergent thinking originality (β =.40, p <.001) above and beyond specific *Gf* and mind wandering factors. Importantly, in the bifactor model, mind wandering was a nonsignificant, negative predictor of divergent thinking performance, and the residual effects of *Gf* were no longer significant, indicating that the relationship between *Gf* and divergent thinking is explained by shared variance with a common executive attention factor. This study provides novel evidence suggesting that the relationship between *Gf* and divergent thinking may be largely driven by the top-down control of attention.

Keywords: creative cognition | divergent thinking | executive attention | intelligence | mind wandering

Article:

Modern society is constantly evolving, demanding that people think creatively to respond adaptively in the face of unprecedented challenges. Given the importance of creativity to everyday problem-solving and social advancement, the cognitive basis of creative thinking has been of increasing interest. An ongoing controversy in creativity research concerns fluid intelligence (*Gf*). Although several studies have demonstrated a link between *Gf* and divergent creative thinking (Akhtar & Kartika, 2019; Batey, Furnham, & Safiullina, 2010; Beaty, Nusbaum, & Silvia, 2014; Beaty, Silvia, Nusbaum, Jauk, & Benedek, 2014; Benedek, Franz, Heene, & Neubauer, 2012; Benedek, Jauk, Sommer, Arendasy, & Neubauer, 2014; Cho, Nijenhuis, van Vianen, Kim, & Lee, 2010; Furnham, Batey, Anand, & Manfield, 2008; Furnham, Zhang, & Chamorro-Premuzic, 2005; Karwowski et al., 2016; Kenett, Beaty, Silvia, Anaki, & Faust, 2016; Liu, Liu, Chen, Song, & Liu, 2019; Nusbaum & Silvia, 2011; Preckel, Holling, & Wiese, 2006; Silvia, 2008, 2015; Silvia & Beaty, 2012; Sligh, Conners, & Roskos-Ewoldsen, 2005), the underlying mechanism of this relation remains unclear. Given the strong overlap between *Gf* and working memory (Brewin & Beaton, 2002; Burgess, Gray, Conway, & Braver, 2011; Chuderski, 2013; Conway, Cowan, Bunting, Therriault, & Minkoff, 2002; Conway, Kane, & Engle, 2003; Engle & Kane, 2004; Engle, Tuholski, Laughlin, & Conway, 1999; Fukuda, Vogel, Mayr, & Awh, 2010; Kane & Engle, 2002; Kane, Hambrick, & Conway, 2005; Kane et al., 2004), one possibility is that the intelligence–divergent thinking relation reflects variation in the executive control of attention – the ability to strategically direct attention and cognition to solve problems (Eslinger, 1996; Zelazo, Craik, & Booth, 2004). Yet creative thinking has also been connected to mind wandering, which may be considered the antithesis of attention control (Kane & McVay, 2012; McVay & Kane, 2009, 2010; Smallwood & Schooler, 2006; Thomson, Besner, & Smilek, 2015). The purpose of the present study was to investigate the unique relation between attention control and divergent thinking, above the influence of *Gf*. We also examined whether individual differences in mind-wandering during ongoing tasks (i.e., task-unrelated thoughts; TUTs) were associated with people's ability to think creatively.

Cognitive theories of creativity

Creativity research often measures divergent thinking as an indicator of creative potential (Runco & Acar, 2012). Divergent thinking assessments require people to generate a variety of uncommon, original ideas from a single prompt or stimulus. For example, the Alternative Uses Task (Guilford, 1967) prompts responses that focus on novel ways to use an everyday object that differ from normal uses. This task is thought to capture elements of creative cognition because, unlike standard problem-solving (e.g., matrix reasoning), the goal is to produce task-appropriate solutions that differ from what anyone has thought of before (Sawyer, 2006; Silvia et al., 2008). That is, the cognitive processes of creative ideation are perhaps more ambiguous than other mental operations because there is no definitive "right" way to think. In fact, the criteria often used to appraise divergent thinking quality hinges on determining whether a given response is subjectively clever or surprising, remote (i.e., distantly associated with standard response candidates), and rare or uncommon (Amabile, 1982; Silvia et al., 2008). For individuals to successfully generate high-quality ideas and solutions, they must not only grapple with ambiguity in the creative problem-solving process, but they also must overcome the threat of mentally fixating on prior knowledge and experiences (Jansson & Smith, 1991; Wiley, 1998).

The *associative theory* of creativity posits that individual differences in creative thinking relate to variation in the organization of concepts in semantic memory (Mednick, 1962). According to this theory, the creative thought process becomes disrupted when people activate salient but unoriginal semantic representations. Thus, less-creative people tend to be constrained by strong, close associates to a target stimulus, whereas highly creative people can overcome such constraints and establish remote conceptual combinations (Kenett & Faust, 2019). Several studies have used network science methods to empirically validate this claim, finding that more creative people have a more "flexible" semantic network structure marked by short paths (distances) and high connectivity between concepts (Benedek et al., 2017; Gray et al., 2019; Kenett, Anaki, & Faust, 2014; Kenett & Faust, 2019; Kenett et al., 2018). The associative theory of creativity therefore highlights a critical feature of the creative thought process – semantic interference – positing that the *structure* of knowledge plays a key role in bypassing interfering concepts (Beaty, Christensen, Benedek, Silvia, & Schacter, 2017).

Another line of research has examined the *processes* that operate on the structure of semantic networks, emphasizing a role of controlled attention. The *controlled-attention theory* of creativity asserts that creative thinking depends on top-down attentional control (Beaty et al., 2014; Benedek et al., 2012; Jauk et al., 2013). Attention control is core component of executive function, which is an overarching term that incorporates various complex control processes responsible for regulating goal-directed thought and behavior (Eslinger, 1996; Zelazo et al., 2004), especially during effortful, novel tasks (Banich, 2009; Engle & Kane, 2004; Kane, Bleckley, Conway, & Engle, 2001; Kane & Engle, 2002; Kane & McVay, 2012; Lezak, Howieson, Loring, & Fischer, 2004; Miyake & Friedman, 2012). In the context of creativity, successful attention control may permit access to a wider variety of remote, original ideas, by directing the creative thought process away from strong, common associates. For example, although the stimulus item "shoe" may initially activate close associates (e.g., walking, running, etc.), uncommon associates to "shoe" may be activated, or otherwise made accessible (e.g., bucket, glove, etc.), when attention is focused on inhibiting salient, yet unoriginal responses (Beaty et al., 2017; Cassotti, Agogué, Camarda, Houdé, & Borst, 2016). In this case, controlled attention may redirect and drive search processes by intervening in an otherwise spontaneous process of spreading activation within semantic memory networks.

Intelligence and creativity

The controlled attention theory of creativity has received support from research on intelligence and creative thinking. Cattell (1971) proposed that creativity emerges as a function of general intelligence, with *Gf* likely playing the most prominent role in creative thinking because it is characterized by the ability to adapt to novel circumstances and solve problems using complex reasoning. In addition, *Gf* is thought to facilitate the manipulation and selection of task-relevant concepts among competing mental representations elicited during divergent thinking tasks (Batey, Chamorro-Premuzic, & Furnham, 2009; Shipstead, Harrison, & Engle, 2016). In this way, relationships between *Gf* and divergent thinking may reflect effective regulation of top-down executive control (Beaty & Silvia, 2012; Beaty et al., 2014). The structure of knowledge appears to passively influence creative idea generation per the associative theory (Mednick, 1962); however, controlled-attention processes, which are associated with *Gf* (Engle et al., 1999), are thought to actively influence creative thinking by promoting inhibition of initial, less-creative response options (Beaty & Silvia, 2012), shifting across multiple semantic categories (Beaty et al., 2014; Nusbaum & Silvia, 2011), and updating information in working memory to satisfy task demands (Engle et al., 1999). Relatedly, Nusbaum and Silvia (2011) argued that (1) *Gf* is central to identifying strategies for inhibiting or shifting thought away from standard responses and (2) executive control is central to implementing these strategies to generate more novel ideas during divergent thinking. Latent variable analysis demonstrated that executive switching ability mediated the link between *Gf* and divergent thinking (Nusbaum & Silvia, 2011). That is, *Gf* predicted divergent thinking performance, and individuals with higher *Gf* were better able to use executive strategies to combat response interference when generating novel ideas.

An executive-ability approach may also provide insight into the role *Gf* plays in information processing and updating under temporal constraints during divergent thinking (Batey et al., 2010). For instance, Beaty and Silvia (2012) found that, during a ten-minute divergent thinking task, subjects with higher *Gf* did not exhibit the serial-order-effect, which occurs when responses are less creative at the beginning of the testing period but become more creative over time (Christensen, Guilford, & Wilson, 1957; Parnes, 1961; Ward, 1969). One plausible explanation for this outcome is that *Gf* may be an effective governor of higher-order cognition from the onset of creative thinking, such that more time is not needed to successfully inhibit conventional ideas because attention can be rapidly directed toward less salient responses throughout the problem solving process (Beaty & Silvia, 2012). Benedek et al. (2014) offer preliminary support for an attention control explanation, finding that working memory capacity (controlled attention to actively maintain and manipulate task-relevant concepts; Engle, 2002; Kane et al., 2001) attenuated the shared variance between latent *Gf* and divergent thinking ability by 43%. The authors concluded that the intelligence–creativity relationship appears to be uniquely impacted by executive control over the goal-directed search for, and strategic retrieval of, remote ideas (Benedek et al., 2014). Furthermore, research outside of creativity has shown that the contribution of executive attention to working memory is a predictive mechanism of *Gf* in latent-variable analyses (Draheim, Tsukahara, Martin, Mashburn, & Engle, 2020; Oberauer, Schulze, Wilhelm, & Süβ, 2005; Shipstead, Lindsey, Marshall, & Engle, 2014; Süss, Oberauer, Wittmann, Wilhelm, & Schulze, 2002). Taken together, evidence points to the possibility that top-down executive processes may underlie the relationship between intelligence and creative ideation (Beaty et al., 2017; Beaty & Silvia, 2012; Nusbaum & Silvia, 2011), but specific mechanisms remain unclear. Given the link between controlled attention and intelligence, and controlled attention and creative thinking, we sought to investigate whether attentional control may drive the *Gf*–creative cognition relationship.

Creative cognition and attention control

Executive control processes are proposed to underlie the association between *Gf* and creativity (Benedek et al., 2014). This is because Gf involves cognitive functions that work together to actively maintain and update information in working memory so that effortful, goal-directed behavior can be executed (Heitz et al., 2006; Kane & Engle, 2002). These mental abilities are generally attributed to frontal lobe networks (McCabe, Roediger, McDaniel, Balota, & Hambrick, 2010; Miyake et al., 2000; Phillips & Della Sala, 1998), and their interplay is posited to represent a common executive attention mechanism (Shallice, Burgess, Baddeley, &

Weiskrantz, 1993) that relies heavily on working memory (McCabe et al., 2010) and is strongly associated with intelligence (Engle, 2018; Engle & Kane, 2004; Kane & Engle, 2002).

In order to override the habit of responding conventionally during creative thinking, strategy maintenance and manipulation of task stimuli in working memory may be essential (Lee & Therriault, 2013; Nusbaum & Silvia, 2011). Working memory fulfills two basic functions: to keep novel information available for active processing and to discriminate between task-relevant and task-irrelevant information (Engle & Kane, 2004; Engle et al., 1999; Unsworth & Engle, 2007). However, the role of working memory and executive control for creative cognition has not been empirically clarified, with some authors reporting evidence for a positive relation (Beaty & Silvia, 2012; Benedek et al., 2014; De Dreu, Nijstad, Baas, Wolsink, & Roskes, 2012; Dygert & Jarosz, 2020; Gilhooly, Fioratou, Anthony, & Wynn, 2007; Nusbaum & Silvia, 2011; Oberauer, Süss, Wilhelm, & Wittmann, 2008; Süss et al., 2002) and others failing to observe an association (Furley & Memmert, 2015; Jarosz, Colflesh, & Wiley, 2012; Lin & Lien, 2013; Moraru, Memmert, & van der Kamp, 2016; Smeekens & Kane, 2016; Wiley & Jarosz, 2012). It is possible that executive attention, as indicated by working memory, is not always positively related to creative cognition because strategically defocusing attention may allow for unconstrained mental access to remote ideas (Zabelina & Robinson, 2010; Zabelina, Saporta, & Beeman, 2016). Shifts to defocused attention may also unfold in a less strategic manner during creative thinking, meaning that attention regulation is not always a goal-directed process. Attention is influenced by other cognitive factors, such as inhibitory control (Martindale, 2007) and/or the efficiency of forging spontaneous associations among concepts in semantic memory (Gabora, 2018b; Kenett et al., 2014; Kenett & Faust, 2019; Kenett et al., 2018). Semantic memory networks have been proposed to scaffold the development of new connections between distributed, unrelated concepts in a self-organizing process that oscillates between focused, analytic thought to more defocused, associative thought (Gabora, 2017, 2018a, 2018b). Taken together, too much attentional control may restrict the ability to mentally explore the boundaries of semantic space, thereby preventing an expansive search for distant associates during divergent thinking (Jarosz et al., 2012; White & Shah, 2006). Therefore, some theorists have emphasized the utility of mind-wandering for facilitating creative cognition (Baars, 2010; Fox & Beaty, 2019; Schooler et al., 2011; Smallwood & Schooler, 2006; Smith et al., 2020).

