Psychology of Aesthetics, Creativity, and the Arts

Seeing Outside the Box: Salient Associations Disrupt Visual Idea Generation

James Lloyd-Cox, Alexander P. Christensen, Paul J. Silvia, and Roger E. Beaty

Online First Publication, December 7, 2020. http://dx.doi.org/10.1037/aca0000371

CITATION

Lloyd-Cox, J., Christensen, A. P., Silvia, P. J., & Beaty, R. E. (2020, December 7). Seeing Outside the Box: Salient Associations Disrupt Visual Idea Generation. *Psychology of Aesthetics, Creativity, and the Arts*. Advance online publication. http://dx.doi.org/10.1037/aca0000371

AMERICAN PSYCHOLOGICAL ASSOCIATION
DIVISION 10
Psychology of Aesthetics, Creativity, and the Arts

ISSN: 1931-3896
https://doi.org/10.1037/aca0000371

Seeing Outside the Box: Salient Associations Disrupt Visual Idea Generation

James Lloyd-Cox[1], Alexander P. Christensen[2], Paul J. Silvia[2], and Roger E. Beaty[1]
[1] Department of Psychology, Pennsylvania State University
[2] Department of Psychology, University of North Carolina at Greensboro

Generating creative ideas involves flexibly combining concepts stored in memory. Although memory provides a foundation for creative thought, existing associations can also constrain idea generation by acting as a source of interference, particularly when salient and unoriginal information becomes activated. Overcoming fixating effects of salient associations is therefore required to generate novel associations. Although previous research has explored fixation effects in verbal creativity, less is known about how it affects the generation of visual associations. In the present research, we investigated the impact of priming salient associations on the generation of creative visual ideas. In an initial pilot study, participants were shown ambiguous images and asked to provide labels describing them; from these labels, 2 subsets were selected based on their relative frequency in the sample (i.e., high- and low-frequency labels). In 2 experiments, we then tested whether priming participants with these high- and low-frequency labels impacted the subsequent generation of new creative labels. Across both experiments, we found that high-frequency labels had a constraining effect on idea generation: Participants took significantly longer to generate their first response and generated fewer total responses in the high-frequency condition. Moreover, visuospatial intelligence (Gv) reduced susceptibility to this constraining effect, with high-Gv participants generating more creative labels in the high-frequency condition, pointing to a potential inhibitory benefit of Gv. The findings indicate that salient associations have a constraining effect on visual idea generation—even when these associations are linked to ambiguous images—and that Gv may support creative thinking via increased inhibitory control.

Keywords: creativity, divergent thinking, fixation, imagery, intelligence

Creativity is a hugely important feature of human cognition, enabling us to reinterpret problems, generate novel solutions, and adapt to changing environments. Despite its importance, however, the creativity construct remains incompletely understood; in particular, it is unclear how (and under what circumstances) memory influences creativity. Memory provides a knowledge base for creative thought, and evidence suggests that brain areas underlying both episodic and semantic memory also operate in creative thinking (Beaty, Benedek, Silvia, & Schacter, 2016). Yet considerable evidence has found that, in many instances, memory can constrain creative thinking, biasing thought toward the generation of salient and common ideas (Beaty, Christensen, Benedek, Silvia, & Schacter, 2017; Gilhooly, Fioratou, Anthony, & Wynn, 2007; Gupta, Jang, Mednick, & Huber, 2012). Such studies have typically used purely verbal paradigms, and although memory constraints have been examined in tasks with visual components (Chrysikou, Motyka, Nigro, Yang, & Thompson-Schill, 2016; Chrysikou & Weisberg, 2005; Ward, Patterson, & Sifonis, 2004), such tasks tend to use images of familiar objects, which may immediately activate a single semantic representation and thus bias the generation of ideas to nonvisual domains.

Here we test whether the cognitive constraints of visual idea generation can be more precisely targeted by using ambiguous images, which may have a more complex interaction with memory because they do not associate strongly to a single existing semantic representation. Visual creativity has been well explored using ambiguous stimuli (e.g., Lubart, Besançon, & Barbot, 2011; Torrance, 1966; Wallach & Kogan, 1965), but very few studies have examined how memory constraints affect visual idea generation. Moreover, little is known about how individual differences such as personality and intelligence interact with memory constraint, and the capacity to overcome it. In the current study, we investigated the effects of salient associations on the generation of creative ideas in the visual domain, with the aim of further understanding how memory influences creative thought.

How Memory Can Constrain Creativity

Memory is the conceptual structure on which creativity operates (Kenett & Faust, 2019). The organization of this structure is gradually built over many years through learning, allowing us to

Alexander P. Christensen https://orcid.org/0000-0002-9798-7037
Roger E. Beaty https://orcid.org/0000-0001-6114-5973
James Lloyd-Cox is now at Department of Psychology, Goldsmiths, University of London.

Roger E. Beaty is supported by a grant from the National Science Foundation [DRL-1920653].

Correspondence concerning this article should be addressed to Roger E. Beaty, Department of Psychology, Pennsylvania State University, 140 Moore Building, University Park, PA 16801, United States. Email: rebeaty@psu.edu

act appropriately and efficiently in many different situations (Feldhusen, 2002). However, the same structure that guides our behavior in familiar environments can also constrain our ability to think in novel ways and for good reason: Failing to apply existing knowledge when searching for new ways to cook a meal, repair an engine, or treat a disease might well lead to novel ideas but likely not useful ones. Perhaps because of their utility in most cases, the constraints of memory can be difficult to overcome if a problem requires particularly novel thinking (Bristol & Viskontas, 2006). A classic example of this is Duncker's (1945) candle problem, in which participants are fixated on the typical uses for objects and struggle to use them in new ways.

