Are intelligence and creativity really so different? Fluid intelligence, executive processes, and strategy use in divergent thinking.

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Emily C. Nusbaum & Paul J. Silvia (2011). Are intelligence and creativity really so different? Fluid intelligence, executive processes, and strategy use in divergent thinking. *Intelligence, 39(1)*, 36-45.

Abstract:

Contemporary creativity research views intelligence and creativity as essentially unrelated abilities, and many studies have found only modest correlations between them. The present research, based on improved approaches to creativity assessment and latent variable modeling, proposes that fluid and executive cognition is in fact central to creative thought. In Study 1, the substantial effect of fluid intelligence (Gf) on creativity was mediated by executive switching, the number of times people switched idea categories during the divergent thinking tasks. In Study 2, half the sample was given an effective strategy for an unusual uses task. The strategy condition interacted with Gf: people high in Gf did better when given the strategy, consistent with their higher ability to maintain access to it and use it despite interference. Taken together, the findings suggest that divergent thinking is more convergent than modern creativity theories presume.

Keywords: creativity | intelligence | divergent thinking | executive process | interference | psychology

Article:

Does a person have to be smart to be creative? Modern creativity research emphasizes the difference between intelligence and creativity—all of the recent creativity textbooks, for example, contend that creativity and intelligence are essentially unrelated abilities (Kauman, 2009, Runco, 2007, Sawyer, 2006 and Weisberg, 2006)—and this distinction dates to Guilford's (1967) classic distinction between convergent and divergent production. The general aim of the present work, in contrast, is to suggest that intelligence is more central to creative cognition than is currently believed by creativity research. We develop an interpretation of divergent thinking tasks as executive tasks (Gilhooly, Fioratou, Anthony, & Wynn, 2007), in which successful performance requires overcoming interference and applying task strategies. As a result, executive abilities and processes ought to play a substantial role in divergent thinking performance. We illustrate how advances in creativity assessment overcome significant limitations in traditional assessment methods, which are partly responsible for the modest effects found in past work.

The present studies explore two questions. First, does intelligence more strongly predict creativity when creativity is assessed using modern scoring methods and when latent variable models are estimated? Second, is successful divergent thinking performance predicted by executive processes? Stated differently, do people who come up with creative ideas do so because they successfully use convergent processes, such as fluid cognitive abilities and task strategies? If so, then divergent thinking may be more convergent than creativity research acknowledges.

1. How do creativity and intelligence relate?

Contemporary creativity research views intelligence and creativity as distinct traits that are only modestly related (for reviews see Batey and Furnham, 2006, Kauman, 2009, Kim et al., 2010 and Runco, 2007). In his seminal work, Guilford, 1957 and Wilson et al., 1953 took a more subtle view of the two abilities. He theorized that creativity is made up of a number of intellectual factors, with an emphasis on factors such as fluency, flexibility, and originality, that amount to a person's productive thinking ability. Guilford coined the now-famous distinction between convergent and divergent thinking—processes that lead to single, correct conclusions versus processes that generate multiple possibilities—but he viewed both as guided by similar traits and placed each within the umbrella of his Structure of Intellect model of cognitive abilities.

Later researchers, however, drew a sharper contrast between convergent and divergent thinking, equating the first with executive aspects of cognition and the second with associationistic aspects. Wallach and Kogan (1965), in their classic research, argued that divergent thinking reflects an associative process in which obvious, accessible ideas cue connected ideas, which in turn cue connected ideas, and so on. Creative ideas occur when the associative spread reaches distal concepts that are remotely related to the original concept. This explanation for divergent thinking is structural rather than executive: creative people are thought to have many loosely-related concepts, so their associative processes are more likely to generate remote, distal concepts. Wallach and Kogan's model was greatly influenced by Mednick's (1962) model of creative thought—a similar structural model—that explained individual differences in creativity with differences in whether “associative hierarchies” were steep or flat. People with flat hierarchies—i.e., with numerous and loose conceptual connections—were potentially more creative.

Since Wallach and Kogan's work, creativity researchers have continued to explain individual differences in creativity in terms of differences in the structure of knowledge, particularly the nature and extent of associations between concepts (see reviews by Runco, 2007 and Weisberg, 2006). For this reason, it is not surprising that modern creativity research expects weak effects of fluid and executive processes on creative thought, given that creative ideation is viewed as structural and associationistic. Moreover, a large body of work supports Wallach and Kogan's view that intelligence and creativity are modestly related. In a recent meta-analysis of 447 effect sizes, Kim (2005) found an average weighted effect size of r = .174.

2. An executive interpretation of divergent thinking tasks

Despite the historical emphasis on knowledge structure and associative processes, recent work has reinterpreted divergent thinking tasks as essentially executive tasks that are founded on managing interference. Gilhooly et al. (2007) recently proposed that generating unusual uses for a common object entails managing interference from several sources: the object's obvious, highly accessible uses (e.g., using a brick to build a wall or make a path); concrete features of the object, which interfere with abstracting general features that can transfer across domains (e.g., getting stuck on a brick's shape and density); and interference from one's own previous responses, which often intrude into the list of responses. To generate creative responses, people have to identify a useful strategy and use it in the face of this interference, so executive cognition is central to successful performance on a divergent thinking task.