Mind wandering – particularly in the form of task-unrelated thought (Seli et al., 2018) – may sometimes result from a failure of controlled attention, although mind wandering has been favorably linked with creative thinking performance in some studies. Relaxing attentional control may benefit creativity when mind wandering occurs within a non-demanding incubation period, which is essentially a planned break during problem-solving (Baird et al., 2012; Sio & Ormerod, 2009), or during open-monitoring meditation, which encourages intentional distribution of attention to freely experience incoming sensations and thoughts without judgment (Colzato et al., 2012; Lebuda, Zabelina, & Karwowski, 2016). However, mind wandering events have also been linked to lower executive control ability and may occur during both easy and challenging tasks (Kane et al., 2007; McVay & Kane, 2010; Randall et al., 2014; Unsworth, Brewer, & Spillers, 2012). This is because task-unrelated thought (TUT), may be indicative of executive control failures, as task-irrelevant stimuli occupy critical executive attention resources (Kane & McVay, 2012; McVay & Kane, 2010, 2012a; Schooler et al., 2011; Smallwood & Schooler, 2006; Smeekens & Kane, 2016) and attention shifts from the goals of the target task to an individual's internal environment (Levinson, Smallwood, & Davidson, 2012). Because attention guides the content of conscious experience, it is plausible that it also guides the content of goal-directed creative thought (Smeekens & Kane, 2016). Attention allocated to auxiliary goals may therefore reflect goal-neglect during creative problem-solving. However, mixed findings on the mind wandering–creativity relationship warrant further exploration (e.g., Baird et al., 2012; Gable et al., 2019; Hao et al., 2015; Smeekens & Kane, 2016).

The present research

Cognitive abilities, such as fluid intelligence and executive attention, likely play essential roles in creative thinking. However, little is known about how, and under what circumstances, such controlled cognitive abilities uniquely relate to performance on divergent thinking tasks. Some evidence suggests that the shared variance between *Gf* and divergent thinking may be accounted for by specific executive functions (e.g., updating; Benedek et al., 2014), but the role of attention control in creative cognition remains controversial (Smeekens & Kane, 2016). The present research takes a unique approach to modeling executive attention as a potentially stronger predictor of creative cognition than *Gf*-specific and TUT-specific factors. Executive attention can be conceptualized as a higher-order cognitive construct that incorporates many varieties of controlled, top-down mental activity. We contend that executive attention may regulate creative cognition such that individuals are able to adopt self-regulated, reasoned strategies for generating original ideas (Beaty & Silvia, 2012, 2013; Benedek et al., 2014; Nusbaum & Silvia, 2011; Silvia, 2015). Additionally, given mixed findings within the mind wandering literature, TUTs during executively-demanding tasks may either benefit or disrupt creative cognition (cf., Agnoli, Vanucci, Pelagatti, & Corazza, 2018). To this end, we hypothesized that individual differences in executive attention would uniquely predict divergent thinking performance and would also help explain the relationship between *Gf* and divergent thinking.

Method

Participants

This study was approved by the institutional review board at the University of North Carolina at Greensboro and participants provided written informed consent before any data collection began. Determination of sample size was based on the typical structural equation modeling sample sizes utilized in latent variable studies within the creativity literature (e.g., Silvia, Beaty, & Nusbaum, 2013), and was also constrained by grant funding. The total sample was comprised of 186 adults (129 women, mean age = 22.74 years, *SD* = 6.37), recruited as part of a larger study measuring individual differences in creative cognition and receiving up to 100 USD depending on the amount of time invested across several laboratory and ecological research activities (see Beaty et al., 2018; Maillet et al., 2018); the executive attention tasks were administered on the final day of the study, and some participants did not return to complete these tasks (n = 17), yielding a reduced sample of 169 for only the executive attention analysis. Participants were excluded from the study if they reported a history of diagnosed neurological disorder, cognitive disability, or current use of medications known to affect the central nervous system. Participants completed neuroimaging and behavioral tasks during two laboratory phases. The first phase consisted of an fMRI task protocol and several behavioral assessments, and the second phase involved completion of the remaining behavioral assessments. The fMRI protocol included divergent thinking with recorded verbal responses; here, we present the behavioral performance but not the fMRI data (see Beaty et al., 2018; Frith et al., 2020).

Divergent thinking assessments

fMRI task procedures

Participants completed a divergent thinking AUT (23 experimental trials) and an object characteristics task (OCT; 23 control trials; not analyzed here) to facilitate event-related fMRI measurement of creative cognition. The AUT required thinking of a creative use for a common object, and participants were instructed to "be creative" and "to come up with something clever, humorous, original, compelling, or interesting" (Beaty et al., 2014; Nusbaum, Silvia, & Beaty, 2014). In contrast, the OCT required semantic recall and participants were instructed to think of prototypical characteristics of common objects. For more on the specific task procedures, see Beaty et al. (2015) and Fink et al. (2009). During each of the 46 total trials, participants were first shown a jittered fixation cross (4–6 s), followed by a cue that signaled whether the next trial would be an AUT or OCT trial (3 s). Next, the prompt was presented in text and participants spent the entire time imagining (or recalling) their most creative (or appropriate) response (12 s). Lastly, each participant verbalized their response into an MRI-compatible microphone (5s; cf., Beaty et al., 2018; Benedek et al., 2014) while a research assistant also recorded each response so that idea quality could be assessed afterward by four trained raters. Raters were blind to participants' identities (responses were alphabetized and deidentified) and they provided ratings for each idea on a scale of 1 (*not at all creative*) to 5 (*very creative*) using the criteria of uncommonness, remoteness, and cleverness of responses (Silvia et al., 2008; see Table 3 for inter-rater correlations). A practice phase preceded fMRI measurement in order to familiarize participants with the trial sequence.

Table 1. Descriptive statistics for fluid intelligence, attention control, and mind wandering measures

Task	***M***	***SD***	***R* (min-max)**	***Skew***	***Kurtosis***
gf_cfiq	7.97	1.63	3–11	−0.58	0.40
gf_letters	8.93	2.21	1–14	−0.30	0.53
gf_nums	9.55	2.69	3–15	–0.05	–0.61
rtsd	166	61	52–399	1.08	1.42
dprime	2.05	0.88	-0.13–5.79	0.66	1.56
antiacc	0.70	0.16	0.3–0.98	–0.46	–0.75
inconrt	680	103	481–1069	1.11	1.71
sart_mw	.47	0.23	0–1	0.12	–0.43
strp_mw	.37	0.21	0–0.92	0.45	-0.43

gf_cfiq = fluid intelligence, Cattell Series Completion; gf_letters = fluid intelligence, letter sets; gf_nums = fluid intelligence, number series; rtsd = SEM-SART(SD of RTs to "go" trials); dprime = SEM-SART (difference between proportion of correct responses and failures); antiacc = antisaccade; inconrt = N-Stroop; sart_mw = TUTs during SEM-SART; strp_mw = TUTs during N-Stroop.

Table 2. Descriptive statistics (creativity ratings), by rater, for the divergent thinking tasks

Task	*M*	*SD*	*R* (min-max)	*Skew*	*Kurtosis*
DT_mri_r1	2.29	0.39	1.22–3.78	0.44	0.79
DT_mri_r2	1.46	0.24	1–2.37	1.04	1.40
DT_mri_r3	1.91	0.29	1–2.70	0.03	−0.16
DT_mri_r4	1.76	0.38	1–3.36	1.08	2.17
DT1_r1	1.90	0.47	1–3.25	0.59	0.23
DT1_r2	1.45	0.33	1–2.67	0.95	0.55
DT1_r3	1.59	0.37	1–3.33	1.19	3.12
DT1_r4	1.39	0.42	1–3	1.43	2.02
DT2_r1	1.75	0.54	1–3.67	1.10	1.03
DT2_r2	1.50	0.41	1–3.5	1.77	4.82
DT2_r3	1.69	0.44	1–3.5	1.05	1.48
DT2_r4	1.34	0.43	1–4	2.55	9.44

dt1 = divergent thinking, box; dt2 = divergent thinking, rope; dt_mri = divergent thinking, MRI; r1-r4 = rater 1-rater 4.

Table 3. Pearson correlations between all observed variables

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1. dt_mri_r1	1																				
2. dt_mri_r2	0.83	1																			
3. dt_mri_r3	0.87	0.77	1																		
4. dt_mri_r4	0.84	0.80	0.78	1																	
5. dt1_r1	0.52	0.47	0.40	0.47	1																
6. dt1_r2	0.35	0.26	0.25	0.36	0.68	1															
7. dt1_r3	0.46	0.42	0.38	0.41	0.70	0.58	1														
8. dt1_r4	0.44	0.39	0.35	0.41	0.77	0.70	0.69	1													
9. dt2_r1	0.43	0.32	0.41	0.44	0.50	0.41	0.46	0.48	1												
10. dt2_r2	0.34	0.22	0.33	0.33	0.39	0.36	0.42	0.44	0.77	1											
11. dt2_r3	0.47	0.35	0.43	0.46	0.53	0.47	0.56	0.56	0.86	0.78	1										
12. dt2_r4	0.26	0.21	0.25	0.31	0.38	0.42	0.49	0.52	0.72	0.67	0.74	1									
13. gf_cfiq	0.10	0.13	0.23	0.09	0.13	0.15	0.10	0.08	0.05	−0.01	0.04	0.05	1								
14. gf_lets	0.14	0.18	0.21	0.12	0.12	0.11	0.08	0.12	0.06	0.02	−0.01	0.04	0.27	1							
15. gf_nums	0.17	0.20	0.10	0.17	0.13	0.14	0.18	0.11	0.10	0.11	0.14	0.13	0.31	0.41	1						
16. antiacc	0.10	0.17	0.13	0.08	0.11	0.11	0.25	0.13	0.10	0.09	0.14	0.13	0.19	0.25	0.23	1					
17. rtsd	−0.21	−0.14	−0.20	−0.12	−0.18	−0.16	−0.25	−0.17	−0.13	−0.10	−0.17	−0.12	−0.09	−0.21	−0.25	−0.47	1				
18. dprime	0.12	0.05	0.11	0.12	0.14	0.22	0.11	0.18	0.21	0.15	0.21	0.22	0.11	0.20	0.30	0.25	−0.41	1			
19. inconrt	−0.16	−0.16	−0.15	−0.14	−0.18	−0.10	−0.16	−0.19	−0.03	−0.04	−0.06	−0.07	−0.03	−0.17	−0.13	−0.25	0.27	0.02	1		
20. sart_mw	−0.09	−0.11	−0.10	−0.07	−0.08	0.00	−0.06	0.00	−0.12	−0.14	−0.02	−0.08	0.24	−0.15	0.01	−0.11	0.26	−0.16	0.03	1	
21. strp_mw	0.01	−0.01	0.01	−0.02	−0.12	−0.13	−0.14	−0.11	0.02	0.00	0.03	−0.05	0.06	−0.10	−0.11	−0.02	0.14	−0.10	0.17	0.54	1

dt_mri = divergent thinking, MRI; r1 = rater 1; r2 = rater 2; r3 = rater 3; r4 = rater 4; dt1 = divergent thinking, box; dt2 = divergent thinking, rope; gf_cfiq = fluid intelligence, Cattell Series Completion; gf_lets = fluid intelligence, letter sets; gf_nums = fluid intelligence, number series; antiacc = antisaccade; rtsd = SEM-SART (SD of RTs to "go" trials); dprime = SEM-SART (difference between proportion of correct responses and failures); inconrt = N-Stroop; sart_mw = TUTs during SEM-SART; strp_mw = TUTs during N-Stroop.