Such fixation effects have been explored within the contexts of both convergent and divergent creative thinking. For example, in the Remote Associates Test, participants are given three unrelated cue words (e.g., shot, sun, dark) and must converge on a solution word that relates to all three cues (in this case glasses). Participants perform considerably worse on this task if they are primed with misleading associations between a cue and another word (e.g., sun-moon) that interfere with solution generation (Koppel & Storm, 2014; Smith & Blankenship, 1991). In the alternative uses task, a measure of divergent thinking in which participants generate unusual uses for common objects, participants often start by recalling existing uses before generating more novel uses (i.e., the serial order effect; Beaty & Silvia, 2012; Gilhooly et al., 2007; Hass & Beaty, 2018) and produce less original ideas when primed with common as opposed to rare example solutions (Yagolkovskiy & Kharkhurin, 2016). Using another divergent thinking paradigm, Beaty et al. (2017) asked participants to study noun-verb associations before generating their own verbs in response to both unstudied and studied nouns. They found that participants generated fewer original verbs when the noun had been studied, demonstrating the fixating effects of salient information. Similarly, participants produce less original drawings when referencing examples from memory (compared with using alternative strategies; Ward et al., 2004), and they tend to follow examples in problem-solving tasks, even when instructed to avoid doing so (Chrysikou et al., 2005).

These findings reveal that idea generation is often automatically biased toward existing, salient knowledge. However, a considerable body of work suggests that deliberate cognitive control mechanisms can overcome this bias, suppressing the constraints imposed by salient associations. Such control processes—often conceptualized as distinct but overlapping executive functions, including updating, shifting, and inhibition (Benedek, Jauk, Sommer, Arendasy, & Neubauer, 2014; Nusbaum & Silvia, 2011)—seem to have a complex relationship with creative ability (see Chrysikou, 2019). In some situations, such as jazz improvisation, evidence suggests that reduced cognitive control can aid creative idea generation (Limb & Braun, 2008), in a state in which deactivated frontal brain regions enable spontaneous processes to occur unhindered (see Dietrich, 2003). In the context of memory constraints, however, deliberate control processes seem to play a beneficial role in creativity. Indeed, creative ability has been linked to fluid intelligence (Nusbaum et al., 2011; Wilken, Forthmann, & Holling, 2020), switching ability (Pan & Yu, 2018; Zabelina & Ganis, 2018), retrieval ability (Forthmann et al., 2019; Silvia, Beaty, & Nusbaum, 2013), and inhibitory control (Benedek, Franz, Heene, & Neubauer, 2012; Benedek et al., 2014). Evidence suggests that those with higher cognitive control ability might be better able to inhibit unoriginal salient information, suppressing the constraints of memory to access more original ideas (Beaty et al., 2012).

Supporting this notion, it has been shown that reducing cognitive control with a concurrent inhibition task during divergent thinking leads to both fewer ideas and less original ideas (Camarda et al., 2018), whereas reducing working memory capacity (a strong correlate of inhibitory control; Diamond, 2013) leads to less diverse responses during free association (Baror & Bar, 2016). Evidence also suggests that participants are in general biased toward considering high-frequency solutions to creative problems (Gupta et al., 2012) but that they are better able to access remote ideas in the presence of inhibitory temporal alpha waves (Luft, Zioga, Thompson, Banissy, & Bhattacharya, 2018). Moreover, some evidence from noninvasive brain stimulation research indicates that increasing the firing of neurons within frontal brain regions associated with executive control can improve creative task performance (Peña, Sampedro, Ibarretxe-Bilbao, Zubiaurre-Elorza, & Ojeda, 2019). Functional brain imaging studies also increasingly suggest that interactions between executive control and default mode brain networks commonly reported during creative thinking (Beaty et al., 2016; Beaty et al., 2018) are stronger when there is a need for controlled inhibition of salient information (Beaty et al., 2017; Beaty, Seli, & Schacter, 2019; Christensen, Benedek, Silvia, & Beaty, 2019).

The Present Research

A wealth of research now indicates that memory can constrain creative thought and that cognitive control can help to alleviate these constraints. Further work remains, however, to identify the nature of this interaction—specifically the role of task domain (visuospatial or verbal) and how different experimental contexts engender different fixation effects. To address these questions, the present research investigated how priming salient associations impacts idea generation in a combined visual-verbal paradigm, similar in nature to Wallach et al.'s (1965) classic tasks. We conducted two experiments using a divergent thinking task (loosely based on the purely verbal paradigm of Beaty et al., 2017), in which participants were shown a series of ambiguous figures, together with a verbal priming label to activate constraining salient associations. Participants were then asked to think creatively while generating their own possible labels for the images. Half of the trials presented priming labels that resembled the figures (high-constraint condition), and the other half presented priming labels that did not resemble the figures (low-constraint condition). Assuming that high-constraint labels activate conceptual representations with stronger visual associations to their images, we hypothesized that they would exert a more constraining effect on idea generation compared with low-constraint labels.

In visual-verbal paradigms, it is not always clear precisely in which domain idea generation occurs. Some previous studies have used familiar visual stimuli and verbal responses (e.g., Chrysikou et al., 2016; 2005), whereas others used verbal stimuli and visual responses (Ward et al., 2004). We hypothesized that by using ambiguous stimuli, our paradigm would successfully target visual association making by requiring participants to consider possible visual associations between different semantic representations and the unfamiliar images.