Two studies provided support for an executive interpretation of creative ideation. In their first study, Gilhooly et al. (2007) used verbal protocols—also known as think-alouds—to identify the strategies people spontaneously used for an unusual uses task, and they rated each task response for novelty. They found several common strategies that didn't foster novel responses, such as memory retrieval (e.g., scanning long-term memory for examples of creative uses) and self-cueing (e.g., repeating the name and features of the object). But several infrequent and abstract strategies were associated with responses of a more creative nature, such as disassembly (e.g., breaking the object into parts). In a second study, a measure of executive ability (a letter fluency task) significantly predicted coming up with more “new” responses (i.e., generated during the task itself) but not “old” responses (i.e., retrieved from long-term memory).

Recasting divergent thinking tasks as executive tasks represents a shift away from structural and associationistic explanations of divergent thinking, and it has widespread implications for explaining individual differences in creativity. For the present purposes, the most salient implication is that one would expect executive abilities and processes—such as Gf, working memory capacity, interference management, and strategy use (e.g., Conway et al., 2003 and Unsworth, 2010)—to have strong relationships with creative ideation. But as we noted earlier, a recent meta-analysis found only a modest positive relationship between intelligence and creativity (r = .174; Kim, 2005). We contend that the true effect is much larger, but that flaws in traditional methods of scoring divergent thinking are obscuring it.

3. Assessing divergent thinking

3.1. Uniqueness scoring

Given the meta-analytic finding of only minor overlap between intelligence and creativity, why are we proposing that the relationship between them is substantial and rooted in executive processes? The key, we think, concerns the assessment of creativity. Despite Guilford's many innovations in creativity assessment, it was Wallach and Kogan's (1965) approach that gained traction in creativity research. Most modern approaches to assessing divergent thinking are rooted in their methods. Wallach and Kogan suggested a clever and simple scoring method: each divergent thinking task can be scored for fluency (the number of responses) and uniqueness (the number of unique responses). All of the responses are pooled, and people receive a point for each response that is literally unique within the pool. Uniqueness scoring has many virtues: it is straightforward, and it doesn't require more than one rater to do it. Other popular methods offer variations on uniqueness scoring, such as creating a list of common responses and giving points for each response not on the list (Torrance, 2008) and giving points for responses not mentioned by 5% or 10% of the sample (see Michael & Wright, 1989).

The problems with uniqueness scoring, however, are serious. Soon after Wallach and Kogan's (1965) work appeared, several researchers pointed out that uniqueness scores and fluency scores were practically confounded (Clark and Mirels, 1970, Hocevar, 1979a, Hocevar, 1979b and Hocevar and Michael, 1979). For example, a latent variable reanalysis of Wallach and Kogan's data found a correlation of r = .89 between the latent fluency and uniqueness variables (Silvia, 2008b). In the latest norms for the Torrance (2008) tests, uniqueness and fluency are just as highly correlated (r = .88). As the sample size increases, the correlation between fluency and uniqueness increases, so this confound cannot be mitigated through large-sample methods.

A second problem—one that is subtle yet fatal—is that uniqueness scores are strongly sample-dependent. As the sample size increases, the sample's mean uniqueness score decreases (see

Silvia et al., 2008). Each person's creativity score thus depends on the sample size: participants in smaller samples will be more creative because their responses are more likely to be unique within a small response pool. Perversely, it becomes harder to detect creative responses as the sample becomes larger; it is possible in a huge sample for no participant to have any unique responses. Few classical assessment methods yield sample-independent scores (Embretson & Reise, 2000), but it is rare to find an assessment method that performs more poorly as the sample size increases.

Third, the strong confounding of fluency and uniqueness means that divergent thinking tasks probably resemble traditional verbal fluency tasks too closely, particularly in large samples. Verbal fluency tasks ask people to generate as many instances of a category as possible (Troyer & Moscovitch, 2006), such as letter categories (e.g., the letters F, A, and S) or semantic categories (e.g., occupations, animals, vegetables). When divergent thinking tasks are scored simply for fluency, the scores probably reflect verbal fluency, albeit for an unusual semantic category (e.g., noisy things) or for an ad hoc category (e.g., unusual uses for a brick). In Carroll's (1993) model, the tasks probably tap the FI (Ideational Fluency) and FW (Word Fluency) factors more than the FO (Originality/Creativity) factor.

In short, it isn't surprising that past research has found only modest effects of Gf on divergent thinking, in the range of $r = .20$, depending in the tasks used (Kim, 2005). With the traditional scoring methods, the outcome is essentially verbal fluency. Indeed, many researchers use only the fluency score to quantify divergent thinking performance (e.g., Batey et al., 2009 and Preckel et al., 2006). Fortunately, recent developments in creativity assessment afford an opportunity to examine the effects of Gf on divergent thinking more decisively.