Behavioral task procedures

In addition to the fMRI divergent thinking assessment, participants completed two AUTs lasting 3 minutes each. This AUT measurement allowed us to compare divergent thinking performance between an fMRI assessment requiring brief AUT ideation and a conventional AUT protocol with a longer assessment period. Participants were given the same "be creative" instructions (Beaty et al., 2014; Nusbaum et al., 2014) and were asked to continuously generate ideas for the stimulus items *box* and *rope*, which had not been presented during the fMRI assessment. Responses were typed by participants into a text field using MediaLab software and recorded so that the idea quality of individual responses could be subsequently assessed by the same four blinded raters (along with the fMRI scanner responses).

Attentional control and intelligence assessments

Executive attention tasks

Participants completed three measures of attentional restraint (Kane et al., 2016; McVay & Kane, 2012).

The *Antisaccade Letters* task required visual identification of a target letter on a computer screen. Participants completed 18 response-mapping practice trials and 12 antisaccade practice trials (see Kane et al., 2001). Ninety antisaccade experimental trials were presented to participants, during which three centrally-located fixation asterisks appeared on the screen for either 200 (18 trials), 600 (18 trials), 1000 (18 trials), 1400 (18 trials), or 1800 ms (18 trials) in random order. Subsequent flashing cues (" = ") preceded target letter presentation 8.6 c to the left or right of fixation. Letter targets (B, P, or R) were located opposite of the flashing cue. Letter targets corresponded with a response keypad labeled B (30 trials), P (30 trials), and R (30 trials). Pattern-masking of the target letter occurred after 100 ms. The dependent variable for this task was the proportion of correct keypad responses.

The *Numerical Stroop (N-Stroop)* task required participants to identify the number of digits presented on computer screen during each trial, while ignoring the identity of the digits. One horizontal row of 2–4 repeating digits (in Courier New 24 pt. font) was presented in the center of the screen for each trial. Numerical targets corresponded with one of three labeled keys on a response keypad (2, 3, 4), which allowed participants to report the number of digits. Participants completed two seamless blocks of 150 trials (300 total). Each block was 80% congruent (120 trials in each block) for both number of digits and digit identity (e.g., *333*). Incongruent trials presented conflicting numbers and identities (e.g., *222*). The dependent variable for this task was mean reaction time (RT) on incongruent trials on the first block; although attention control is ideally measured as a difference score between incongruent and congruent RTs, this difference score did not correlate with the other executive variables (rs = −.10–.10) and so, like many prior studies, we used RTs on incongruent trials instead as our indicator of attention control (e.g., Kane et al., 2016; McVay & Kane, 2012b). There were two unanalyzed thought probes in block one and 20 analyzed thought probes in block two, which was specifically implemented to measure mind wandering (thought probes followed 13% of trials in block 2; see "*Mind wandering assessments*").

The *Semantic Sustained Attention to Response (SEM-SART)* task required participants to respond via spacebar press to target words presented on a computer screen that were members of a prespecified semantic category (e.g., animals), while inhibiting responses to a different category (e.g., vegetables). All target stimuli were presented for 300 ms followed by a 1500 ms mask (i.e., XXXXXXXX). First, participants completed 10 practice trials responding to boys', but not to girls' names. Next, 5 blocks of 135 trials were presented (675 total trials) and were further partitioned into 3 seamless "mini-blocks" of 45 trials. There were 40 "go" trials (i.e., requiring a response) and 5 "no-go" trials (i.e., requiring response inhibition). In each mini-block, there were 3 thought probes following no-go trials (45 total probes; see "Mind wandering assessments"). There were two dependent variables for this task: the SD of RTs to "go" trials and d′, which corresponds with the normalized proportion of correct categorization responses minus the proportion of commission errors/failed inhibitory responses.

Mind wandering assessments

During the N-Stroop and SEM-SART, participants reported their immediately preceding thoughts by responding to several unpredictable thought probes (see McVay & Kane, 2009, 2012a, 2012b; probe placements in each task are detailed above). Prior to N-Stroop and SEM-SART task completion, participants engaged in 90 thought probe practice trials during which they judged whether colored X's presented for 3000 ms each were warm hues (red, yellow, pink) or cool hues (blue, dark blue, purple) via keypad press. Probes followed 12 (13.3%) practice trials. Each probe specifically asked: "What are you thinking about?" after which participants were instructed to press a corresponding number on the keypad that most represented the content of their thoughts. Participants were asked to report on their thoughts immediately preceding unpredictable thought probes during the N-Stroop and SEM-SART tasks. A set of eight thought content items was presented on the computer screen and re-explained for each probed task. The thought content items (italicized as follows) were used to calculate TUTs (see Kane et al., 2016; McVay & Kane, 2009, 2012a, 2012b). (1) *The task*, thoughts pertaining to the executive attention task (e.g., task stimuli or appropriate responses); (2) *Task performance*, thoughts focused on evaluating one's immediate task performance; (3) *Everyday things*, thoughts about recent or forthcoming events salient to one's daily life; (4) *Current state of being*, thoughts about one's physical or emotional state (e.g., hunger, sleepiness); (5) *Personal worries*, thoughts about fears, and/or troubling influences on one's life; (6) *Daydreams*, thoughts that are fantastical and disconnected from reality; (7) *External environment*, task-unrelated thoughts about the immediate environmental context; (8) *Other*, only thoughts which failed to align with the 7 alternative categories. The proportion of TUTs was defined at response options 3–8. The Appendix presents descriptive statistics for each mind-wandering response category as a proportion of all TUT reports. Probe practice performance was not analyzed; the TUT dependent variables for the N-Stroop and SEM-SART attention control tasks are described below.

N-Stroop-TUT. The total proportion of reported TUTs following thought probes (e.g., 10 reports of mind wandering following 20 total probes in block 2 = 0.5).

SEM-SART-TUT. The total proportion of reported TUTs following thought probes (e.g., 20 reports of mind-wandering following 45 total probes = 0.44).

Gf

Participants completed three measures of *Gf*. The *number series task* (Thurstone, 1938) required participants to correctly identify a numerical pattern by selecting the next number in a sequence (15 trials, 5 minutes). The dependent variable for this task was the sum of correctly reported numbers across trials. The *letter sets task* (Ekstrom, Dermen, & Harman, 1976) required participants to identify a letter pattern by selecting a set of four letters that violated a task-rule across a larger set (16 trials, 4 minutes). The dependent variable for this task was the sum of correctly identified rule violations. The *series completion task* from the Culture Fair Intelligence Test (CFIT; Cattell & Cattell, 1961/2008) required participants to select a fourth image that most appropriately completed the visual pattern represented by three sequential images (13 trials, 3 minutes). The dependent variable for this task was the sum of correct images selected.

Analysis plan and model specification

Outliers for executive attention task performance were identified using boxplots. Specifically, observations that exceeded three times the interquartile range (IQR) from the upper and lower plot hinges (Q1 – 3 * IQR or Q3 + 3 * IQR) were excluded from subsequent analyses. In total, 168 participants were retained for the antisaccade task, 164 for N-Stroop, 165 for SEM-SART (rtsd), 169 for SEM-SART (d’)), and 166 for both mind wandering measurements (N-Stroop-TUT and SEM-SART-TUT). Latent variable models were specified and estimated using maximum likelihood estimation in Mplus 8. Using the behavioral tasks as indicators, we specified the latent variables attention control (antisaccade, N-Stroop, and SEM-SART (rtsd) and SEM-SART (d’)), mind wandering rate (N-Stroop-TUT and SEM-SART-TUT), and *Gf* (number series, letter sets, and series completion). The factor variances were fixed to 1, and the loadings for the two mind wandering indicators were constrained to be equal. Using idea quality assessed by the four independent raters (Rs) as indicators, we specified three lower-order latent divergent thinking variables: d_box (R1, R2, R3, and R4), dt_rope (R1, R2, R3, and R4), and dt_MRI (R1, R2, R3, and R4). These lower-order factors were in turn specified as indicators of a higher-order DT factor (cf., Frith et al., 2020). The measurement models informed a series of regression and bifactor models that assessed specific and general contributions of attention control, *Gf*, and mind wandering on DT. Attention control measures (e.g., reaction time) were standardized prior to analysis; the standardized effects reported below correspond with the *r* metric, which can be interpreted using the established small (.10), medium (.20), and large (.30) guidelines (Gignac & Szodorai, 2016). Additionally, measurement model fit can be interpreted using the established acceptable (CFI = .90, TLI = .90, RMSEA = .08, SRMR = .08) and excellent (CFI = .95, TLI = .95, RMSEA = .05, SRMR = .05) fit indices (Kline, 2015).

Results

Descriptive statistics for attention control, mind wandering, and *Gf* measures are displayed in Table 1. Descriptive statistics for the divergent thinking measures are displayed in Table 2. Correlations among all observed variables are displayed in Table 3.

Confirmatory factor analyses

We first specified a measurement model for DT (n = 186), which fit well: χ^2 (51 df) 78.354, p = .008; CFI = .985; TLI = .98; RMSEA = .054 [90% CI: 0.028, .076]; SRMR = .04. This model reproduces our prior work with the same behavioral data (Frith et al., 2020) showing significant loadings of the two lab-based DT tasks (box and rope) and the MRI-based task onto a higher-order DT factor (see Frith et al., 2020, for the lower-order DT factor solution).

Next, we specified a measurement model to assess how the four attention control variables (antisaccade, N-Stroop, SEM-SART [rtsd], and SEM-SART [d']) load onto a latent attentional control factor (AC; n = 169). The residual correlation of rtsd and d' was modeled because these variables came from the same task (i.e., SEM-SART). This model fit the data well: χ^2 (1 df) 1.745, p = .187; CFI = .990; TLI = .942; RMSEA = .066 [90% CI: 0, .228]; SRMR = .022; all indicators loaded significantly onto the latent *AC* variable, with antisaccade accuracy showing the highest loading.

Our final measurement model examined loadings of the three Gf tasks onto a latent Gf factor (n = 184). This model showed good fit: χ^2 (1 df) 1.275, p = .259; CFI = .995; TLI = .986; RMSEA = .039 [90% CI: 0, .204]; SRMR = .07.

We next specified a confirmatory factor analysis to model relationships between AC, DT, *Gf*, and mind wandering (MW; n = 186). The model fit the data well: χ^2 (181 df) 243.739, p = .001; CFI = .97; TLI = .965; RMSEA = .043 [90% CI: .028, .057]; SRMR = .054. We found significant positive correlations between *Gf*, AC, and DT factors (p < .001; see Figure 1), with large magnitudes (95% CI in brackets): *Gf* and DT, r = .38 [19, .57]; AC and DT, r = .41 [.22, .60]; AC and *Gf, r* = .60 [.41, .79]. Consistent with prior studies, the model also showed a significant, medium negative correlation between AC and MW, $r = -.24$ (e.g., Kane et al., 2016; Robison & Unsworth, 2018; Unsworth & Robison, 2017) with all other MW intercorrelations small and non-significant. Results thus replicate the established correlation between *Gf* and AC (Engle, 2018; Shipstead et al., 2014; Unsworth & Spillers, 2010) and Gf and DT (Batey et al., 2010; Beaty et al., 2014; Benedek et al., 2012, 2014; Furnham et al., 2008, 2005; Nusbaum & Silvia, 2011; Silvia, 2008, 2015; Silvia & Beaty, 2012; Sligh et al., 2005), with a novel finding being a large correlation between AC and DT.

Multiple regression of AC, DT, Gf, and MW

Having modeled latent correlations, we then specified a structural regression model to assess the relative contribution of AC, *Gf*, and MW to DT. This allowed us to test a key question of interest: does attention control predict divergent thinking, above and beyond *Gf*? To address this question, we modeled AC, *Gf*, and MW as predictors of DT (note the fit indices were identical to the CFA). Interestingly, despite large correlations found for the CFA, this regression model showed nonsignificant effects of *Gf* on DT (β = .22, p = .15), AC on DT (β = .26, p = .09), and MW on DT ($\beta = -.05$, p = .62), indicating that AC and *Gf* do not *uniquely* predict DT; their predictive power apparently is driven by the shared variance among two or more of these constructs.

Bifactor analysis of common executive attention

The fact that the shared AC-*Gf* variance appeared to play a role in the prediction of DT motivated a bifactor model to estimate the effects of both a general executive control factor (i.e., the variance common to AC, *Gf*, and MW indicators) and residual *Gf*-specific and MW-specific factors on DT. Modeling general and specific factors in the same bifactor model allows for a parsimonious interpretation of variance across tasks not captured by a general factor. However, specific factors may also be incorporated into the general factor when indicators cannot be statistically distinguished from it. That is, an indicator may not demonstrate residual variance distinct from a general factor.

