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Verbal fluency and creativity: General and specific contributions of broad retrieval ability (Gr) factors to divergent thinking☆

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ABSTRACT

The Cattell–Horn–Carroll (CHC) model of intelligence views creativity as a first-level factor within the second-level factor of broad retrieval ability (Gr), alongside other first-level abilities such as ideational fluency and word fluency. Traditional methods of measuring creativity, however, confound idea quality with idea quantity, which might exaggerate the relationship between creativity scores and verbal fluency factors. Participants ($n = 131$ adults) completed two divergent thinking tasks (unusual uses for a rope and a box), which were scored using newer methods that effectively separate creativity (scored via subjective ratings) and fluency (scored as number of responses). They then completed 16 verbal fluency tasks that assessed six lower-order Gr factors: word fluency, associational fluency, associative flexibility, ideational fluency, letter fluency, and dissociative ability. Viewed singly, many of the lower-order factors significantly predicted creative quality and fluency. General Gr had substantial effects on creative quality (standardized $\beta = .443$) and fluency ($\beta = .339$) in a higher-order model as well as in a bifactor model (quality $\beta = .380$, fluency $\beta = .327$). Moreover, general Gr was the only significant predictor in the bifactor model, suggesting that it, not the specific factors, was most important. All effects were essentially the same after controlling for typing speed and vocabulary knowledge. The findings thus support the CHC view of creativity/originality as a lower-order component of Gr, illuminate the relationships between creativity and first-level Gr factors, extend the study of creativity and intelligence beyond fluid intelligence, and further indicate that creativity is more closely tied to cognitive abilities than creativity research has yet recognized.

1. Introduction

How do people come up with clever and creative ideas, and why are some people better at it than others? Most research on these questions has used divergent thinking tasks, which prompt people to generate ideas than can be scored, based on a variety of systems, for creativity (Kaufman, Plucker, & Baer, 2008; Plucker & Renzulli, 1999). In the Cattell–Horn–Carroll (CHC) model of cognitive abilities (McGrew, 2005, 2009), idea generation tasks fall under the second-level factor known as *broad retrieval ability*, abbreviated as Gr (Carroll, 1993). But as many researchers have argued, traditional methods for assessing divergent thinking yield only a fluency score—the simple number of valid responses—or yield quality scores that are confounded with quantity (Hocevar, 1979b; Michael & Wright, 1989; Silvia et al., 2008). Two problems result: (1) divergent thinking tasks might resemble verbal fluency tasks too closely, leading to questions of construct validity, and (2) the weak correlations between creativity and intelligence observed in past work (Kim, 2005) might be due to weak assessment of creativity, not to a genuinely small effect size.

The present research thus addresses two issues. First, when newer assessment methods that effectively dissociate creativity and fluency are used, how does creativity fit within

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the Gr domain? The dominance of fluency-based scoring systems available at the time of Carroll's (1993) landmark analysis might have inflated the association of divergent thinking and Gr. Second, how does divergent thinking relate to both the Gr factor and to its first-level factors? What first-level factors contribute the most to generating creative ideas? In the present research, people completed two divergent thinking tasks and 16 Gr tasks that mapped on to six lower-order Gr factors: word fluency, associational fluency, associative flexibility, ideational fluency, letter fluency, and dissociative ability. Using structural equation modeling, we estimated the contributions of the lower-order factors and the higher-order Gr factor—modeled using higher-order and bifactor models—to both the quality and quantity of responses to the divergent thinking tasks.

2. The creativity-and-intelligence debate

Creativity research has had an ambivalent relationship with the construct of intelligence. Guilford, in a program of work that launched modern creativity research, extensively studied how both convergent and divergent modes of thought fit into his Structure of Intellect Model (Guilford, 1967), which contained many novel tasks for measuring creativity. Later creativity researchers, however, contended that creativity and intelligence are essentially unrelated (Getzels & Jackson, 1962). Wallach and Kogan's (1965) work on creativity and intelligence in children, a touchstone in this field, found a correlation of only $r = .09$ between measures of divergent thinking and intelligence. Work since then supported their view—a meta-analysis by Kim (2005) found a weighted average correlation of $r = .17$ between intelligence and divergent thinking. For this reason, most reviews conclude that creativity and intelligence are at most weakly related (Kaufman, 2009; Kaufman & Plucker, 2011; Kim, Cramond, & VanTassel-Baska, 2010; Runco, 2007; Weisberg, 2006).

In our recent work, we have argued that this debate deserves a new look (Nusbaum & Silvia, 2011; Silvia & Beaty, 2012). Using the Cattell–Horn–Carroll model as a framework, we have proposed that creativity and intelligence are more closely linked than past research has found. Several methodological factors have caused underestimates of the creativity–intelligence relationship. First, most studies have measured only a few individual tasks and then analyzed the observed scores. Assessing creativity and intelligence as latent variables yields higher effect sizes because task-specific error variance is modeled appropriately (Kline, 2011; Silvia, 2008a). In Wallach and Kogan's (1965) classic study, for example, the observed correlation of $r = .09$ increased to $r = .20$ when the data were reanalyzed with latent variable models (Silvia, 2008b).