To explore potential individual differences in fixation effects, we assessed openness to experience, a personality trait typified by imagination and abstract thinking (DeYoung, 2014). Openness is among the most consistent predictors of creative task performance (Jauk, Benedek, & Neubauer, 2014; Kaufman et al., 2016; McCrae, 1987; Oleynick et al., 2017; Shi, Dai, & Lu, 2016; Silvia, Nusbaum, Berg, Martin, & O'Connor, 2009). Moreover, evidence suggests that openness relates to increased connectivity between the default and executive control networks (Beaty et al., 2018), a pattern of brain connectivity highly relevant to creative thinking that has been linked to overcoming fixation effects in the verbal domain (Beaty et al., 2017). Given these links between openness, abstract thinking, and stronger default-executive coupling, it seems possible that those higher in openness may have more awareness of, and control over, their thought processes, allowing them to suppress fixating ideas and access more creative ones when needed. We also included several measures of visual-spatial intelligence (Gv), a cognitive ability involving the mental rotation and transformation of external objects that is strongly correlated with other executive and working memory tasks (see Miyake et al., 2001). Given the relationships found between intelligence, executive functions, and creativity (Benedek et al., 2014; Beaty et al., 2012; Camarda et al., 2018) and the visual nature of the current creative task, we hypothesized that participants with stronger visualization skills might be better able to overcome the constraining effects of salient visual associations to produce more creative responses.

Study 1

In the first study, we developed and tested our visual fixation task. The task involved a priming manipulation in which participants rated the similarity of an ambiguous figure to a corresponding label that was either similar (high constraint) or not (low constraint). To obtain figure labels of varying similarity, we first conducted a pilot study in which participants were shown a larger set of figures and asked to generate a label for each one. Our first study experiment then consisted of priming a figure with either a high- or low-similarity (i.e., constraint) label immediately before a label generation phase, in which participants had to imagine new labels for the figure. We hypothesized that, compared with low-constraint trials, participants in high-constraint trials would generate significantly fewer total responses (i.e., decreased fluency), indicating a fixating effect of salient associations on visual idea production.

Method

Participants

Sixty-four English-speaking adults were recruited using Amazon Mechanical Turk (MTurk), an online platform for contacting participants who are representative of the U.S. population (Buhrmester, Kwang, & Gosling, 2011). To qualify for the study, participants had to be located in the United States and meet high standards for experience (more than 50 previously completed MTurk human intelligence tasks) and compliance (task approval rate of greater than 90%). Participants had 25 min to complete the study.

Materials

We used 20 ambiguous, line-drawn shapes as the visual stimuli in both studies. During an initial pilot study, these images were selected from a larger set of 58 images gathered from the following studies on visual creativity and creative imagery: the Evaluation of Potential Creativity (Lubart et al., 2011), the Test of Creative Imagery Abilities (Jankowska & Karwowski, 2015), the Torrance Tests of Creative Thinking (Torrance, 1966), and the Wallach et al.'s (1965) tests. In the pilot study, participants (n = 55, recruited from MTurk using the same inclusion criteria as above) were shown all 58 images and asked to provide labels for them. Specifically, they were asked to type a label that most resembled the figure. From this larger pool, a subset of images was chosen that had a label given by at least 20% of participants (i.e., high-consensus labels). The arbitrary 20% threshold was thought to offer a balance between ensuring labels were sufficiently high consensus and maintaining an adequate number of images for the subsequent experiment (many images did not have a label given by this proportion of participants). High-consensus labels were then used as high-constraint stimuli in the current experiments. We further identified low-consensus labels for each figure (i.e., drawn from the larger pool but never provided for that particular figure); these labels were used as low-constraint stimuli in the current experiments. All tasks were completed online using Qualtrics software.

Procedure

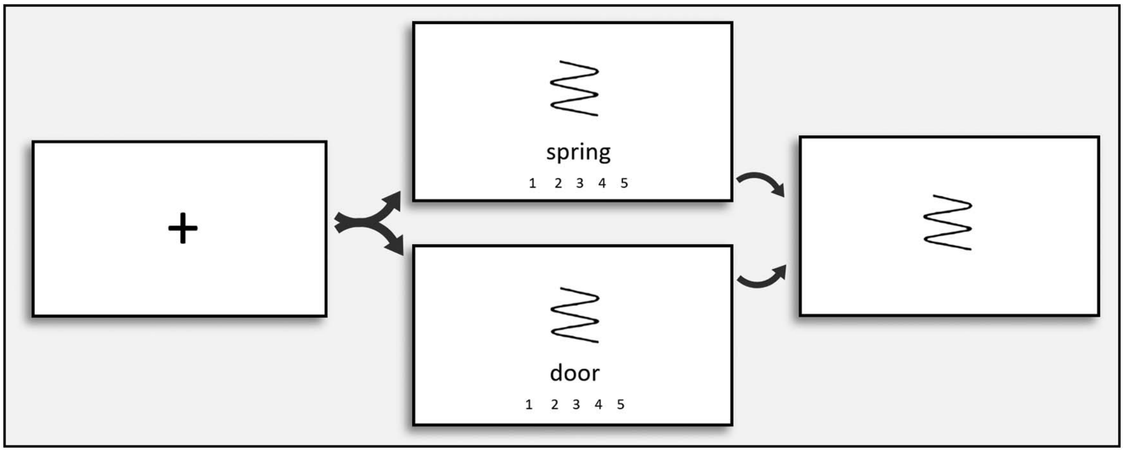
Participants completed 10 low-constraint and 10 high-constraint trials, with trial order counterbalanced in a within-subjects design. Trials consisted of three parts, shown in Figure 1. Following a fixation cross, participants were asked to rate the similarity between an image and either a low-constraint or high-constraint label, using a 5-point scale (1 = *not at all similar*, 5 = *very similar*). Next, the label was removed from the figure, and participants were asked to generate as many new labels for it as they could (multiple responses were encouraged). Specifically, they were asked to think of creative or unusual labels for the images. Each trial lasted 30 seconds. Fluency (total number of responses) was recorded as a measure of idea generation performance.

Results

We began by comparing similarity ratings for the high- and low-constraint trials. In all following t test results, we report Cohen's d_{av} as a measure of effect size (Lakens, 2013). A paired-sample t test confirmed that, compared with low-constraint labels (M = 1.27, SD = .39), high-constraint labels were rated as substantially more similar to images (M = 3.96, SD = .74; $t[63]$ = 28.74, $p < .001$, d_{av} = 4.73). This observation validates the selection of high- and low-constraint labels from our pilot study.