We first specified a bifactor CFA, with a general "executive attention" factor and specific *Gf* and MW factors (n = 185). The executive attention and residual factors (*Gf* and MW) were modeled to be orthogonal. This model converged and adequately fit the data: χ^2 (23 df) 42.388, p = .008; CFI .92; TLI = .875; RMSEA = .068 [90% CI: .034, .099]; SRMR = .06. All indicators loaded significantly onto the general executive factor, with the exception of N-Stroop TUTs (β = −.14, p = .14) and Cattell Series Completion

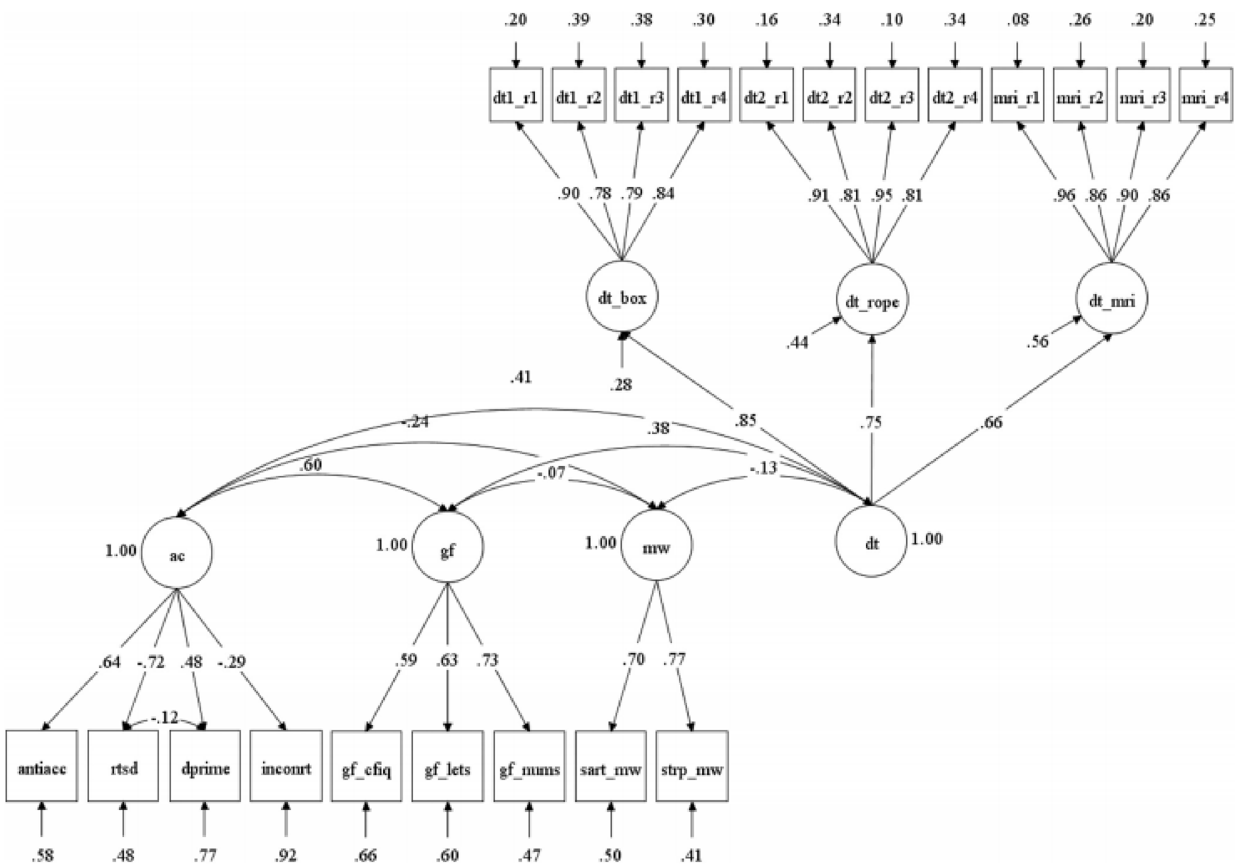

Figure 1. Confirmatory factor analysis of attention control, divergent thinking, fluid intelligence, and mind wandering relationships. ac = attention control; antiacc = antisaccade; rtsd = SEM-SART (SD of RTs to "go" trials); dprime = SEM-SART (difference between proportion of correct responses and failures); inconrt = N-Stroop; gf = fluid intelligence; gf_cfiq = Cattell Series Completion; gf_lets = fluid intelligence, letter sets; gf_nums = fluid intelligence, number series; mw = mind wandering; sart_mw = TUTs during SEM-SART; strp_mw = TUTs during N-Stroop; dt = divergent thinking; dt_box = divergent thinking, box (raters 1–4); dt_rope = divergent thinking, rope (raters 1–4); dt_mri = latent variable of creativity ratings from MRI trials (rater 1–4); N = 186

(β = .17, $p = .07$); the highest loading on the executive factor was SART rtsd, followed by antisaccade accuracy (see Figure 2). This bifactor solution is consistent with past work reporting a common executive factor underlying *Gf* and AC (Benedek et al., 2014).

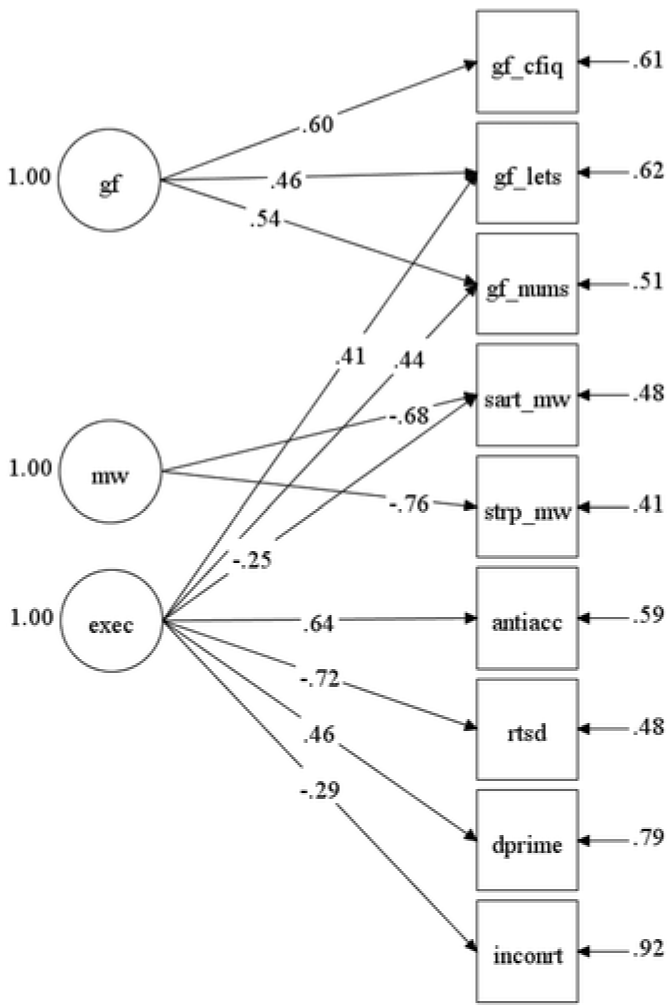

Figure 2. Bifactor confirmatory factor analysis of fluid intelligence, mind wandering, and general executive attention. Only significant paths are shown. gf = fluid intelligence; gf_cfiq = Cattell Series Completion; gf_lets = fluid intelligence, letter sets; gf_nums = fluid intelligence, number series; mw = mind wandering; sart_mw = TUTs during SEM-SART; strp_mw = TUTs during N-Stroop; exec = general executive attention; antiacc = antisaccade; rtsd = SEM-SART (SD of RTs to "go" trials); dprime = SEM-SART (difference between proportion of correct responses and failures); inconrt = N-Stroop; N = 185

How do general executive control and specific *Gf* and MW factors predict DT? A bifactor regression model examined how these common and specific factors relate to DT ability. The model converged and fit the data well: χ^2 (179 df) 238.592, $p < .001$; CFI = .971; TLI = .966; RMSEA = .042 [90% CI: .027, .056]; SRMR = .049 (see Figure 3). The general executive factor significantly predicted DT (β = .40, $p < .001$); however, the model yielded nonsignificant effects of residual *Gf* (β = .20, $p = .09$) and MW (β = −.05, $p = .67$), indicating that the relationship between *Gf* and DT is driven by shared variance with a common executive attention factor.

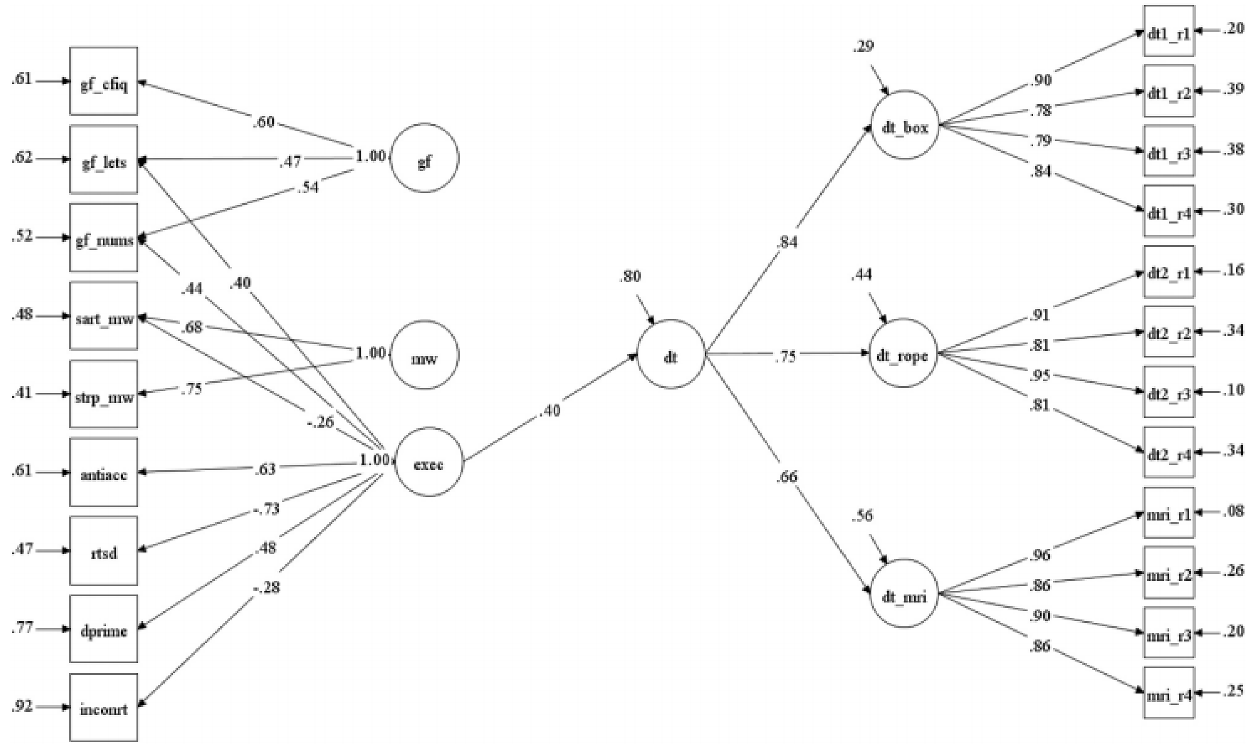

Figure 3. Bifactor multiple regression analysis of the contribution of fluid intelligence, mind wandering, and general executive attention to divergent thinking. Only significant paths are shown. gf = fluid intelligence; gf_cfiq = Cattell Series Completion; gf_lets = fluid intelligence, letter sets; gf_nums = fluid intelligence, number series; mw = mind wandering; sart_mw = TUTs during SEM-SART; strp_mw = TUTs during N-Stroop; exec = general executive attention; antiacc = antisaccade; rtsd = SEM-SART (SD of RTs to "go" trials); dprime = SEM-SART (difference between proportion of correct responses and failures); inconrt = N-Stroop; dt = divergent thinking; dt_box = divergent thinking, box (raters 1–4); dt_rope = divergent thinking, rope (raters 1–4); dt_mri = latent variable of creativity ratings from MRI trials (raters 1–4); N = 186

Discussion

The present study explored the unique and shared contributions of executive attention and *Gf* to divergent thinking performance. We predicted that executive attention control would predict divergent thinking and would help to explain the contribution of *Gf* to creative cognition. In line with earlier work, we observed distinct positive associations between executive factors and divergent thinking, as well as *Gf* and divergent thinking (Benedek et al., 2014). However, findings from this study build upon previous research by demonstrating additional support for the executive nature of creative cognition, which appears to be predominantly driven by executive attention. That is, general executive attention control emerged as a higher-order factor that attenuated the strong (and often-observed) relationship between *Gf* and divergent thinking. We also found that mind wandering, as measured using TUTs, was a negative, nonsignificant predictor of divergent thinking performance – consistent with some past work (Smeekens & Kane, 2016; but see Baird et al., 2012) – suggesting that a tendency to engage in task-unrelated thought during executively-demanding tasks is not conducive to generating original ideas. Taken together, this study is the first to provide evidence suggesting that the relationship between *Gf* and DT is driven by the top-down control of attention.