3.2. Scoring for creative quality as an alternative

An alternative to uniqueness scoring is found in Guilford's early research (Christensen et al., 1957, Guilford, 1957 and Wilson et al., 1953). Guilford and his research group often had judges rate the creative quality of responses on quantitative scales, such as the cleverness of titles (Christensen et al., 1957) or the remoteness of ideas (Wilson et al., 1953), but this approach was used only sporadically until the 1980s. Amabile's (1982) development of the consensual assessment technique (CAT), which assesses creativity by having judges (usually experts) give subjective ratings on quantitative scales, represented a major advance in the use of subjective scoring for creativity research, and the CAT continues to receive extensive attention in modern creativity work (e.g., Baer et al., 2004, Hennessey et al., 2008 and Kaufman et al., 2008).

The CAT was designed for judging creative products, such as drawings, poems, and short stories, but the general approach works well for divergent thinking tasks. Several recent studies have considered the psychometric properties of subjective ratings of different kinds of divergent thinking tasks (Silvia, in press, Silvia et al., 2009 and Silvia et al., 2008). In this approach, participants are given timed divergent thinking tasks, which are described as creativity tasks, and they are instructed to try to come up with creative and unusual responses. Judges then rate the creativity of each response (Silvia et al., 2008) or the set of responses as a whole (Silvia, Martin, & Nusbaum, 2009), using a 5-point scale (1 = not at all creative, 5 = very creative). The judges are given Guilford's description of creative ideas as uncommon, remote, and clever (see Silvia et al., 2008) as a guide to rating.

Several studies have found good evidence for the reliability of these methods. According to generalizability analyses (Silvia et al., 2008, Study 1) and maximal reliability analyses (Silvia, in press), raters and tasks contribute little variance to unusual uses scores—true trait scores are the largest source of variance, as they should be. Using 2 or 3 unusual uses tasks and 3 or 4 raters seems to be adequate for a reliability level of .80 (Silvia et al., 2008). Furthermore, the evidence for validity is strong: divergent thinking scores covary strongly with personality traits, particularly openness to experience (Silvia et al., 2008, Study 2; Silvia, Nusbaum, Berg, Martin, & O'Connor, 2009), and with creative activities and achievements (Silvia & Kimbrel, 2010).

Subjective scoring overcomes the two limitations associated with uniqueness scoring. First, fluency scores and creativity scores (the rated level of creativity) are not inherently confounded, and research finds much lower correlations between ratings and fluency than between uniqueness scores and fluency (Silvia et al., 2008 and Silvia et al., 2009). Second, unlike uniqueness scores, creativity ratings are not confounded with sample size, so they do not necessarily decline as the sample size increases. As a result, creativity ratings are better suited for large-sample latent variable methods, which are important for drawing inferences about higher-order abilities.

4. The present research

In the present research, two latent variable studies explored the role of executive and strategic processes in the Gf–creativity relationship. Both studies assessed divergent thinking using standard unusual uses tasks, but we scored these tasks using recent scoring systems that avoid some of the problems associated with traditional uniqueness scoring. In the first study, we examined how Gf predicted divergent thinking overall and if executive switching—how often people switched from one idea category to a new idea category (Troyer & Moscovitch, 2006)—mediated Gf's effect. In the second study, people were given a strategy that enhances divergent thinking scores (Gilhooly et al., 2007). We expected the rich to get richer: people high in Gf should be better able to use the strategy, so it ought to exaggerate the effects of Gf on divergent thinking. Taken together, the two studies demonstrate a significant role for executive processes in divergent thinking, which suggests that divergent and convergent processes have more in common than creativity theories claim.

5. Study 1

Study 1 examined how individual differences in Gf predict individual differences in divergent thinking. To overcome some limitations of past work, we modeled both variables as latent constructs, and we assessed creativity using subjective scoring methods that have fared well in recent research. Study 1 focused on two questions: how strongly does Gf predict creativity, and is its effect mediated by markers of executive cognition? As noted earlier, theories of divergent thinking have emphasized knowledge-based explanations for individual differences in creativity, in which activation spreads toward increasingly remote concepts (Wallach & Kogan, 1965). In contrast, we suggest that executive processes are critical to successful divergent thinking performance.

To index executive processes during the divergent thinking task, we borrowed a paradigm from the verbal fluency literature, which has identified switching and clustering as two major processes that underlie task performance (Troyer, Moscovitch, & Winocur, 1997). In an unusual uses task, responses can be scored for switching (how often people shift from categories of uses) and clustering (how many uses are in a category). In their research, Troyer et al. (1997) found that switching in particular reflected executive processes: older adults made fewer switches, and switching was impaired by a divided attention manipulation. Based on this work, we expected that people high in Gf would switch more often, and that frequent switching in turn would predict higher creativity ratings.

5.1. Method

5.1.1. Participants

The data from Study 1 had been collected as part of a prior investigation of individual differences in cognitive abilities (see Silvia et al., 2008).1 The divergent thinking data were rescored (creativity was scored using the holistic snapshot scoring method) and recoded (the tasks were coded for executive switching and clustering) for the present study and have not been presented elsewhere. A total of 226 people comprised our sample—178 women and 48 men—all of whom were students enrolled in an introductory psychology class at the University of North Carolina at Greensboro. The sample was mostly Caucasian (63%) and African American (27%), according to self-reported ethnicity. Participants with extensive missing data or limited English language proficiency were excluded (original n = 242).