We then examined the number of labels that participants generated during the two conditions. Compared with the high-constraint condition (M = 3.01, SD = 1.28), participants generated significantly more labels in the low-constraint condition (M = 3.21, SD = 1.28; $t[63]$ = 3.01, p = .004, d_{av} = 0.16). Thus,

Figure 1
Trial procedure for the label generation task



Note. Trial procedure (left to right). Following a fixation cross, participants rated the similarity between a figure and either a high-constraint (top) or low-constraint (bottom) label, before lastly generating their own new labels.

high-constraint labels constrained idea generation by limiting the number of ideas participants generated.

Study 2

Fixation has been shown to affect performance on verbal creative tasks, but less is known about how fixation impacts idea generation in the visual domain. In Study 1, we developed a task that primed salient associations (rating labels that resemble ambiguous figures) immediately prior to idea generation (generating new labels for the figures). We found that high-constraint priming yielded significantly fewer ideas compared with low-constraint priming. In Study 2, we sought to replicate and extend this online study with a larger sample in a controlled laboratory context, which afforded a more fine-grained examination of how fixation impacts response times (RTs) during idea generation. To explore potential individual differences in susceptibility to fixation effects, we assessed visual-spatial ability (i.e., Gv) and openness to experience—traits that consistently predict performance on creative thinking tasks. Measuring openness also provided a proxy measure of creativity to validate against performance on this task.

Method

Participants

One hundred fifty-three English-speaking adults were recruited from [the University of North Carolina at Greensboro (UNCG)]. Participants received credit toward a voluntary research option for their participation. Of the 153 participants who enrolled in the study, 10 were excluded because of missing data resulting from noncompliance or software failure. This yielded a final sample of 143 participants (98 females; mean age = 19.15 years, *SD* = 1.81). The study was approved by [UNCG's] Institutional Review Board.

Materials and Procedure

For the label-generation task, the same images and constraint labels were used as in Study 1. The task also followed precisely the same design as in Study 1 but was completed in our laboratory using MediaLab software.

Individual Difference Measures

Following the label-generation task, participants completed measures of personality and visual-spatial ability (i.e., Gv). Personality was assessed with the openness/intellect subsections of the Big Five Aspect Scales (DeYoung, Quilty, & Peterson, 2007). This scale includes 10 items for openness and 10 items for intellect. Gv was assessed with three visual-spatial reasoning tasks (Ekstrom, French, Harman, & Dermen, 1976): (a) a paper-folding task (10 items, 3 min), in which people indicate what a piece of paper would look like after being folded, punched with holes, and unfolded; (b) a block rotation task (10 items, 8 min), in which people determine the congruency of three dimensional blocks presented at different orientations; and (c) a cube comparison task (21 items, 3 min), in which people indicate whether pairs of three dimensional cubes with letters on each face are the same based on the letters visible in the array.

Creativity Measures

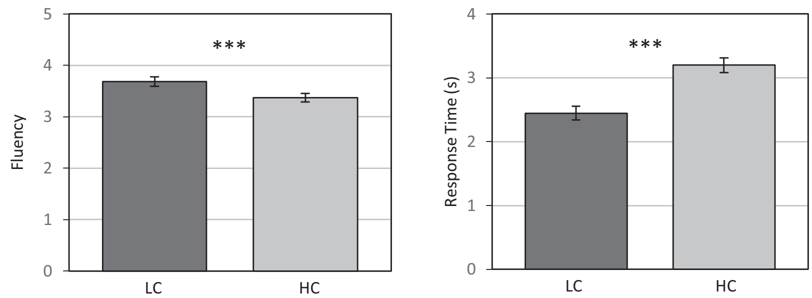
In addition to fluency, we computed two additional measures for the label-generation task: creativity and first RT. Creativity for each individual response was assessed by three trained, independent raters using the subjective scoring method, using a 1 (*not at*

Table 1
Means and Standard Deviations of Study 2 Measures for Low- and High- Constraint Conditions

Variables	Low constraint *M*	Low constraint *SD*	High constraint *M*	High constraint *SD*
Similarity rating	1.49	0.43	4.04	0.54
Fluency	3.68	1.08	3.38	0.98
Response time (s)	2.45	1.27	3.20	1.37
Creativity	2.60	0.35	2.64	0.36

Figure 2

Bar charts comparing fluency and RT across conditions



Note. HC = high-constraint; LC = low-constraint; RT = response time. Error bars are standard errors. *** $p < .001$.

all creative) to 5 (*very creative*) scale (Silvia et al., 2008). As reported by Silvia et al., (2008), this method has been found to yield reliable (dependable; G >.80) and valid ratings of responses in the alternative uses task, with measures of personality and college course explaining 21.8% of the variance in creativity score. First RT was the time (in seconds), for each trial, that it took participants to enter their first response following the onset of the idea generation phase (i.e., time between cue onset and pressing the ENTER key).

To explore the effects of greater memory constraint more closely, we examined how fixation costs in the different variables related to one another. Fixation cost was defined as the difference in performance between the high- and low-constraint trials. For example, those with more reduced fluency in high-constraint trials might possess less affected creativity scores, generating fewer but more creative ideas after a fixating prime. We also assessed the roles of Gv, and the twin aspects of openness to experience (openness and intellect), first to verify how these relate to creativity measures across both conditions (i.e., a person's creative performance in general) and then to test whether they had a negative relationship with fixation cost (e.g., are those with higher visualization abilities less affected by fixation?).

Results

Descriptive statistics are shown in Table 1. Regarding creativity ratings, we found interrater reliability between the three raters was in the excellent range (>.90) with an intraclass correlation coefficient of .92 (.90–.94). Bar charts comparing condition means in fluency and RT are provided in Figure 2.