We used a latent variable approach to examine the unique effects of *Gf*, attention control, and mind wandering on divergent thinking, with attention control yielding the largest individual effect on divergent thinking performance. Initially, we observed a medium correlation of *Gf* with divergent thinking, which is similar to evidence highlighting the role of fluid reasoning ability in creative cognition (Akhtar & Kartika, 2019; Batey et al., 2010; Beaty et al., 2014, 2014; Benedek et al., 2012, 2014; Cho et al., 2010; Furnham et al., 2008, 2005; Karwowski et al., 2016; Kenett et al., 2016; Liu et al., 2019; Nusbaum & Silvia, 2011; Preckel et al., 2006; Silvia, 2008, 2015; Silvia & Beaty, 2012; Sligh et al., 2005). Additionally, in the present research, the Gf path to divergent thinking became non-significant in a structural regression model that included attention control as a predictor, and in a structural bifactor model with a general attention control factor and a residual Gf-specific factor. Benedek et al. (2014) found a weakened, albeit significant, residual correlation between *Gf* and divergent thinking when the executive functions updating, shifting, and inhibition were modeled as latent predictors. However, updating ability, which is thought to be governed by broader attention control (Engle, 2002; Kane et al., 2001), largely accounted for the attenuated relationship between *Gf* and divergent thinking (Benedek et al., 2014). Our findings uniquely extend this line of evidence and provide preliminary support for attention control as a core mechanism underlying the intelligence-creativity relationship.

There are several reasons why attention may be central to creative cognition. First, focused attention has been suggested to benefit divergent thinking (Zabelina, 2018). This is because top-down executive control processes are thought to permit focused, goal-directed internal attention (Benedek et al., 2011; Benedek et al., 2014) that guides memory search and facilitates the efficient generation of remote, novel ideas at the expense of dominant, but conventional ideas (De Dreu et al., 2012; Gilhooly et al., 2007; Nusbaum & Silvia, 2011; Wiley & Jarosz, 2012; Zabelina et al., 2016). Additionally, working memory capacity appears to be associated with the maintenance of attention and persistence during divergent thinking (Baas, De Dreu, & Nijstad, 2008; De Dreu et al., 2012). This ability to selectively and effortfully focus attention on task-relevant stimuli aligns with the *controlled-attention* theory of creativity (Beaty et al., 2014; Benedek et al., 2012; Jauk, Benedek, Dunst, & Neubauer, 2013).

However, creative cognition has also been favorably associated with both “leaky” and flexible attention (Baird et al., 2012; Zabelina & Beeman, 2013; Zabelina, O’Leary, Pornpattananangkul, Nusslock, & Beeman, 2015; Zabelina & Robinson, 2010). Leaky attention is characterized by a natural tendency to diffusely attend to a panoply of extraneous stimuli, which is thought to allow potentially novel connections to be more readily identified (Carson, Peterson, & Higgins, 2003; Zabelina, 2018). The benefits of leaky attention may be explained via the *associative theory* of creativity (Mednick, 1962; Zabelina et al., 2016). This is because remotely linked semantic concepts may extemporaneously pass through the attentional filter, promoting the accessibility of novel ideas with minimal top-down executive control (Eysenck, 1993, 1995; Martindale, 1981, 1995). Leaky attention is also more consistently linked to real-world creativity, suggesting that creative achievement may benefit from a more diffuse attentional scope, and thus a less selective filter that permits the entry of “irrelevant” stimuli into conscious awareness (Zabelina et al., 2016). On the other hand, flexible attention may constitute a controlled ability to switch from diffuse to directed attentional states (Gabora, 2010; Vartanian, 2009; Zabelina & Robinson, 2010). In this way, flexible attention may be analogous to an executive strategy for initiating a broad search of semantic knowledge and then focusing internal attention to selectively retrieve information that supports divergent thinking (Beaty & Silvia, 2012; Benedek et al., 2012; Zabelina, 2018). Previous work suggests that higher divergent thinking performance is associated with the ability to rapidly shift attention to relevant aspects of the task, while inhibiting incoming distractors capable of inundating attention (Cassotti et al., 2016; Zabelina et al., 2016). Although the proposed benefits of attention control to creativity may be attributed to associative cognition and controlled-attention, it is important to emphasize that the roles of *Gf* and executive attention likely depend on the creativity outcome measured. That is, creativity assessed via divergent thinking may be more influenced by *flexible* attention compared to creativity assessed via creative behavior/achievement, which appears to benefit from *leaky* attention (Zabelina et al., 2016). It is therefore important for continued empirical efforts to study whether *Gf* and executive attention also contribute to real-world creativity, and to what extent.

The integration of both *associative* and *controlled-attention* theoretical perspectives can offer a clarified interpretation of the role of attention for creative thinking across domains. Specifically, several lines of evidence have identified a flexible semantic network structure that tends to characterize creative thinkers (Benedek et al., 2017; Gray et al., 2019; Kenett et al., 2014; Kenett & Faust, 2019; Kenett et al., 2018). The scope of attention within this structure may be broadly distributed across a range of associative links (Gruszka & Necka, 2002; Rossmann & Fink, 2010), although this does not necessarily mean that the mental search for novel response candidates is operating in a spontaneous, uncontrolled manner. Rather, the array of possible associations within this network is likely constrained by executive operations, which minimize the salience of less creative or task-inappropriate mental representations (Nusbaum & Silvia, 2011; Unsworth, Spillers, & Brewer, 2011). Relatedly, Faust and Kenett (2014) developed a model that views semantic processing along a continuum that spans highly organized, rigid structure at one extreme, to a chaotic, uncontrolled structure at the other. Neither extreme appears to optimally benefit creativity because while creative cognition requires expansive and atypical semantic processing, top-down regulation effectively counters the intrusion of bizarre, irrelevant stimuli (Faust & Kenett, 2014; Kenett et al., 2014).

Taken together, relaxing attention is capable of reinforcing novel idea generation, whereas attentional persistence may also ensure that novel ideas are useful and task-appropriate (Gabora, 2010). Therefore, we contend that these seemingly disparate perspectives need not be viewed as incompatible. People must be able to selectively focus attention, inhibit extraneous information, and flexibly shift attention across multiple elements in the problem-solving process (Vartanian, 2009; Zabelina, 2018; Zabelina et al., 2016). To this point, attention is one fundamental aspect of creative cognition that requires direction to optimally assist ideation and problem-solving (Zabelina, 2018). Without sufficient top-down control of attention, creative problem-solving appears to suffer; however, the duration and strength of control necessary for creative thinking has not been unequivocally pinpointed (Chrysikou, 2019). Although studies have shown that creative individuals exhibit greater attention control than their less-creative counterparts (Baas et al., 2008; De Dreu et al., 2012), work also suggests that control is fleeting (Zabelina, 2018; Zabelina et al., 2016). Transient, yet goal-directed attention regulation may help explain why creative individuals are able to readily shift focus across multiple stimuli to generate a variety of original responses (Zabelina et al., 2015), and it may also signify a protective mechanism against unintentional mind-wandering.

Being distracted against one's will likely indicates that one is not in full control of their thoughts, but *purposefully* relaxing attentional constraints may portend a seemingly paradoxical ability to regulate attention more effectively. Mind wandering, which is often measured as TUTs, exhibits variable associations with creative thinking. As aforementioned, some research suggests that mind wandering, while engaged in an undemanding task, offers modest benefits to creative cognition (Agnoli et al., 2018; Baird et al., 2012; Sio & Ormerod, 2009) perhaps via enhanced associative processing (Agnoli et al., 2018; Baird et al., 2012). However, other evidence points to mind wandering as a manifestation of executive control failures that do not subserve creative thinking (Hao et al., 2015; Smeekens & Kane, 2016). Similarly, we found that mind wandering was not significantly associated with divergent thinking. While we anticipate that unintentional mind wandering is equivalent to attentional control failure, it may not always derail the divergent thinking process.

It is notable that unproductive lapses in executive task-related attention appeared to bear no relation to divergent thinking performance in this study. However, this finding extends recent evidence showing that mind-wandering is not causally related to the creative quality of ideas (Smeekens & Kane, 2016). Nevertheless, future work should consider alternative methods for assessing mind-wandering. We probed TUTs in (only two) shorter executive function tasks (approximately 20 minutes) and did not compare this variety of mind wandering to mind wandering during the divergent creativity tasks. First, measuring TUTs in longer tasks could reveal significant effects of mind wandering on divergent thinking outcomes, as attention may be harder to control over longer assessment periods (Smeekens & Kane, 2016); however, we chose to employ shorter executive function tasks to offset the potential for undue participant time burden and attrition in this multi-phase study.

Second, research should examine whether individuals who perform well on divergent thinking tasks are not only better able to regulate attention, but also whether an ability to recover more quickly from distracting information is also beneficial to creative cognition. That is, it may not be that those with high executive attention control are impervious to the allure of distraction; perhaps these individuals are simply able to combat interfering stimuli by readily switching attention back to the target task (Zabelina, 2018). One way to investigate this in the laboratory may be to examine the time course of distraction-recovery from the point of attending to task-irrelevant stimuli, to switching attention back to salient aspects of the target task (Fukuda & Vogel, 2011). Another way to explore this dynamic relationship between distraction and attention recovery may be to model the content of TUTs. Although beyond the scope of the present experiment, recent work has shown that individuals with higher executive control exhibit more varied, albeit infrequent, mind wandering episodes (Welhaf et al., 2020). Future research should investigate whether abbreviated streams of TUTs flow in many directions because higher ability individuals are better able to maintain task-relevant goals. It is plausible that fluctuating TUTs may serve as functional cues to re-focus attention on the task at hand, or be shallowly entertained, which may allow for efficient attentional switches back to task-relevant goals (Welhaf et al., 2020). Additionally, more work is needed to clarify whether certain types of off-task thought would be more (or less) conducive for creative idea generation. Preliminary evidence suggests that in controlled laboratory contexts: 1) participants' TUTs about the external environment may occur infrequently, 2) higher executive control is related to less TUTs pertaining to one's current state, and 3) lower executive control is related to more TUTs featuring personal worries (Welhaf et al., 2020). A natural extension to this line of research is to address not only the type of TUTs and when they occur, but also to determine the impact of specific TUT categories on creative cognition. However, future research in this area should also consider accounting for low endorsement rates of specific TUT categories with larger samples and perhaps Poisson modeling due to skew and kurtosis.

Furthermore, when engaged in unintentional mind wandering, attentional focus spontaneously shifts to internal thoughts, rather than goal-directed consideration of the task at hand (Agnoli et al., 2018; Smeekens & Kane, 2016). Experiments designed to assess intentional and unintentional mind wandering may be useful to isolate differential impacts of mind wandering type on creative thinking. Although, it is important to note that other research suggests that too much deliberate mind wandering may also conflict with task goals and harm divergent thinking performance (Agnoli et al., 2018). Continued research is needed to clarify whether there is an optimal balance between deliberately attending to extraneous thoughts and diminishing their intrusion. This will facilitate a better understanding of the interplay between focused attention and mind wandering in the context of divergent thinking. Lastly, our study evaluated the impact of attention control on domain-general divergent thinking, but the utility of mind wandering for domain-specific creativity (e.g., artistic, scientific, etc.) also warrants examination. It is possible that experience and/or expertise in a given domain may impact the way individuals respond to task-related mental workload, and thereby dictate the extent to which TUTs impact creative cognition.

In conclusion, our findings suggest that attention control supports divergent thinking above the effects of *Gf*, which lends additional credence to the executive nature of creative cognition. Moreover, the putative role of mind wandering in creative thinking warrants additional investigation, as TUTs may represent executive control failures, but could also allow “irrelevant” stimuli to pass through the attentional filter for productive exploration during divergent thinking. Continued work is needed to further empirical understanding of the influence of attention control on creativity – such as modeling the unique and shared contributions of attention and general intelligence factors in addition to *Gf* (e.g., crystallized intelligence, visuospatial intelligence, and broad retrieval ability) – and also potentially manipulating attention during creativity assessment to examine consequences of mind wandering while generating novel ideas and solutions.