5.1.2. Procedure

Students participated in groups of 1 to 13. Upon entering the lab room, they were given a consent form to sign and the experimenter explained the purpose of the study. After agreeing to participate, students were given a number of questionnaires, intelligence tests, personality scales, and creativity tasks (see Silvia et al., 2008, for full details).

5.1.2.1. Creativity tasks

Participants completed two divergent thinking tasks: they were instructed to come up with “unusual, creative, and uncommon” uses for a brick and a knife. After working on the task for 3 min, participants were asked to stop working and circle the two responses they viewed as their most creative responses. To assign a creativity score, we used snapshot scoring (Silvia, Martin, & Nusbaum, 2009), which gives a single creativity score to the entire set of responses (cf. Runco & Mraz, 1992). Three raters scored each task using a 1 (not at all creative) to 5 (very creative) scale. For a review of the snapshot scoring method, see Silvia, Martin, and Nusbaum (2009).

5.1.2.2. Clustering and switching

Following the work of Gilhooly et al., 2007 and Troyer and Moscovitch, 2006, we scored the divergent thinking tasks for the number of unique response categories—or switches—and the number of responses within that category—or cluster size. One rater scored each task for the number of switches, using criteria from past studies of clustering and switching. First, each switch must be unique—that is, reverting to a category already used doesn't count as a switch—and second, categories should be general enough so that, for example, “build a house” and “build a staircase” both fit under the same brick-uses category of construction. Switches for a task were tallied and each switch was awarded one point towards the total switching score. Cluster size was then computed as the average number of responses per category.

5.1.2.3. Gf tasks

Following the creativity tasks, participants completed three fluid reasoning tasks: Ravens Advanced Progressive Matrices (18 items, 12 min); a letter sets task, in which people see five sets of four letters and must decide which set violates a rule followed by the others (16 items, 4 min); and a paper folding task, in which people must decide how a square paper would look if folded, punched with a hole, and then unfolded (10 items, 4 min). Verbal fluency was assessed with four fluency tasks: the letter F, animals, the letter M, and occupations (2 min per task). Finally, participants completed three strategy generation tasks. In her research examining cognitive processes involved in verbal fluency, Phillips (1999) found that intelligence correlated positively with the ability to identify strategies for verbal fluency tasks. In our experiment, participants were asked to come up with strategies for naming parts of the body, countries in the world, and examples of food (2 min per task). Each task was then scored for the number of distinct strategies.

5.2. Results and discussion

5.2.1. Model specification

The analyses were conducted with Mplus 6, using maximum likelihood estimation. There were few missing observations: the variables with the most missing data were nevertheless 99.1% complete. Fig. 1 displays the basic model; Table 1 displays the descriptive statistics. Fluid intelligence (Gf) was modeled as a higher-order factor indicated by the three latent fluid reasoning, verbal fluency, and strategy generation variables, each of which was indicated by its respective tasks. The variance of Gf was fixed to 1. Creativity was modeled as a latent variable indicated by the latent Brick and Knife tasks, each of which was indicated by the three raters' scores. The paths from Creativity to the Brick and Knife tasks were constrained to be equal for identification, and the variance of Creativity was fixed to 1. A CFA of this measurement model suggested good fit, $\chi^2(97\ df) = 158.74$, $p < .001$; $\chi^2/df = 1.64$; CFI = .933; RMSEA = .053; SRMR = .053.

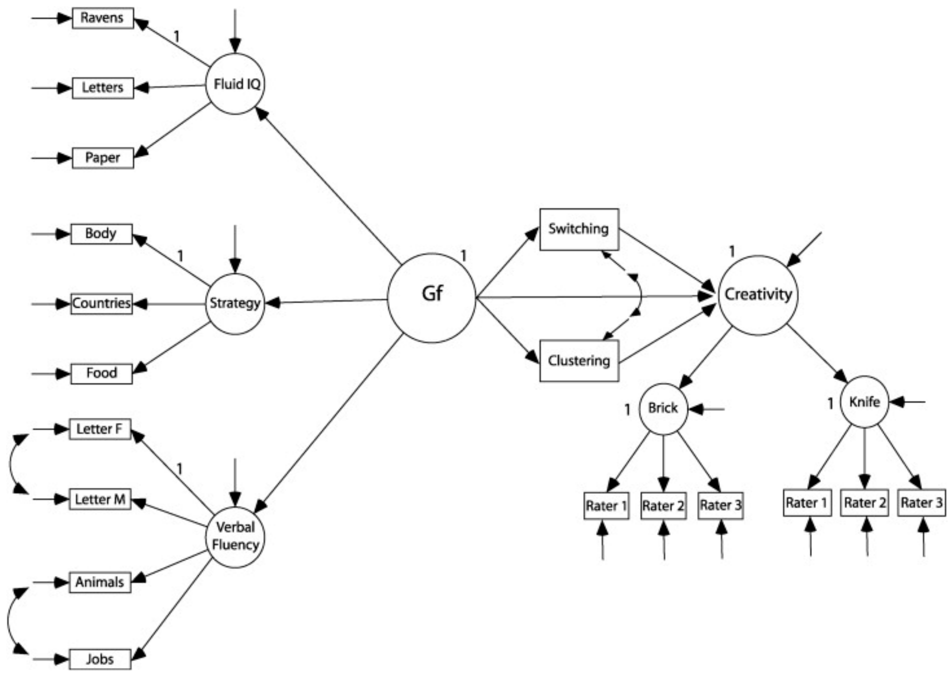

Fig. 1. Gf's direct and indirect effects on divergent thinking: Study 1.