Second, and most relevant to the present research, traditional methods of measuring divergent thinking have struggled with dissociating *fluency* (the number of responses to the divergent thinking tasks) from *creative quality* (the originality or merit of those responses). The best known approaches to divergent thinking assessment use some form of uniqueness scoring: people receive a point for each response they gave that no one else in the sample gave (Wallach & Kogan, 1965) or that doesn't appear on a list of common responses (Torrance, 2008). Since these methods were published, many researchers have criticized them for confounding fluency and creativity: people who give more responses are likely to have more unique responses (Clark & Mirels, 1970; Dixon, 1979; Hocevar, 1979a, 1979b; Hocevar & Michael, 1979; Michael & Wright, 1989; Plucker, Qian, & Wang, 2011; Silvia et al., 2008; Speedie, Asher, & Treffinger, 1971). In fact, the correlation between fluency and creativity is quite high in several gold-standard data sets, including $r = .89$ in Wallach and Kogan's (1965) landmark study (see Silvia, 2008b) and $r = .88$ in the most recent norms for the Torrance Tests of Creative Thinking (Torrance, 2008). As a result, many researchers use only fluency scores when assessing divergent thinking (e.g., Batey, Chamorro-Premuzic, & Furnham, 2009; Preckel, Holling, & Wiese, 2006; Preckel, Wermer, & Spinath, 2011).[1]

3. Divergent thinking and Gr

The confounding of fluency and creativity is interesting for several reasons. For one, it sheds new light on the modest relationships between divergent thinking and intelligence (Kim, 2005; Wallach & Kogan, 1965). Divergent thinking tests are probably the most widely used tools for measuring creativity, and an extensive literature provides evidence for their validity (Kaufman et al., 2008; Ma, 2009; Plucker, 1999; Silvia et al., 2008). Nevertheless, in his review of the originality/creativity (FO) factor, Carroll (1993) noted substantial differences in test administration: researchers "tend to give insufficient information as to whether subjects are made aware that they are being tested for originality or creativity, or as to whether subjects are instructed to try to give original or creative responses" (p. 429). In fact, researchers commonly don't inform participants to be creative (e.g., Runco & Acar, 2010). When such tasks are then scored for fluency, it seems hard to claim that the scores measure "creative ability" or "creative potential" instead of ideational fluency. Much of the evidence supporting the claim that creativity and intelligence are weakly related is thus founded on questionable measures of creativity.

Furthermore, if divergent thinking scores have historically been confounded with fluency, then it isn't surprising that Carroll's (1993) analysis found that they formed a lower-order factor of Gr alongside factors such as word fluency, ideational fluency, and associational fluency. Most models of the Gr domain include a first-level factor of creativity (Horn & Blankson, 2005; Kaufman, Kaufman, & Lichtenberger, 2011; McGrew, 2005), and the most typical measures of creative ability are divergent thinking tasks (Carroll, 1993; Runco, 2007). It is thus possible that conventional methods of assessing divergent thinking exaggerate the relationship between Gr and creativity. As noted earlier, omitting instructions to "be creative" and scoring the tasks in ways that confound creativity and fluency yields tasks that resemble ideational fluency tasks. This raises a key question for a CHC approach to creativity: is creativity still strongly

[1] The more common method is Wallach and Kogan's (1965) uniqueness scoring: people get a point for each response they gave that no one else gave or that falls under a cut-off (e.g., one point for a response that no more than 5% of the sample gave). The confounding of creativity and fluency is a problem, but the most fatal problem with this method, in our view, is that estimates of creativity are doubly sample-dependent. First, each person's level of creativity depends on the other people in the sample. Second, as the sample size increases, creativity scores decline, so the task's "difficulty" increases with the sample size. Both forms of sample dependency are obviously undesirable.

associated with Gr and its first-level factors when it is assessed using newer methods that effectively dissociate creative quality and fluency?

Despite the ambiguity stemming from traditional methods of measuring divergent thinking, an analysis of the cognitive processes involved in divergent thinking suggests that Gr should play a substantial role in creativity. Recent work has found large effects of fluid intelligence ($\beta = .45$, Nusbaum & Silvia, 2011, Study 1; $\beta = .51$, Benedek, Franz, Heene, & Neubauer, 2012), which are attributed to the ability to maintain the task goal, manage interference, and identify and deploy complex ideational strategies (Gilhooly, Fioratou, Anthony, & Wynn, 2007). Gr captures additional processes that are critical to creative thought. Strong performance on verbal fluency tasks involves self-generating cues and categories for retrieval as well as switching categories when an impasse is reached (Unsworth, Spillers, & Brewer, 2011). The ability to selectively retrieve knowledge despite interference—such as from prepotent associates, exemplary category members, and previously generated responses—appears to be fundamental to Gr (Rosen & Engle, 1997; Troyer, Moscovitch, & Winocur, 1997; Unsworth et al., 2011). This ability seems obviously important to generating creative ideas, which are necessarily less common and prepotent than other ideas.