Disclosure statement. No potential conflict of interest was reported by the authors.

Funding. This work was supported by the National Science Foundation [DRL-1920653] and the John Templeton Foundation [RFP-15-12].

References

Agnoli, S. , Vanucci, M. , Pelagatti, C. , & Corazza, G. E. (2018). Exploring the link between mind wandering, mindfulness, and creativity: A multidimensional approach. *Creativity Research Journal* , 30(1), 41–53. doi:10.1080/10400419.2018.1411423

Akhtar, H. , & Kartika, Y. (2019). Intelligence and creativity: An investigation of threshold theory and its implications. *Journal of Educational Sciences and Psychology* , 9(1), 131–138.

Amabile, T. M. (1982). Social psychology of creativity: A consensual assessment technique. *Journal of Personality and Social Psychology* , 43(5), 997. doi:10.1037/0022-3514.43.5.997

Baars, B. J. (2010). Spontaneous repetitive thoughts can be adaptive: Postscript on "mind wandering". *Psychological Bulletin* , 136(2), 208. doi:10.1037/a0018726

Baas, M. , De Dreu, C. K. , & Nijstad, B. A. (2008). A meta-analysis of 25 years of mood-creativity research: Hedonic tone, activation, or regulatory focus? *Psychological Bulletin* , 134(6), 779. doi:10.1037/a0012815

Baird, B. , Smallwood, J. , Mrazek, M. D. , Kam, J. W. , Franklin, M. S. , & Schooler, J. W. (2012). Inspired by distraction: Mind wandering facilitates creative incubation. *Psychological Science* , 23(10), 1117–1122. doi:10.1177/0956797612446024

Banich, M. T. (2009). Executive function: The search for an integrated account. *Current Directions in Psychological Science* , 18(2), 89–94. doi:10.1111/j.1467-8721.2009.01615.x

Batey, M. , Chamorro-Premuzic, T. , & Furnham, A. (2009). Intelligence and personality as predictors of divergent thinking: The role of general, fluid and crystallised intelligence. *Thinking Skills and Creativity* , 4(1), 60–69. doi:10.1016/j.tsc.2009.01.002

Batey, M. , Furnham, A. , & Safiullina, X. (2010). Intelligence, general knowledge and personality as predictors of creativity. *Learning and Individual Differences* , 20(5), 532–535. doi:10.1016/j.lindif.2010.04.008

Beaty, R. E. , Benedek, M. , Kaufman, S. B. , & Silvia, P. J. (2015). Default and executive network coupling supports creative idea production. *Scientific Reports* , 5(1), 1–14. doi:10.1038/srep10964

Beaty, R. E. , Christensen, A. P. , Benedek, M. , Silvia, P. J. , & Schacter, D. L. (2017). Creative constraints: Brain activity and network dynamics underlying semantic interference during idea production. *NeuroImage* , 148, 189–196. doi:10.1016/j.neuroimage.2017.01.012

Beaty, R. E. , Kenett, Y. N. , Christensen, A. P. , Rosenberg, M. D. , Benedek, M. , Chen, Q. , … Silvia, P. J. (2018). Robust prediction of individual creative ability from brain functional connectivity. *Proceedings of the National Academy of Sciences* , 115(5), 1087–1092. doi:10.1073/pnas.1713532115

Beaty, R. E. , Nusbaum, E. C. , & Silvia, P. J. (2014). Does insight problem solving predict real-world creativity? *Psychology of Aesthetics, Creativity, and the Arts* , 8(3), 287. doi:10.1037/a0035727

Beaty, R. E. , & Silvia, P. J. (2012). Why do ideas get more creative across time? An executive interpretation of the serial order effect in divergent thinking tasks. *Psychology of Aesthetics, Creativity, and the Arts* , 6(4), 309. doi:10.1037/a0029171

Beaty, R. E. , & Silvia, P. J. (2013). Metaphorically speaking: Cognitive abilities and the production of figurative language. *Memory & Cognition* , 41(2), 255–267. doi:10.3758/s13421-012-0258-5

Beaty, R. E. , Silvia, P. J. , Nusbaum, E. C. , Jauk, E. , & Benedek, M. (2014). The roles of associative and executive processes in creative cognition. *Memory & Cognition* , 42(7), 1186–1197.

Benedek, M. , Bergner, S. , Könen, T. , Fink, A. , & Neubauer, A. C . (2011). EEG alpha synchronization is related to top-down processing in convergent and divergent thinking. *Neuropsychologia* , 49(12), 3505–3511. doi:10.1016/j.neuropsychologia.2011.09.004

Benedek, M. , Franz, F. , Heene, M. , & Neubauer, A. C. (2012). Differential effects of cognitive inhibition and intelligence on creativity. *Personality and Individual Differences* , 53(4), 480–485. doi:10.1016/j.paid.2012.04.014

Benedek, M. , Jauk, E. , Fink, A. , Koschutnig, K. , Reishofer, G. , Ebner, F. , & Neubauer, A. C. (2014). To create or to recall? Neural mechanisms underlying the generation of creative new ideas. *NeuroImage* , 88, 125–133. doi:10.1016/j.neuroimage.2013.11.021

Benedek, M. , Jauk, E. , Sommer, M. , Arendasy, M. , & Neubauer, A. C. (2014). Intelligence, creativity, and cognitive control: The common and differential involvement of executive functions in intelligence and creativity. *Intelligence* , 46, 73–83. doi:10.1016/j.intell.2014.05.007

Benedek, M. , Kenett, Y. N. , Umdasch, K. , Anaki, D. , Faust, M. , & Neubauer, A. C. (2017). How semantic memory structure and intelligence contribute to creative thought: A network science approach. *Thinking & Reasoning* , 23(2), 158–183. doi:10.1080/13546783.2016.1278034

Brewin, C. R. , & Beaton, A. (2002). Thought suppression, intelligence, and working memory capacity. *Behaviour Research and Therapy* , 40(8), 923–930. doi:10.1016/S0005-7967(01)00127-9

Burgess, G. C. , Gray, J. R. , Conway, A. R. , & Braver, T. S. (2011). Neural mechanisms of interference control underlie the relationship between fluid intelligence and working memory span. *Journal of Experimental Psychology. General* , 140(4), 674. doi:10.1037/a0024695

Carson, S. H. , Peterson, J. B. , & Higgins, D. M. (2003). Decreased latent inhibition is associated with increased creative achievement in high-functioning individuals. *Journal of Personality and Social Psychology* , 85(3), 499. doi:10.1037/0022-3514.85.3.499

Cassotti, M. , Agogué, M. , Camarda, A. , Houdé, O. , & Borst, G. (2016). Inhibitory control as a core process of creative problem solving and idea generation from childhood to adulthood. *New Directions for Child and Adolescent Development* , 2016(151), 61–72. doi:10.1002/cad.20153

Cattell, R. B. (1971). *Abilities: Their structure, growth, and action* . Boston, Massachusetts: Houghton-Mifflin.

Cattell, R. B. , & Cattell, A. K. S. (1961/2008). *Measuring intelligence with the culture fair tests* . Oxford, UK: Hogrefe.

Cho, S. H. , Nijenhuis, J. T. , van Vianen, A. E. , Kim, H. B. , & Lee, K. H. (2010). The relationship between diverse components of intelligence and creativity. *The Journal of Creative Behavior* , 44(2), 125–137. doi:10.1002/j.2162-6057.2010.tb01329.x

Christensen, P. R. , Guilford, J. P. , & Wilson, R. C. (1957). Relations of creative responses to working time and instructions. *Journal of Experimental Psychology* , 53(2), 82. doi:10.1037/h0045461

Chrysikou, E. G. (2019). Creativity in and out of (cognitive) control. *Current Opinion in Behavioral Sciences* , 27, 94–99. doi:10.1016/j.cobeha.2018.09.014

Chuderski, A. (2013). When are fluid intelligence and working memory isomorphic and when are they not? *Intelligence* , 41(4), 244–262. doi:10.1016/j.intell.2013.04.003

Colzato, L. S. , Szapora, A. , & Hommel, B . (2012). Meditate to create: The impact of focused-attention and open-monitoring training on convergent and divergent thinking. *Frontiers in Psychology* , 3, 116. doi:10.3389/fpsyg.2012.00116

Conway, A. R. , Cowan, N. , Bunting, M. F. , Therriault, D. J. , & Minkoff, S. R. (2002). A latent variable analysis of working memory capacity, short-term memory capacity, processing speed, and general fluid intelligence. *Intelligence* , 30(2), 163–183. doi:10.1016/S0160-2896(01)00096-4

Conway, A. R. A. , Kane, M. J. , & Engle, R. W. (2003). Working memory capacity and its relation to general intelligence. *Trends in Cognitive Sciences* , 7(12), 547–552. doi:10.1016/j.tics.2003.10.005

De Dreu, C. K. , Nijstad, B. A. , Baas, M. , Wolsink, I. , & Roskes, M. (2012). Working memory benefits creative insight, musical improvisation, and original ideation through maintained task-focused attention. *Personality & Social Psychology Bulletin* , 38(5), 656–669. doi:10.1177/0146167211435795

Draheim, C. , Tsukahara, J. S. , Martin, J. D. , Mashburn, C. A. , & Engle, R. W. (2020). A toolbox approach to improving the measurement of attention control. *Journal of Experimental Psychology. General* . Advance online publication. doi:10.1037/xge0000783.

Dygert, S. K. , & Jarosz, A. F. (2020). Individual differences in creative cognition. *Journal of Experimental Psychology. General* , 149(7), 1249. doi:10.1037/xge0000713

Ekstrom, R. B. , Dermen, D. , & Harman, H. H. (1976). *Manual for kit of factor-referenced cognitive tests* (Vol. 102). Princeton, NJ: Educational testing service.

Engle, R. W. (2002). Working memory capacity as executive attention. *Current Directions in Psychological Science* , 11(1), 19–23. doi:10.1111/1467-8721.00160

Engle, R. W . (2018). Working memory and executive attention: A revisit. *Perspectives on Psychological Science* , 13(2), 190–193. doi:10.1177/1745691617720478

Engle, R. W. , & Kane, M. J. (2004). Executive attention, working memory capacity, and a two-factor theory of cognitive control. *Psychology of Learning and Motivation* , 44, 145–200.

Engle, R. W. , Tuholski, S. W. , Laughlin, J. E. , & Conway, A. R. A. (1999). Working memory, short-term memory, and general fluid intelligence: A latent-variable approach. *Journal of Experimental Psychology. General* , 128(3), 309–331. doi:10.1037/0096-3445.128.3.309

Eslinger, P. J. (1996). Conceptualizing, describing, and measuring components of executive function: A summary. In G. R. Lyon & N. A. Krasnegor (Eds.), *Attention, memory, and executive function* (pp. 367–395). Baltimore, MD: Paul H. Brookes Publishing Company.

Eysenck, H. J. (1993). Creativity and personality: Suggestions for a theory. *Psychological Inquiry* , 4(3), 147–178. doi:10.1207/s15327965pli0403_1

Eysenck, H. J. (1995). *Genius* . Cambridge: Cambridge University Press.