First, we sought to replicate the effects of similarity rating and fluency reported in Study 1. Consistent with Study 1, a paired-sample t test revealed that similarity ratings were significantly higher in high-constraint ($M = 4.04$, $SD = .54$) than low-constraint trials ($M = 1.49$, $SD = .43$; $t[142] = 50.15$, $p < .001$, $d_{av} = 1.32$). Regarding fluency, we found that fluency was significantly greater in low-constraint trials ($M = 3.68$, $SD = 1.08$) than high-constraint trials ($M = 3.38$, $SD = .98$; $t[142] = 6.95$, $p < .001$, $d_{av} = 0.07$).

Next, we compared first RT (in seconds) in the high- and low-constraint conditions. As expected, RTs were significantly larger in the high-constraint condition ($M = 3.20$, $SD = 1.37$) compared with the low-constraint condition ($M = 2.45$, $SD = 1.27$; $t[142] = 6.96$, $p < .001$, $d_{av} = 0.14$): People took significantly longer to generate their first idea in the high-constraint condition. Regarding creativity, no significant difference emerged between conditions.[1]

Together these results indicate a constraining effect of priming more meaningful associations on the quantity and processing speed of subsequent idea generation.

Individual Difference Analyses

Pearson correlations between the individual differences measures (Gv and openness/intellect) and fixation costs are presented in Table 2. Fixation costs were computed as the difference in RT, fluency, and creativity between the high- and low-constraint conditions (e.g., RT cost = high-constraint RT – low-constraint RT).

As expected, based on past work using the subjective scoring method (e.g., Benedek, Mühlmann, Jauk, & Neubauer, 2013), fluency and creativity were not significantly correlated, either across conditions or in terms of fixation cost. More interesting were the relationships between fixation costs in the three label generation task measures. RT cost was positively related to fluency cost, $r = .30$, $p < .001$, but negatively related to creativity cost, $r = -.34$, $p < .001$, demonstrating that participants with a greater RT deficit in high-constraint trials generated fewer ideas but more creative ideas. Scatter plots of these relationships are displayed in Figure 3.

Both openness and intellect were positively correlated with fluency and creativity when collapsed across conditions (ps $< .020$), providing some evidence for the validity of the label generation task as a measure of creative performance (e.g., DeYoung, 2014; Kaufman et al., 2016). Contrary to expectations, neither openness nor intellect was negatively related to fixation costs, indicating that participants with higher values in these measures were not less affected by high-constraint primes.

Indeed, we found that openness actually had a positive relationship with fluency cost, $r = .21$, $p = .012$. Taken together with the relationship between openness and overall fluency, this indicates

[1] Notably, participants in low-constraint trials did not see the high-constraint priming label and in some instances gave this label as a response. When these responses were removed, we found slightly higher creativity ratings in low-constraint trials ($M = 2.71$, $SD = .40$) than high-constraint trials ($M = 2.64$, $SD = .36$; $t[142]) = 2.61$, $p = .01$, $d_{av} = 0.05$).

Table 2
Correlations Between All Measures

Variables	Creativity	F. cost	C. cost	RT cost	Openness	Intellect	Gv
Fluency	.09	.19*	−.04	−.14	.24**	.21*	.11
Creativity		.16	−.06	.19*	.21*	.20*	.23**
F. cost			−.12	.30**	.21*	.16	−.02
C. cost				−.34**	−.07	−.15	−.18*
RT cost					.05	.01	.08
Openness						.41**	.09
Intellect							.14

Note. F. cost = fluency cost; C. cost = creativity cost; RT = response time; Gv = visuospatial intelligence.
* $p < .05$. ** $p < .01$.

that those higher in openness came up with more ideas (and more creative ideas) overall but were more affected by the high-constraint primes (see Figure 4).

In line with our predictions, Gv was found to be positively related to creativity, $r = .23$, $p = .006$, and negatively related to creativity cost, $r = -.18$, $p = .029$, indicating that those with stronger visuospatial skills generated more creative ideas overall and were also less affected by fixation (see Figure 4).

Discussion

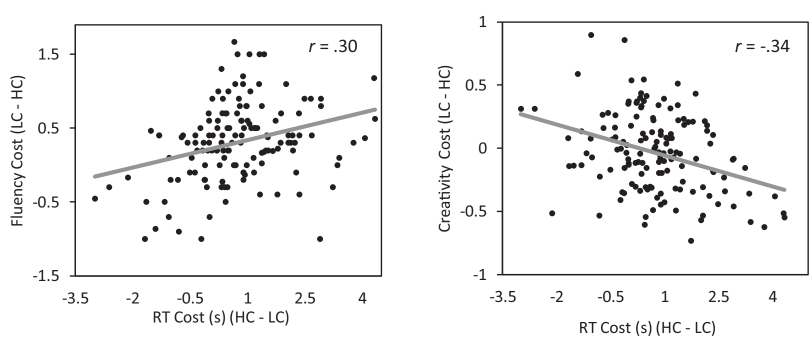
Creativity research is building an increasingly detailed picture of how cognitive processes and brain regions interact to enable novel idea generation. A central component of this picture is understanding how and when memory supports and constrains creativity. In the present research, we examined how the saliency of visual associations affects the degree to which they constrain idea generation, using a label generation task. We primed associations between ambiguous images and both high-constraint and low-constraint labels, testing how these influenced people's ability to imagine new labels for the images.

In two experiments, we found that after high-constraint primes, participants generated significantly fewer ideas (Study 1 and Study 2) and took significantly longer to produce their first idea (Study 2). These findings are broadly in line with previous studies that have found fixation-inducing primes to impair performance in creative tasks (e.g., Beaty et al., 2017; Camarda et al., 2018; Koppel et al., 2014). Our results indicate that more salient associations cause a greater disruption of idea generation in the visual domain, even when such associations relate to ambiguous figures.