Table 1. Descriptive statistics and correlations: Study 1.

	M	*SD*	*Min, Max*	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1. Brick: rater 1	1.93	.69	1, 4	1																		
2. Brick: rater 2	1.69	.77	1, 4	.505	1																	
3. Brick: rater 3	1.67	.78	1, 4	.536	.483	1																
4. Knife: rater 1	1.81	.71	1, 4	.361	.290	.270	1															
5. Knife: rater 2	1.76	.81	1, 4	.199	.251	.155	.479	1														
6. Knife: rater 3	1.77	.79	1, 4	.446	.328	.573	.572	.415	1													
7. Clusters	1.73	.82	1, 7.50	−.367	−.224	−.260	−.340	−.222	−.334	1												
8. Switches	4.62	1.74	1.50, 10.50	.423	.363	.353	.273	.176	.323	−.343	1											
9. Fluency	7.14	2.89	2, 20	.093	.139	.082	−.101	−.042	−.011	.329	.645	1										
10. Ravens	9.89	3.15	1, 17	.146	.128	.171	.160	.123	.092	−.172	.168	−.002	1									
11. Paper folding	5.66	2.27	0, 10	.221	.119	.141	.128	.108	.130	−.190	.128	−.017	.438	1								
12. Letter sets	7.48	2.33	1, 13	.081	.107	.068	.134	.044	.066	−.112	.018	−.035	.306	.340	1							
13. VF: F	19.20	4.98	7, 33	.148	.216	.101	.115	.000	.107	.045	.235	.269	.181	.019	.197	1						
14. VF: M	18.14	4.22	7, 30	.256	.291	.130	.130	.044	.173	.001	.186	.181	.201	.069	.148	.647	1					
15. VF: animals	25.19	5.44	5, 39	.089	.160	.087	.105	.089	.152	−.041	.237	.159	.187	.183	.195	.341	.320	1				
16. VF: jobs	19.00	4.49	9, 32	.212	.110	.103	.127	.064	.137	−.039	.278	.267	.082	.102	.172	.428	.423	.509	1			
17. Body parts	3.32	1.18	0, 6	.082	.042	.025	−.027	−.021	.059	−.011	.191	.155	−.026	−.007	.097	.155	.150	.284	.207	1		
18. Food types	4.07	1.08	1, 6	.025	.085	.044	.029	.055	-.002	-.156	.166	.076	.128	.117	.139	.212	.138	.174	.167	.283	1	
19. Countries	3.96	1.19	1, 7	.180	.152	.146	.028	-.019	.019	-.056	.193	.168	.059	.160								

Note. *n* = 226. VF = verbal fluency. See text for details about the tasks.

5.2.2. Fluid intelligence and divergent thinking

Our first model examined the direct effect of fluid intelligence on creativity. Kim's (2005) meta-analysis, which found an effect of r = .17, provides a benchmark. The latent Gf construct significantly predicted creativity (β = .447, p < .001, R^2 = 19.9), and its standardized effect was notably larger than Gf effects found in past research.

5.2.3. Switching and clustering as mediators

Our second model examined whether the direct effect of Gf was mediated by switching, a marker of executive action within the task. This model specified two mediators‒switching (number of idea categories) and clustering (number of responses per category)‒as well as a direct effect of Gf; the mediators were allowed to covary (see Fig. 1). This model explained 45.9% of the variance in creativity scores. Gf significantly predicted switching (β = .467, p < .001) but not clustering (β = −.122, p = .214): people higher in Gf made significantly more category changes during the divergent thinking tasks, but they didn't have more ideas per category. In turn, switching (β = .310, p = .001) and clustering (β = −.368, p < .001) each predicted creativity scores. Gf's direct effect on creativity was substantially reduced, β = .241, p = .031, but still notable.

Formal tests of mediation indicated that executive switching significantly mediated between Gf and creativity scores. We examined two tests: the Sobel test for the significance of indirect effects and confidence intervals based on bias-corrected bootstrapping (using 1000 bootstrap samples) of the indirect effect (Cheung, 2007 and MacKinnon, 2008). Switching was a significant mediator based on the Sobel test (b = .197, SE = .064, Z = 3.06, p = .002), and the bias-corrected bootstrapped confidence intervals around its indirect effect excluded zero (95% CI = .081 to .452), again indicating significant mediation. Clustering, in contrast, was not a significant mediator according to either the Sobel test (b = .061, SE = .049, Z = 1.24,p = .216) or its bias-corrected bootstrapped confidence intervals, which included zero (95% CI = −.046 to .167).