Faust, M. , & Kenett, Y. N. (2014). Rigidity, chaos and integration: Hemispheric interaction and individual differences in metaphor comprehension. *Frontiers in Human Neuroscience* , 8, 511. doi:10.3389/fnhum.2014.00511

Fink, A. , Grabner, R. H. , Benedek, M. , Reishofer, G. , Hauswirth, V. , Fally, M. , & Neubauer, A. C. (2009). The creative brain: Investigation of brain activity during creative problem solving by means of EEG and FMRI. *Human Brain Mapping* , 30(3), 734–748. doi:10.1002/hbm.20538

Fox, K. C. , & Beaty, R. E. (2019). Mind-wandering as creative thinking: Neural, psychological, and theoretical considerations. *Current Opinion in Behavioral Sciences* , 27, 123–130. doi:10.1016/j.cobeha.2018.10.009

Frith, E. , Elbich, D. , Christensen, A. P. , Rosenberg, M. D. , Chen, Q. , Silvia, P. , … Beaty, R. E. (2020). Intelligence and creativity share a common cognitive and neural basis. *Journal of Experimental Psychology. General* . Advance online publication. doi:10.1037/xge0000958

Fukuda, K. , Vogel, E. , Mayr, U. , & Awh, E. (2010). Quantity, not quality: The relationship between fluid intelligence and working memory capacity. *Psychonomic Bulletin & Review* , 17(5), 673–679. doi:10.3758/17.5.673

Fukuda, K. , & Vogel, E. K. (2011). Individual differences in recovery time from attentional capture. *Psychological Science* , 22(3), 361–368. doi:10.1177/0956797611398493

Furley, P. , & Memmert, D. (2015). Creativity and working memory capacity in sports: Working memory capacity is not a limiting factor in creative decision making amongst skilled performers. *Frontiers in Psychology* , 6(115). doi:10.3389/fpsyg.2015.00115

Furnham, A. , Batey, M. , Anand, K. , & Manfield, J. (2008). Personality, hypomania, intelligence and creativity. *Personality and Individual Differences* , 44(5), 1060–1069. doi:10.1016/j.paid.2007.10.035

Furnham, A. , Zhang, J. , & Chamorro-Premuzic, T. (2005). The relationship between psychometric and self-estimated intelligence, creativity, personality and academic achievement. *Imagination, Cognition and Personality* , 25(2), 119–145. doi:10.2190/530V-3M9U-7UQ8-FMBG

Gable, S. L. , Hopper, E. A. , & Schooler, J. W . (2019). When the muses strike: Creative ideas of physicists and writers routinely occur during mind wandering. *Psychological Science* , 30(3), 396–404. doi:10.1177/0956797618820626

Gabora, L. (2010). Revenge of the "neurds": Characterizing creative thought in terms of the structure and dynamics of memory. *Creativity Research Journal* , 22(1), 1–13. doi:10.1080/10400410903579494

Gabora, L. (2017). Honing theory: A complex systems framework for creativity. *Nonlinear Dynamics, Psychology, and Life Sciences* , 21(1), 35–88.

Gabora, L. (2018a). Reframing convergent and divergent thought for the 21st century. In A. Goel, C. Seifert, & C. Freska (Eds.), *Proceedings of 41st annual meeting of the cognitive science society* (pp. 1794–1800). Austin TX: Cognitive Science Society.

Gabora, L. (2018b). The neural basis and evolution of divergent and convergent thought. In R. E. Jung & O. Vartanian (Eds.), *The Cambridge handbook of the neuroscience of creativity* (pp. 58–70). Cambridge, United Kingdom: Cambridge University Press.

Gignac, G. E. , & Szodorai, E. T. (2016). Effect size guidelines for individual differences researchers. *Personality and Individual Differences* , 102, 74–78. doi:10.1016/j.paid.2016.06.069

Gilhooly, K. J. , Fioratou, E. , Anthony, S. H. , & Wynn, V. (2007). Divergent thinking: Strategies and executive involvement in generating novel uses for familiar objects. *British Journal of Psychology* , 98(4), 611–625. doi:10.1111/j.2044-8295.2007.tb00467.x

Gray, K. , Anderson, S. , Chen, E. E. , Kelly, J. M. , Christian, M. S. , Patrick, J. , … Lewis, K. (2019). "Forward flow": A new measure to quantify free thought and predict creativity. *American Psychologist* , 74(5), 539–554. doi:10.1037/amp0000391

Gruszka, A. , & Necka, E. (2002). Priming and acceptance of close and remote associations by creative and less creative people. *Creativity Research Journal* , 14(2), 193–205. doi:10.1207/S15326934CRJ1402_6

Guilford, J. P. (1967). *The nature of human intelligence* .

Hao, N. , Wu, M. , Runco, M. A. , & Pina, J . (2015). More mind wandering, fewer original ideas: Be not distracted during creative idea generation. *Acta Psychologica* , 161, 110–116. doi:10.1016/j.actpsy.2015.09.001

Heitz, R. P. , Redick, T. S. , Hambrick, D. Z. , Kane, M. J. , Conway, A. R. , & Engle, R. W. (2006). Working memory, executive function, and general fluid intelligence are not the same. *Behavioral and Brain Sciences* , 29(2), 135–136. doi:10.1017/S0140525X06319036

Jansson, D. G. , & Smith, S. M. (1991). Design fixation. *Design Studies* , 12(1), 3–11. doi:10.1016/0142-694X(91)90003-F

Jarosz, A. F. , Colflesh, G. J. , & Wiley, J. (2012). Uncorking the muse: Alcohol intoxication facilitates creative problem solving. *Consciousness and Cognition* , 21(1), 487–493. doi:10.1016/j.concog.2012.01.002

Jauk, E. , Benedek, M. , Dunst, B. , & Neubauer, A. C. (2013). The relationship between intelligence and creativity: New support for the threshold hypothesis by means of empirical breakpoint detection. *Intelligence* , 41(4), 212–221. doi:10.1016/j.intell.2013.03.003

Kane, M. J. , Bleckley, M. K. , Conway, A. R. A. , & Engle, R. W. (2001). A controlled-attention view of working-memory capacity. *Journal of Experimental Psychology. General* , 130(2), 169–183. doi:10.1037/0096-3445.130.2.169

Kane, M. J. , Brown, L. H. , McVay, J. C. , Silvia, P. J. , Myin-Germeys, I. , & Kwapil, T. R. (2007). For whom the mind wanders, and when: An experience-sampling study of working memory and executive control in daily life. *Psychological Science* , 18(7), 614–621. doi:10.1111/j.1467-9280.2007.01948.x

Kane, M. J. , & Engle, R. W. (2002). The role of prefrontal cortex in working-memory capacity, executive attention, and general fluid intelligence: An individual-differences perspective. *Psychonomic Bulletin & Review* , 9(4), 637–671.

Kane, M. J. , Hambrick, D. Z. , & Conway, A. R. (2005). *Working memory capacity and fluid intelligence are strongly related constructs: Comment on Ackerman* . Beier, and Boyle (2005). *Psychological Bulletin, 131*(1), 66–71.

Kane, M. J. , Hambrick, D. Z. , Tuholski, S. W. , Wilhelm, O. , Payne, T. W. , & Engle, R. W. (2004). The generality of working memory capacity: A latent-variable approach to verbal and visuospatial memory span and reasoning. *Journal of Experimental Psychology. General* , 133(2), 189. doi:10.1037/0096-3445.133.2.189

Kane, M. J. , & McVay, J. C. (2012). What mind wandering reveals about executive-control abilities and failures. *Current Directions in Psychological Science* , 21(5), 348–354. doi:10.1177/0963721412454875

Kane, M. J. , Meier, M. E. , Smeekens, B. A. , Gross, G. M. , Chun, C. A. , Silvia, P. J. , & Kwapil, T. R. (2016). Individual differences in the executive control of attention, memory, and thought, and their associations with schizotypy. *Journal of Experimental Psychology. General* , 145(8), 1017–1048. doi:10.1037/xge0000184

Karwowski, M. , Dul, J. , Gralewski, J. , Jauk, E. , Jankowska, D. M. , Gajda, A. , … Benedek, M. (2016). Is creativity without intelligence possible? A necessary condition analysis. *Intelligence* , 57, 105–117. doi:10.1016/j.intell.2016.04.006

Kenett, Y. N. , Anaki, D. , & Faust, M. (2014). Investigating the structure of semantic networks in low and high creative persons. *Frontiers in Human Neuroscience* , 8, 407. doi:10.3389/fnhum.2014.00407

Kenett, Y. N. , Beaty, R. E. , Silvia, P. J. , Anaki, D. , & Faust, M. (2016). Structure and flexibility: Investigating the relation between the structure of the mental lexicon, fluid intelligence, and creative achievement. *Psychology of Aesthetics, Creativity, and the Arts* , 10(4), 377. doi:10.1037/aca0000056

Kenett, Y. N. , & Faust, M. (2019). A semantic network cartography of the creative mind. *Trends in Cognitive Sciences* , 23(4), 271–274. doi:10.1016/j.tics.2019.01.007

Kenett, Y. N. , Levy, O. , Kenett, D. Y. , Stanley, H. E. , Faust, M. , & Havlin, S. (2018). Flexibility of thought in high creative individuals represented by percolation analysis. *Proceedings of the National Academy of Sciences* , 115(5), 867–872. doi:10.1073/pnas.1717362115

Kline, R. B. (2015). *Principles and practice of structural equation modeling* . New York, NY: Guilford publications.

Lebuda, I. , Zabelina, D. L. , & Karwowski, M. (2016). Mind full of ideas: A meta-analysis of the mindfulness–creativity link. *Personality and Individual Differences* , 93, 22–26. doi:10.1016/j.paid.2015.09.040

Lee, C. S. , & Therriault, D. J. (2013). The cognitive underpinnings of creative thought: A latent variable analysis exploring the roles of intelligence and working memory in three creative thinking processes. *Intelligence* , 41(5), 306–320. doi:10.1016/j.intell.2013.04.008

Levinson, D. B. , Smallwood, J. , & Davidson, R. J. (2012). The persistence of thought: Evidence for a role of working memory in the maintenance of task-unrelated thinking. *Psychological Science* , 23(4), 375–380. doi:10.1177/0956797611431465

Lezak, M. D. , Howieson, D. B. , Loring, D. W. , & Fischer, J. S. (2004). *Neuropsychological assessment* . USA: Oxford University Press.

Lin, W. L. , & Lien, Y. W. (2013). The different role of working memory in open-ended versus closed-ended creative problem solving: A dual-process theory account. *Creativity Research Journal* , 25(1), 85–96. doi:10.1080/10400419.2013.752249

Liu, X. , Liu, L. , Chen, Z. , Song, Y. , & Liu, J. (2019). Indirect effects of fluid intelligence on creative aptitude through openness to experience. *Current Psychology* , 38(2), 563–571.

Maillet, D. , Beaty, R. E. , Jordano, M. L. , Touron, D. R. , Adnan, A. , Silvia, P. J. , … Kane, M. J. (2018). Age-related differences in mind-wandering in daily life. *Psychology and Aging* , 33(4), 643–653. doi:10.1037/pag0000260

Martindale, C. (1981). *Cognition and consciousness* . Homewood, Illinois: Dorsey.

Martindale, C. (1995). Creativity and connectionism. In S. M. Smith, T. B. Ward, & R. A. Finke (Eds.), *The creative cognition approach* (pp. 249–268). Cambridge, Massachusetts: The MIT Press.

Martindale, C. (2007). Creativity, primordial cognition, and personality. *Personality and Individual Differences* , 43(7), 1777–1785. doi:10.1016/j.paid.2007.05.014

McCabe, D. P. , Roediger, H. L. , McDaniel, M. A. , Balota, D. A. , & Hambrick, D. Z. (2010). The relationship between working memory capacity and executive functioning: Evidence for a common executive attention construct. *Neuropsychology* , 24(2), 222–243. doi:10.1037/a0017619

McVay, J. C. , & Kane, M. J. (2009). Conducting the train of thought: Working memory capacity, goal neglect, and mind wandering in an executive-control task. *Journal of Experimental Psychology. Learning, Memory, and Cognition* , 35(1), 196.

McVay, J. C. , & Kane, M. J. (2010). Does mind wandering reflect executive function or executive failure? Comment on Smallwood and Schooler (2006) and Watkins (2008). *Psychological Bulletin* , 136(2), 188–197. doi:10.1037/a0018298

McVay, J. C. , & Kane, M. J . (2012). Why does working memory capacity predict variation in reading comprehension? On the influence of mind wandering and executive attention. *Journal of Experimental Psychology: General* , 141(2), 302. doi:10.1037/a0025250

McVay, J. C. , & Kane, M. J. (2012a). Drifting from slow to "d'oh!": Working memory capacity and mind wandering predict extreme reaction times and executive control errors. *Journal of Experimental Psychology. Learning, Memory, and Cognition* , 38(3), 525.