In terms of individual differences, we found that fluency and creativity were not significantly correlated with one another. This was not surprising, however, given past research using the subjective scoring method to assess creativity (e.g., Benedek et al., 2014). Relationships between fixation costs showed that participants with a greater RT deficit in high-constraint trials generated fewer ideas, but more creative ideas, than those with less-affected RT. This suggests that, whereas all participants are affected by fixation, some use extra time to better overcome fixation effects, producing more creative responses at the cost of fluency. The notion that more creative ideas take longer to produce has been discussed previously (e.g., Barbot, 2018). However, it is worth noting that we observed this relationship between creativity and RT only among fixation costs; no effect was found between creativity and RT when collapsed across condition.

A somewhat surprising finding was that self-reported intellect did not correlate with fixation costs. Given evidence suggesting creativity and intelligence are overlapping constructs (e.g., Benedek et al., 2014; Benedek, Jung, & Vartanian, 2018) and the links between intelligence and executive functions such as inhibition (Duggan & Garcia-Barrera, 2015), one might have expected those with higher intellect to show lower fixation costs—potentially related to cognitive control strategies needed to overcome

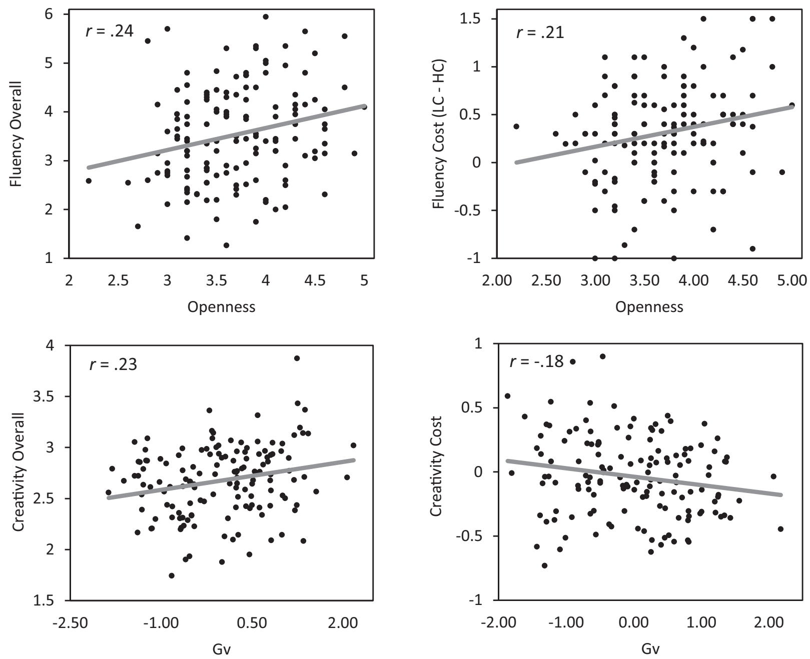
Figure 3
Scatterplots of relationships between RT cost and both fluency cost and creativity cost



Note. HC = high-constraint; LC = low-constraint; RT = response time.

Figure 4

Scatterplots of relationships between openness and both overall fluency and fluency cost, and between Gv and both overall creativity and creativity cost



Note. HC = high-constraint; LC = low-constraint; Gv = visuospatial intelligence; RT = response time.

fixation effects and access more creative ideas (Beaty, Silvia, Nusbaum, Jauk, & Benedek, 2014). The absence of this relationship suggests that the self-report measure of intellect we used here does not particularly assess cognitive control ability.

We found that people higher in Gv generated more creative ideas and were better able to overcome fixation effects on the label-generation task. These findings are consistent with evidence that Gv is related to better verbal divergent thinking (Frith et al., 2020) and previous work linking visualization ability to other executive tasks (such as the Tower of Hanoi; Miyake et al., 2001). A tentative interpretation is that people with stronger visualization abilities can exert greater executive control to reduce fixation effects. To clarify the role of Gv, future research should include inhibitory tasks (both verbal and visuospatial) to contrast relationships between inhibition and fixation effects in both domains.

We did find evidence that openness to experience benefits performance on the label-generation task. Specifically, we found positive correlations between both openness and intellect with creative performance collapsed across condition. This serves as a partial validation of the task, given evidence that higher openness relates to greater creative performance (DeYoung, 2014). The additional, unexpected finding that those higher in openness were more affected by fixating primes, at least for fluency, suggests a nuanced relationship between openness and creativity. It could be that whereas more open people welcome new ideas and ways of thinking, aiding their creativity in general, instead of being better able to recognize and reduce the influence of constraining ideas, they are in fact more open to short-term fixation effects. Indeed, one possibility is that those higher in openness have more leaky attention (Zabelina, Saporta, & Beeman, 2016), allowing them to more readily accept new ideas, at the cost of reduced cognitive control when they need to inhibit distractions or switch to a different task. These possibilities should be explored by future studies on fixation effects in creativity.

Finally, the present research probed visual idea generation but used a joint visual-verbal paradigm. Future research could extend these findings with an all-visual paradigm, perhaps in which participants must respond with drawings using the image as a starting point. Indeed, the images we used in this study were originally designed for creative drawing-completion tasks (e.g., Torrance, 1966), and completing images with drawings is currently the focus of a new time-based approach to assessing creativity (Barbot, 2018)—an approach that should be particularly fruitful for examining interference effects with high resolution.

Conclusion

The present research investigated potential constraining effects of salient associations on creative idea generation in the visual domain. We found that priming more meaningful associations between cue images and labels constrained idea generation, for both fluency and RT. We also found a moderate effect on idea creativity, although only after removing high-constraint labels generated by participants in low-constraint trials. These results conform to previous findings regarding the fixating effects of semantic memory on creativity (e.g., Beaty et al., 2017; Chrysikou et al., 2016; Koppel et al., 2014) and extend them to the visual domain. Moreover, our findings indicate important avenues for future research to clarify how both intelligence and executive functions relate to creativity in the presence of memory constraint and to examine the possibility that openness relates to higher creativity in general but possible deficits in inhibitory control. In general, the results support the notion that the brain favors more meaningful associations over others, likely because they are more useful in typical contexts. When primed, however, such associations may activate memory to a greater extent, constraining cognitive flexibility. A more complete understanding of how memory both aids and constrains idea generation is central to understanding creativity and may ultimately contribute to efforts aimed at enhancing creativity through education or other interventions.