6. Study 2: do task strategies help or hinder people low in Gf?

The results of Study 1 supported an executive interpretation of divergent thinking: Fig. 2 depicts the model; Table 2 displays the descriptive statistics. Gf significantly predicted creativity scores, and its effect was mediated in part by switching, a marker of within-task executive processes (Troyer et al., 1997). Study 2 sought to expand the evidence for the role of executive abilities and processes in creative thought. In particular, we examined strategy use—another marker of executive cognition—during divergent thinking. In their research, Gilhooly et al. (2007) collected think-alouds during an unusual uses task and coded for task strategies that people spontaneously identified and used. Many of the strategies were ineffective, but some strategies were associated with greater creativity of responses. In Study 2, we randomly assigned some people to receive an effective strategy—a disassembly strategy, which involves breaking an object into parts and considering part-whole relations—for generating creative responses.

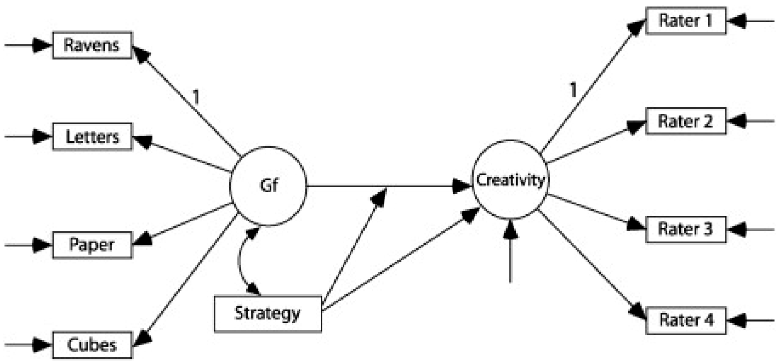

Fig. 2. A depiction of the interaction model: Study 2.

Table 2. Descriptive statistics and correlations: Study 2.

Variable	*M*	*SD*	*Min, Max*	1	2	3	4	5	6	7	8
1. Rater 1	1.25	.457	1, 3	1	.286	.363	.464	.291	.157	.319	.117
2. Rater 2	2.36	.796	1, 5	.678	1	.413	.201	.125	.214	.220	.105
3. Rater 3	1.59	.686	1, 4	.509	.543	1	.480	.038	.101	.138	.094
4. Rater 4	1.47	.562	1, 3	.470	.559	.615	1	.076	.001	.183	.045
5. Ravens	9.73	3.01	0, 16	.052	.038	.105	−.080	1	.349	.448	.070
6. Paper folding	5.56	2.37	0, 10	.183	.127	.230	.057	.459	1	.390	.348
7. Letter sets	7.41	2.31	2, 14	.026	.020	−.075	−.071	.323	.291	1	.268
8. Cube comparisons	9.51	3.79	2, 21	−.009	−.035	−.053	−.081	.254	.156	.416	1

Note. Correlations above the diagonal are for the strategy condition ($n = 91$); correlations below the diagonal are for the control condition ($n = 97$).

Study 2 also measured Gf, which allowed us to see if giving people a helpful strategy narrowed or exaggerated the effects of Gf on creativity. We expected the strategy to exaggerate Gf's effects because people high in Gf are better able to maintain and use the strategy. As noted earlier, divergent thinking tasks involve extensive interference from prior responses, concrete object features, and obvious uses. Successfully using the task strategy requires maintaining access to it in the face of this interference. For people low in Gf, the strategy is likely to slip, leading to a reliance on easy-to-use but ineffective strategies (e.g., retrieving uses from memory, repeating the object's name; Gilhooly et al., 2007).

6.1. Method

6.1.1. Participants and design

A total of 188 people—139 women, 49 men—participated as part of a research option in one of their psychology courses. The sample was primarily Caucasian (58%) and African American (30%), according to self-reported ethnicity. There was one independent variable with two between-person conditions: a strategy condition (n = 91) and a no strategy control condition (n = 97). Participants with extensive missing data or limited English language proficiency were excluded (original n = 196).

6.1.2. Procedure

People participated in groups of 3 to 9 people. The experimenter explained that the study was about creativity and thinking styles, and participants expected to complete a range of tasks and questionnaires.

6.1.2.1. Creativity task and strategy manipulation

The first task people completed was a single unusual uses task, in which they were asked to generate unusual and creative uses for a brick. The strategy manipulation was embedded in the task's instructions. In the no strategy condition, people simply received the standard task instructions, which asked them to "write down all of the original and creative uses for a brick that you can think of." In the strategy condition, people additionally received a strategy that could help them generate better ideas. The strategy was a disassembly strategy, which involves "imagining disassembling the object and using parts or recombining parts" (Gilhooly et al., 2007, p. 616). The experimenter noted:

> If you get stuck or need a strategy that helps come up with more ideas, try to think of the parts that make up an object. For example, when thinking of creative, unusual uses for a shoe, you can imagine the parts of a shoe—the sole, the tongue, the laces, etc.—and come up with creative uses for the parts. In the shoe example, you could use the shoelaces to tie your hair up.

Gilhooly et al.'s (2007, Study 1) protocol analysis found that spontaneously using this strategy was associated with more creative responses. For example, people in the strategy condition suggested crumbling the brick to leave a trail, breaking the brick into small pieces and putting them at the bottom of a fish tank, and melting the brick to make a bowl.

The divergent thinking tasks were scored using snapshot scoring, as in Study 1. Four raters independently gave each set of responses a single score, using a 5-point scale (1 = not at all creative, 5 = very creative). The raters were unaware that a variable had been manipulated and hence were unaware of each person's condition.