McVay, J. C. , & Kane, M. J. (2012b). Why does working memory capacity predict variation in reading comprehension? On the influence of mind wandering and executive attention. *Journal of Experimental Psychology. General* , 141(2), 302. doi:10.1037/a0025250

Mednick, S. (1962). The associative basis of the creative process. *Psychological Review* , 69(3), 220. doi:10.1037/h0048850

Miyake, A. , & Friedman, N. P. (2012). The nature and organization of individual differences in executive functions: Four general conclusions. *Current Directions in Psychological Science* , 21(1), 8–14. doi:10.1177/0963721411429458

Miyake, A. , Friedman, N. P. , Emerson, M. J. , Witzki, A. H. , Howerter, A. , & Wager, T. D. (2000). The unity and diversity of executive functions and their contributions to complex "frontal lobe" tasks: A latent variable analysis. *Cognitive Psychology* , 41(1), 49–100. doi:10.1006/cogp.1999.0734

Moraru, A. , Memmert, D. , & van der Kamp, J. (2016). Motor creativity: The roles of attention breadth and working memory in a divergent doing task. *Journal of Cognitive Psychology* , 28(7), 856–867. doi:10.1080/20445911.2016.1201084

Nusbaum, E. C. , & Silvia, P. J. (2011). Are intelligence and creativity really so different? Fluid intelligence, executive processes, and strategy use in divergent thinking. *Intelligence* , 39(1), 36–45. doi:10.1016/j.intell.2010.11.002

Nusbaum, E. C. , Silvia, P. J. , & Beaty, R. E. (2014). Ready, set, create: What instructing people to "be creative" reveals about the meaning and mechanisms of divergent thinking. *Psychology of Aesthetics, Creativity, and the Arts* , 8(4), 423. doi:10.1037/a0036549

Oberauer, K. , Schulze, R. , Wilhelm, O. , & Süβ, H. M. (2005). Working memory and intelligence–their correlation and their relation: Comment on Ackerman, Beier, and Boyle (2005). *Psychological Bulletin* , 131(1), 61–65. doi:10.1037/0033-2909.131.1.61

Oberauer, K. , Süss, H.-M. , Wilhelm, O. , & Wittmann, W. (2008). Which working memory functions predict intelligence? *Intelligence* , 36(6), 641–652. doi:10.1016/j.intell.2008.01.007

Parnes, S. J. (1961). Effects of extended effort in creative problem solving. *Journal of Educational Psychology* , 52(3), 117–122. doi:10.1037/h0044650

Phillips, L. H. , & Della Sala, S. (1998). Aging, intelligence, and anatomical segregation in the frontal lobes. *Learning and Individual Differences* , 10(3), 217–243. doi:10.1016/S1041-6080(99)80131-9

Preckel, F. , Holling, H. , & Wiese, M. (2006). Relationship of intelligence and creativity in gifted and non-gifted students: An investigation of threshold theory. *Personality and Individual Differences* , 40(1), 159–170. doi:10.1016/j.paid.2005.06.022

Randall, J. G. , Oswald, F. L. , & Beier, M. E . (2014). Mind-wandering, cognition, and performance: A theory-driven meta-analysis of attention regulation. *Psychological Bulletin* , 140(6), 1411. doi:10.1037/a0037428

Robison, M. K. , & Unsworth, N. (2018). Cognitive and contextual correlates of spontaneous and deliberate mind-wandering. *Journal of Experimental Psychology. Learning, Memory, and Cognition* , 44(1), 85.

Rossmann, E. , & Fink, A. (2010). Do creative people use shorter associative pathways? *Personality and Individual Differences* , 49(8), 891–895. doi:10.1016/j.paid.2010.07.025

Runco, M. A. , & Acar, S . (2012). Divergent thinking as an indicator of creative potential. *Creativity Research Journal* , 24(1), 66–75. doi:10.1080/10400419.2012.652929

Sawyer, R. K. (2006). *Explaining creativity: The science of human innovation* . New York: Oxford University Press.

Schooler, J. W. , Smallwood, J. , Christoff, K. , Handy, T. C. , Reichle, E. D. , & Sayette, M. A. (2011). Meta-awareness, perceptual decoupling and the wandering mind. *Trends in Cognitive Sciences* , 15(7), 319–326.

Seli, P. , Kane, M. J. , Smallwood, J. , Schacter, D. L. , Maillet, D. , Schooler, J. W. , & Smilek, D. (2018). Mind-wandering as a natural kind: A family-resemblances view. *Trends in Cognitive Sciences* , 22(6), 479–490. doi:10.1016/j.tics.2018.03.010

Shallice, T. , Burgess, P. , Baddeley, A. , & Weiskrantz, L. (1993). *Attention: Selection, awareness and control* (pp. 171–187). Oxford, United Kingdom: Oxford University Press.

Shipstead, Z. , Harrison, T. L. , & Engle, R. W. (2016). Working memory capacity and fluid intelligence: Maintenance and disengagement. *Perspectives on Psychological Science* , 11(6), 771–799. doi:10.1177/1745691616650647

Shipstead, Z. , Lindsey, D. R. , Marshall, R. L. , & Engle, R. W. (2014). The mechanisms of working memory capacity: Primary memory, secondary memory, and attention control. *Journal of Memory and Language* , 72, 116–141. doi:10.1016/j.jml.2014.01.004

Silvia, P. J. (2008). Another look at creativity and intelligence: Exploring higher-order models and probable confounds. *Personality and Individual Differences* , 44(4), 1012–1021. doi:10.1016/j.paid.2007.10.027

Silvia, P. J. (2015). Intelligence and creativity are pretty similar after all. *Educational Psychology Review* , 27(4), 599–606. doi:10.1007/s10648-015-9299-1

Silvia, P. J. , & Beaty, R. E. (2012). Making creative metaphors: The importance of fluid intelligence for creative thought. *Intelligence* , 40(4), 343–351. doi:10.1016/j.intell.2012.02.005

Silvia, P. J. , Beaty, R. E. , & Nusbaum, E. C. (2013). Verbal fluency and creativity: General and specific contributions of broad retrieval ability (Gr) factors to divergent thinking. *Intelligence* , 41(5), 328–340. doi:10.1016/j.intell.2013.05.004

Silvia, P. J. , Winterstein, B. P. , Willse, J. T. , Barona, C. M. , Cram, J. T. , Hess, K. I. , … Richard, C. A. (2008). Assessing creativity with divergent thinking tasks: Exploring the reliability and validity of new subjective scoring methods. *Psychology of Aesthetics, Creativity, and the Arts* , 2(2), 68. doi:10.1037/1931-3896.2.2.68

Sio, U. N. , & Ormerod, T. C. (2009). Does incubation enhance problem solving? A metaanalytic review. *Psychological Bulletin* , 135(1), 94–120. doi:10.1037/a0014212

Sligh, A. C. , Conners, F. A. , & Roskos-Ewoldsen, B. (2005). Relation of creativity to fluid and crystallized intelligence. *The Journal of Creative Behavior* , 39(2), 123–136. doi:10.1002/j.2162-6057.2005.tb01254.x

Smallwood, J. , & Schooler, J. W. (2006). The restless mind. *Psychological Bulletin* , 132(6), 946–958. doi:10.1037/0033-2909.132.6.946

Smeekens, B. A. , & Kane, M. J. (2016). Working memory capacity, mind wandering, and creative cognition: An individual-differences investigation into the benefits of controlled versus spontaneous thought. *Psychology of Aesthetics, Creativity, and the Arts* , 10(4), 389. doi:10.1037/aca0000046

Smith, A. P. , Brosowsky, N. , Murray, S. , Daniel, R. , Meier, M. , & Seli, P. (2020). Fixation, flexibility, and creativity: The dynamics of mind wandering. *PsyArXiv* . doi:10.31234/osf.io/v4538

Süss, H.-M. , Oberauer, K. , Wittmann, W. W. , Wilhelm, O. , & Schulze, R. (2002). Working-memory capacity explains reasoning ability—and a little bit more. *Intelligence* , 30(3), 261–288. doi:10.1016/S0160-2896(01)00100-3

Thomson, D. R. , Besner, D. , & Smilek, D. (2015). A resource-control account of sustained attention: Evidence from mind-wandering and vigilance paradigms. *Perspectives on Psychological Science* , 10(1), 82–96. doi:10.1177/1745691614556681

Thurstone, L. L . (1938). *Primary mental abilities* (Vol. 119). Chicago: University of Chicago Press.

Unsworth, N. , Brewer, G. A. , & Spillers, G. J. (2012). Variation in cognitive failures: An individual differences investigation of everyday attention and memory failures. *Journal of Memory and Language* , 67(1), 1–16. doi:10.1016/j.jml.2011.12.005

Unsworth, N. , & Engle, R. W. (2007). The nature of individual differences in working memory capacity: Active maintenance in primary memory and controlled search from secondary memory. *Psychological Review* , 114(1), 104–132. doi:10.1037/0033-295X.114.1.104

Unsworth, N. , & Robison, M. K. (2017). The importance of arousal for variation in working memory capacity and attention control: A latent variable pupillometry study. *Journal of Experimental Psychology. Learning, Memory, and Cognition* , 43(12), 1962.

Unsworth, N. , & Spillers, G. J. (2010). Working memory capacity: Attention control, secondary memory, or both? A direct test of the dual-component model. *Journal of Memory and Language* , 62(4), 392–406. doi:10.1016/j.jml.2010.02.001

Unsworth, N. , Spillers, G. J. , & Brewer, G. A. (2011). Variation in verbal fluency: A latent variable analysis of clustering, switching, and overall performance. *The Quarterly Journal of Experimental Psychology* , 64(3), 447–466. doi:10.1080/17470218.2010.505292

Vartanian, O. (2009). Variable attention facilitates creative problem solving. *Psychology of Aesthetics, Creativity, and the Arts* , 3(1), 57. doi:10.1037/a0014781

Ward, W. C. (1969). Rate and uniqueness in children's creative responding. *Child Development* , 40(3), 869–878. doi:10.2307/1127195

Welhaf, M. S. , Smeekens, B. A. , Gazzia, N. C. , Perkins, J. B. , Silvia, P. J. , Meier, M. E. , … Kane, M. J. (2020). An exploratory analysis of individual differences in mind wandering content and consistency. *Psychology of Consciousness: Theory, Research, and Practice* , 7(2), 103.

White, H. A. , & Shah, P. (2006). Uninhibited imaginations: Creativity in adults with attention-deficit/hyperactivity disorder. *Personality and Individual Differences* , 40(6), 1121–1131. doi:10.1016/j.paid.2005.11.007

Wiley, J . (1998). Expertise as mental set: The effects of domain knowledge in creative problem solving. *Memory & cognition* , 26(4), 716–730. doi:10.3758/BF03211392

Wiley, J. , & Jarosz, A. F. (2012). How working memory capacity affects problem solving. *Psychology of Learning and Motivation* , 56, 185–227. Academic Press.

Zabelina, D. , & Beeman, M . (2013). Short-term attentional perseveration associated with real-life creative achievement. *Frontiers in Psychology* , 4, 191. doi:10.3389/fpsyg.2013.00191

Zabelina, D. , Saporta, A. , & Beeman, M. (2016). Flexible or leaky attention in creative people? Distinct patterns of attention for different types of creative thinking. *Memory & Cognition* , 44(3), 488–498. doi:10.3758/s13421-015-0569-4

Zabelina, D. L. (2018). Attention and creativity. In R. E. Jung & O. Vartanian (Eds.), *The Cambridge handbook of the neuroscience of creativity* (pp. 161–179). Cambridge, United Kingdom: Cambridge University Press.

Zabelina, D. L. , & Robinson, M. D. (2010). Creativity as flexible cognitive control. *Psychology of Aesthetics, Creativity, and the Arts* , 4(3), 136. doi:10.1037/a0017379

Zabelina, D. L. , O'Leary, D. , Pornpattananangkul, N. , Nusslock, R. , & Beeman, M. (2015). Creativity and sensory gating indexed by the P50: Selective versus leaky sensory gating in divergent thinkers and creative achievers. *Neuropsychologia* , 69, 77–84. doi:10.1016/j.neuropsychologia.2015.01.034

Zelazo, P. D. , Craik, F. I. , & Booth, L. (2004). Executive function across the life span. *Acta psychologica* , 115(2–3), 167–183. doi:10.1016/j.actpsy.2003.12.005

Appendix

Descriptive statistics (proportion of TUT reports) for each mind wandering response category

	M		***SD***		***R* (min-max)**		***Skew***		***Kurtosis***	
Response Category	**SART**	**Stroop**	**SART**	**Stroop**	**SART**	**Stroop**	**SART**	**Stroop**	**SART**	**Stroop**
3	0.16	0.16	0.18	0.22	0–0.88	0–1	1.56	1.87	2.43	3.55
4	0.29	0.27	0.24	0.25	0–1	0–1	1.17	0.92	1.2	0.53
5	0.15	0.18	0.18	0.23	0–1	0–1	2.18	1.92	6.16	3.88
6	0.22	0.18	0.21	0.22	0–1	0–1	1.27	1.31	1.71	1.4
7	0.11	0.16	0.15	0.23	0–1	0–1	2.7	1.9	9.77	3.65
8	0.08	0.06	0.13	0.16	0–0.67	0–1	2.17	3.77	4.68	17.1

Response option categories for task unrelated thoughts are defined as 3 = everyday things; 4 = current state; 5 = personal worries; 6 = daydreams; 7 = external; 8 = other (not shown are response options 1 = on-task and 2 = task performance). Average proportions displayed are collapsed across participants.