References

Barbot, B. (2018). The dynamics of creative ideation: Introducing a new assessment paradigm. *Frontiers in Psychology*, *9*, 2529.

Baror, S., & Bar, M. (2016). Associative activation and its relation to exploration and exploitation in the brain. *Psychological Science*, *27*(6), 776–789.

Beaty, R. E., Benedek, M., Silvia, P. J., & Schacter, D. L. (2016). Creative cognition and brain network dynamics. *Trends in Cognitive Sciences*, *20*(2), 87–95.

Beaty, R. E., Chen, Q., Christensen, A. P., Qiu, J., Silvia, P. J., & Schacter, D. L. (2018). Brain networks of the imaginative mind: Dynamic functional connectivity of default and cognitive control networks relates to openness to experience. *Human Brain Mapping*, *39*(2), 811–821.

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.

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.

Beaty, R. E., Seli, P., & Schacter, D. L. (2019). Network neuroscience of creative cognition: Mapping cognitive mechanisms and individual differences in the creative brain. *Current Opinion in Behavioral Sciences*, *27*, 22–30.

Beaty, R. E., & Silvia, P. J. (2012). Metaphorically speaking: Cognitive abilities and the production of figurative language. *Memory & Cognition*, *41*(2), 255–267.

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., 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.

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.

Benedek, M., Jung, R. E., & Vartanian, O. (2018). The neural bases of creativity and intelligence: Common ground and differences. *Neuropsychologia*, *118*(Part A), 1–3.

Benedek, M., Mühlmann, C., Jauk, E., & Neubauer, A. C. (2013). Assessment of divergent thinking by means of the subjective top-scoring method: Effects of the number of top-ideas and time-on-task on reliability and validity. *Psychology of Aesthetics, Creativity, and the Arts*, *7*(4), 341–349.

Buhrmester, M. D., Kwang, T., & Gosling, S. D. (2011). Amazon's Mechanical Turk: A new source of inexpensive, yet high-quality, data? *Perspectives on Psychological Science*, *6*, 3–5.

Bristol, A. S., & Viskontas, I. V. (2006). Dynamic processes within associative memory stores. In J. C. Kaufman & J. Baer (Eds.), *Creativity and reason in cognitive development* (p. 60). Cambridge University Press.

Camarda, A., Borst, G., Agogué, M., Habib, M., Weil, B., Houdé, O., & Cassotti, M. (2018). Do we need inhibitory control to be creative? Evidence from a dual-task paradigm. *Psychology of Aesthetics, Creativity, and the Arts*, *12*(3), 351–358.

Christensen, A. P., Benedek, M., Silvia, P. J., & Beaty, R. E. (2019). Executive and default network connectivity reflects conceptual interference during creative imagery generation. *PsyArxiv*. Advance online publication. https://doi.org/10.31234/osf.io/n438d

Chrysikou, E. G. (2019). Creativity in and out of (cognitive) control. *Current Opinion in Behavioral Sciences*, *27*, 94–99.

Chrysikou, E. G., Motyka, K., Nigro, C., Yang, S. I., & Thompson-Schill, S. L. (2016). Functional fixedness in creative thinking tasks depends on stimulus modality. *Psychology of Aesthetics, Creativity, and the Arts*, *10*(4), 425–435.

Chrysikou, E. G., & Weisberg, R. W. (2005). Following the wrong footsteps: Fixation effects of pictorial examples in a design problem-solving task. *Journal of Experimental Psychology: Learning Memory and Cognition*, *31*(5), 1134–1148.

DeYoung, C. G. (2014). Openness/Intellect: A dimension of personality reflecting cognitive exploration. In M. L. Cooper and R. J. Larsen (Eds.), *APA handbook of personality and social psychology: Personality processes and individual differences* (Vol. 4, pp. 369–399). American Psychological Association.

DeYoung, C. G., Quilty, L. C., & Peterson, J. B. (2007). Between facets and domains: 10 aspects of the Big Five. *Journal of Personality and Social Psychology*, *93*(5), 880–896.

Diamond, A. (2013). Executive Functions. *Annual Review of Psychology*, *64*, 135–168.

Dietrich, A. (2003). Functional neuroanatomy of altered states of consciousness: The transient hypofrontality hypothesis. *Consciousness and Cognition*, *12*(2), 231–256.

Duggan, E. C., & Garcia-Barrera, M. A. (2015). Executive functioning and intelligence. In S. Goldstein, D. Princiotta, J. A. Naglieri (Eds.), *Handbook of Intelligence* (pp. 435–458). Springer New York.

Duncker, K. 1945. On problem-solving. *Psychological Monographs*. *58*(5), (i-113).

Ekstrom, R. B., French, J. W., Harman, H. H., & Dermen, D. (1976). *Manual for kit of factor-referenced cognitive tests*. Educational Testing Service.

Feldhusen, J. F. (2002). Creativity: The knowledge base and children. *High Ability Studies*, *13*(2), 179–183.

Forthmann, B., Jendryczko, D., Scharfen, J., Kleinkorres, R., Benedek, M., & Holling, H. (2019). Creative ideation, broad retrieval ability, and processing speed: A confirmatory study of nested cognitive abilities. *Intelligence*, *75*, 59–72.

Frith, E., Elbich, D., Christensen, A. P., Rosenberg, M. D., Chen, Q., Kane, M. J., Silvia, P., Seli, P., Beaty, R. (in press). Intelligence and creativity share a common cognitive and neural basis. *Journal of Experimental Psychology: General*.