6.1.2.2. Gf assessment

Gf was assessed with four tasks. The first three were the Ravens matrices, the letter sets task, and the paper folding task used in Study 1; the fourth task was a cube comparisons task, in which people see two cubes with letters and symbols on the sides and then decide if they could be the same cube or if they must be different (21 items, 3 min).

6.2. Results and discussion

6.2.1. Model specification

The models were estimated with Mplus 6 using maximum likelihood estimation. Fig. 2 depicts the model; Table 2 displays the descriptive statistics. Gf was specified as a latent variable with the four tasks as indicators; the path to the Ravens task was fixed to 1. Creativity was specified as a latent variable with the four raters' scores as indicators; the path to the first rater was fixed to 1. A CFA of this measurement model suggested good fit, $\chi^2(19\ df) = 28.21$, $p = .079$; $\chi^2/df = 1.48$; CFI = .969; RMSEA = .051; SRMR = .044.

6.2.2. Did people high or low in Gf benefit from the strategy?

Did Gf and strategy interactively predict creativity? We first considered the main effects of Gf and the strategy manipulation. Both Gf ($\beta = .21$, $p = .032$) and strategy ($\beta = -.35$, $p = .029$) had significant main effects on creativity scores. (The strategy coefficient is *Y*-standardized: it represents the change in *Y*, in standard deviation units, as the binary predictor shifts from one condition to the other; Long, 1997). Overall, people high in Gf and people in the control condition received higher scores on the unusual uses task.

These main effects, however, were qualified by a significant interaction. To examine the interaction between Gf and strategy condition, we estimated a multiple-group model, which is a common method of testing interactions between latent variables and categorical observed variables (Marsh, Wen, & Hau, 2006). Each strategy condition served as a group, and the path from Gf to creativity was constrained to be equal across the groups. A Wald test found that this constraint significantly worsened model fit, $\chi^2(1\ df) = 6.26$, $p = .0123$, which indicates that Gf's effect on creativity differed significantly between the strategy groups. Gf predicted creativity scores more strongly in the strategy condition ($\beta = .417$, $p = .003$, 95% CI = .15 to .69, $R^2 = 17.4$) than in the control condition ($\beta = .081$, $p = .564$, 95% CI = −.19 to .36, $R^2 = .007$).

As expected, giving people an effective strategy exaggerated the effect of Gf on creativity. The most likely alternate possibility–a good strategy would reduce the difference between people low and high in Gf–was clearly not supported. This finding is consistent with the view that many task strategies are not simply applied, but rather must be engaged and maintained despite interference. Moreover, in the case of divergent thinking, the effective strategies tend to be abstract, such as considering part-whole relations, evaluating the object against broad classes of uses, and using specific object features as cues for uses (Gilhooly et al., 2007). The abstractness of the strategies that foster creative responses makes it more likely that people high in Gf will benefit from them, given that it is more challenging for low Gf people to maintain and use such strategies.[2]

7. General discussion

The start of modern creativity research is usually traced to Guilford's work in the 1950s, and Guilford's early distinction between divergent and convergent production has had a surprisingly long life in creativity research. In particular, the notion that divergent thinking performance is based on associations between concepts persists as an explanation for individual differences in task performance (Kauman, 2009 and Runco, 2007). In the present work, we sought to revisit the widely-held view among creativity researchers that intelligence and creativity are unrelated. Executive abilities and processes may play a larger role than previously thought, for two reasons. First, divergent thinking tasks are probably significantly executive, particularly regarding interference management (Gilhooly et al., 2007). Second, the dominant approaches to scoring divergent thinking confound creative quality with simple fluency and are sample-dependent in problematic ways.

Two studies suggested a larger role for intelligence in creative thought. In the first study, individual differences in Gf significantly predicted creativity, and this effect was partly explained by the effects of Gf on executive switching during the task. In the second study, Gf predicted whether people benefitted from a task strategy: giving people a helpful (but abstract) task strategy exaggerated the differences between people low and high in Gf. It will take an extended body of work to identify how executive processes influence creative ideation, but the present work does suggest that the relationship between creativity and intelligence deserves a new look.

An executive interpretation of divergent thinking offers some new insight into some classic findings. For example, one of Guilford's many intriguing findings was that later responses are more creative than earlier responses (Christensen et al., 1957). This pattern has been replicated using many tasks and scoring methods (e.g., Parnes, 1961), and it is usually explained using the spread of association: the early responses are the close, obvious ideas, but these ideas cue increasingly remote ideas as time passes. An executive approach, however, would suggest that later responses are better because people are seeking and adopting better strategies. In Gilhooly et al.'s (2007) research, participants typically first used a memory retrieval strategy (recalling previously seen uses) and then later (if ever) switched to a more effective strategy. Strategy use thus could also explain why responses become better over time, and it implies that variables that influence strategy use—such as Gf—moderate this effect.

It is ironic that Guilford's model of creativity continues to influence modern creativity research because the model of intelligence it stemmed from—the Structure of Intellect (SOI) model—has relatively little influence in modern intelligence research. Unlike the SOI model, the Cattell–Horn–Carroll (CHC) approach emphasizes a hierarchical structure of abilities (Carroll, 1993 and McGrew, 2005). The CHC approach doesn't necessarily view divergent and convergent processes as opposed dimensions of thought that require different abilities or processes. Instead, this approach would seek to understand what abilities are tapped by divergent thinking tasks and where these abilities reside within the CHC model.

Carroll (1993), for example, viewed divergent thinking tasks as markers of an FO (Originality/Creativity) factor. The FO factor, along with factors such as Ideational Fluency (FI) and Word Fluency (FW), resided under the second-level factor of Gr (Broad Retrieval Ability), the "capacity to readily call up concepts, ideas, and names from long-term memory" (p. 612). Carroll pointed out, however, that tasks that loaded highly on the FO factor typically loaded highly on Gf, Gc, and g as well. Carroll's analysis of FO is a good basis for future research on the abilities that contribute to divergent thinking performance. The present research used only Gf tasks, but a latent variable study that measured many of Carroll's second-level traits (e.g., Gf, Gc, Gr, and Gv) could reveal the unique contributions of different cognitive abilities to divergent thinking.

For example, based on Gilhooly et al.'s (2007) research, we suspect that abilities related to memory retrieval per se are less important than executive abilities. Gilhooly et al. (2007) found that the most common task strategy was "direct retrieval"—simply retrieving unusual uses from memory—but that this strategy did not foster creative responses for the simple reason that uses in memory are things that people have seen before. We suspect that executive abilities, such as the ability to manage interference due to obvious uses and prior responses as well as to identify and deploy task strategies, play a larger role than abilities related to memory search and retrieval. The contribution of Gf to creativity ratings, along with the mediating role of executive switching, is consistent with our view, but an examination of the relative roles of executive and memory processes is an important goal for future research on the role of cognitive abilities in creativity.

The present studies illustrate the value of latent variable models for examining individual differences in creativity. Apart from the landmark factor-analytic research by Guilford's group (e.g., Wilson et al., 1953 and Wilson et al., 1954), creativity research has not seen widespread adoption of latent variable methods. This represents a contrast to modern intelligence research, which commonly uses advanced latent variable methods. We suspect that this is yet another reason—in addition to assessment and scoring methods—why creativity research often finds weak relations between divergent thinking and intelligence. By estimating the separate contributions of latent variables and error, latent variable models enable more precise trait estimates and thus larger effect sizes (Coffman and McCallum, 2005 and Skrondal and Rabe-Hesketh, 2004). As a result, analyses of observed scores probably underestimate the creativity–intelligence relationship. Silvia (2008b) demonstrated this by reanalyzing Wallach and Kogan's (1965) classic data. Modeling intelligence and divergent thinking as latent variables yielded a correlation of $r = .20$, which is notably higher than the correlation between observed scores ($r = .09$) reported by Wallach and Kogan.

Although our research clearly indicates that intelligence and creativity are more closely related than conventional thought alleges, we aren't suggesting they are the same thing, or even that creativity is a facet of intelligence. Much of the variance in divergent thinking is unaccounted for in our research, which highlights the need to consider a range of ability and non-ability factors. For example, other cognitive abilities (e.g., crystallized intelligence and visualization), personality traits (e.g., openness to experience; Silvia, Nusbaum, et al., 2009), domain knowledge (Weisberg, 2006), and motivation (Joy, 2004) play important roles in creative thought, and they should be evaluated for their unique and interactive contributions to individual differences in creative ability.

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We thank Chris Barona, Josh Cram, Karl Hess, Hannah Jones, Casey Kelly, Chris Martin, Jenna Martinez, Crystal Richards, Camilla Sanders, and Mallory Smith for their help with data collection and scoring. Authorship was determined alphabetically.

1 Prior analyses from this dataset (Silvia, 2008a, Silvia, 2008b, Silvia, 2008c and Silvia, in press) have examined “top two scoring”−people are asked to indicate their two best responses, and only ratings of these top-two responses are used to assess creativity. As indicated in the text, for the present analysis we rescored the two unusual uses tasks using snapshot scoring (Silvia, Martin, & Nusbaum, 2009), and for the first time we coded for executive processes using clustering and switching coding.

2 As an aside, interesting effects appeared for fluency−the simple number of responses, regardless of quality−as well. Both Gf (β = .43, p < .001) and the strategy manipulation (β = -.29, p = .039; *Y*-standardized) had main effects on fluency: people high in Gf and people in the control condition generated more responses. The fact that people in the strategy condition generated fewer responses is consistent with the presumed abstractness and difficulty of the strategy. Furthermore, a multiple-group model found a significant interaction, χ^2(1 *df*) = 8.66, p = .0032. Gf predicted fluency in both the control condition (β = .45, p < .001)

and the strategy condition (β = .414, p < .001), but the slope was somewhat higher in the control condition. In short, Gf predicted fluency, as in much past work, but the interaction pattern didn't track the pattern for creativity: an effective strategy greatly exaggerated the creativity difference between people low and high in Gf, but it only modestly affected the fluency difference. Such findings are consistent with our argument that subjective scoring of creativity reveals valid information about creative abilities that are not provided by uniqueness scores and fluency scores.