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.

Gupta, N., Jang, Y., Mednick, S. C., & Huber, D. E. (2012). The road not taken: Creative solutions require avoidance of high-frequency responses. *Psychological Science*, *23*(3), 288–294.

Hass, R. W., & Beaty, R. E. (2018). Use or consequences: Probing the cognitive difference between two measures of divergent thinking. *Frontiers in Psychology*, *9*, 2327.

Jankowska, D. M., & Karwowski, M. (2015). Measuring creative imagery abilities. *Frontiers in Psychology*, *6*, 1591.

Jauk, E., Benedek, M., & Neubauer, A. C. (2014). The road to creative achievement: A latent variable model of ability and personality predictors. *European Journal of Personality*, *28*(1), 95–105.

Kaufman, S. B., Quilty, L. C., Grazioplene, R. G., Hirsh, J. B., Gray, J. R., Peterson, J. B., & DeYoung, C. G. (2016). Openness to experience and intellect differentially predict creative achievement in the arts and sciences. *Journal of Personality*, *84*(2), 248–258.

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

Koppel, R. H., & Storm, B. C. (2014). Escaping mental fixation: Incubation and inhibition in creative problem solving. *Memory*, *22*(4), 340–348.

Lakens, D. (2013). Calculating and reporting effect sizes to facilitate cumulative science: a practical primer for t-tests and ANOVAs. *Frontiers in Psychology*, *4*, 863. https://doi.org/10.3389/fpsyg.2013.00863

Limb, C. J., & Braun, A. R. (2008). Neural substrates of spontaneous musical performance: An fMRI study of jazz improvisation. *PLoS ONE*, *3*, e1679.

Lubart, T. I., Besançon, M., & Barbot, B. (2011). *Evaluation du potentiel créatif (EPoC)*. Paris, France: Editions Hogrefe France.

Luft, C. D. B., Zioga, I., Thompson, N. M., Banissy, M. J., & Bhattacharya, J. B. (2018). Right temporal alpha oscillations as a neural mechanism for inhibiting obvious associations. *Proceedings of the National Academy of Sciences*, *115*(52), E12144–E12152.

McCrae, R. R. (1987). Creativity, divergent thinking, and openness to experience. *Journal of Personality and Social Psychology*, *52*(6), 1258–1265.

Miyake, A., Friedman, N. P., Rettinger, D. A., Shah, P., & Hegarty, M. (2001). How are visuospatial working memory, executive functioning, and spatial abilities related? A latent-variable analysis. *Journal of Experimental Psychology: General*, *130*, 621–640. https://doi.org/10.1037/0096-3445.130.4.621

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.

Oleynick, V. C., DeYoung, C. G., Hyde, E., Kaufman, S. B., Beaty, R. E., & Silvia, P. J. (2017). Openness/Intellect: The core of the creative personality. In G. J. Feist, R. Reiter-Palmon, & J. C. Kaufman (Eds.), *Cambridge handbook of creativity and personality research* (pp. 9–27). Cambridge University Press.

Pan, X., & Yu, H. (2018). Different effects of cognitive shifting and intelligence on creativity. *The Journal of Creative Behavior*, *52*(3), 212–225.

Peña, J., Sampedro, A., Ibarretxe-Bilbao, N., Zubiaurre-Elorza, L., & Ojeda, N. (2019). Improvement in creativity after transcranial random noise stimulation (tRNS) over the left dorsolateral prefrontal cortex. *Scientific Reports*, *9*(1), 7116.

Shi, B., Dai, D. Y., & Lu, Y. (2016). Openness to experience as a moderator of the relationship between intelligence and creative thinking: A study of Chinese children in urban and rural areas. *Frontiers in Psychology*, *7*, 1–10.

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.

Silvia, P. J., Nusbaum, E. C., Berg, C., Martin, C., & O'Connor, A. (2009). Openness to experience, plasticity, and creativity: Exploring lower-order, high-order, and interactive effects. *Journal of Research in Personality*, *43*(6), 1087–1090.

Silvia, P. J., Winterstein, B. P., Willse, J. T., Barona, C. M., Cram, J. T., Hess, K. I., Martinez, J. L., & 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),68–85.

Smith, S. M., & Blankenship, S. E. (1991). Incubation and the persistence of fixation in problem solving. *American Journal of Psychology*, *104*(1), 61–87.

Torrance, E. P. (1966). *The Torrance Tests of Creative Thinking Norms: Technical manual research edition—verbal tests, forms A and B—Figural tests, forms A and B*. Personnel Press.

Wallach, M. A., & Kogan, N. (1965). *Modes of thinking in young children: A study of the creativity-intelligence distinction*. Holt, Rinehart and Winston.

Ward, T. B., Patterson, M. J., & Sifonis, C. M. (2004). The role of specificity and abstraction in creative idea generation. *Creativity Research Journal*, *16*(1), 1–9.

Wilken, A., Forthmann, B., & Holling, H. (2019). Instructions moderate the relationship between creative performance in figural divergent thinking and reasoning capacity. *The Journal of Creative Behavior*, *54*(3), 582–597. https://doi.org/10.1002/jocb.392

Yagolkovskiy, S. & Kharkhurin, A. (2016). The roles of rarity and organization of stimulus material in divergent thinking. *Thinking Skills and Creativity*, *22*, 14–21.

Zabelina, D. L., & Ganis, G. (2018). Creativity and cognitive control: Behavioral and ERP evidence that divergent thinking, but not real-life creative achievement, relates to better cognitive control. *Neuropsychologia*, *118*(Part A), 20–28.

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*, 488–498. https://doi.org/10.3758/s13421-015-0569-4

Received July 4, 2019
Revision received October 5, 2020
Accepted October 16, 2020 ■