The role of Gr in creativity has received renewed attention in recent work. Benedek, Könen, and Neubauer (2012) administered four classes of tasks that measured different facets of associational ability: associational fluency (generating a series of words related to a concept), associative flexibility (generating a chain of associated words, in which each word links to the prior word), dissociative ability (generating a chain of random, unrelated words), and associative combination (generating words that relate to two unrelated words). Divergent thinking was measured with two tasks and scored as a composite of fluency and creative quality. Each of the four types of associational ability correlated between $r = .55$ and $r = .62$ with divergent thinking, and structural equation models showed that the four task types explained around half the variance in divergent thinking. Although the composite fluency/creativity scoring might have inflated their correlations, this study nevertheless suggests that first-level Gr abilities are substantially related to creative thought.

4. The present research

The present research examined the contribution of the second-level Gr factor and several of its first-level factors in divergent thinking. A central aim was to explore the relationship of Gr and divergent thinking using scoring methods that distinguish between the quality and quantity of divergent thinking responses. In our recent work on creativity assessment, we have found strong evidence for the reliability and validity of subjective scoring methods (Silvia, 2011; Silvia, Martin, & Nusbaum, 2009; Silvia et al., 2008), which involve having raters evaluate the responses and provide quantitative ratings. Subjective scoring has a long history in creativity research. It was used extensively by Guilford—such as ratings of cleverness and remoteness (e.g., Christensen, Guilford, & Wilson, 1957)—and subjective ratings are the basis of the consensual assessment technique (Amabile, 1982), perhaps the most common method for evaluating creative products (Kaufman, Plucker, & Russell, 2012; Kaufman et al., 2008). In our work, participants are told that the tasks involve creativity and are asked to come up with creative ideas. Raters judge the responses using a 5-point scale (1 = *not at all creative*, 5 = *very creative*). Whereas uniqueness scoring correlates with fluency usually over $r = .60$ (Silvia et al., 2008; Torrance, 2008; Wallach & Kogan, 1965), our studies have found much lower correlations between subjective ratings and fluency (between $r = .30$ and $r = -.10$). Moreover, many studies have found meaningful effects with these methods (Benedek, Franz, et al., 2012; Silvia & Kimbrel, 2010; Silvia, Nusbaum, Berg, Martin, & O'Connor, 2009), including several studies on CHC abilities (Beaty & Silvia, 2012, 2013; Nusbaum & Silvia, 2011; Silvia & Beaty, 2012). We thus see subjective scoring as a promising way of revealing the distinct effects of Gr abilities on both the quality and quantity of divergent thinking.

We assessed Gr with 16 tasks associated with six lower-level factors (see Table 1). Most of the tasks are commonly used in verbal fluency research and are established markers of first-order Gr factors, particularly the measures of word fluency, letter fluency, associational fluency, and ideational fluency.[2] Some of the tasks, however, are relatively new. One task—the fake words task, which requires generating neologisms that are pronounceable in English—appears not to have been used before. Four of the tasks were taken from Benedek, Könen, et al.'s (2012) recent work on associational abilities: two associative flexibility tasks (the music chain and cold chain tasks) and two dissociative ability tasks (the random baby and random table tasks). Benedek, Könen, et al. found large correlations between these factors and divergent thinking, so we wanted to examine the new tasks further.

Measuring six lower-order factors allowed us to examine how a diverse set of verbal fluency factors might influence creativity, but it also allowed us to examine how the higher-order, general Gr factor itself influences creativity. In the present study, we modeled the general Gr factor using two methods. The first was a conventional higher-order model, in which the lower-order latent factors serve as indicators for a higher-order latent Gr factor. The second was a bifactor model (Reise, 2012), in which the observed indicators are modeled as a function of both lower-order factors and a general Gr factor. Unlike the higher-order model, a bifactor model can simultaneously estimate the effects of the specific factors and the general factor on an outcome (Chen, Hayes, Carver, Laurenceau, & Zhang, 2012; Chen, West, & Sousa, 2006), so it is well suited to the question of how lower-order and higher-order Gr factors influence divergent thinking. As Chen et al. (2012) point out, higher-order and bifactor models are different ways of representing a general factor, and both are commonly used in intelligence research (Gustafsson, 2001; Kvist & Gustafsson, 2008), so we applied both models to general Gr and its specific factors.

We sought to control for several variables that could influence relationships between Gr and creativity. First, because

[2] In our model, we distinguished between letter fluency (generating words that start with a particular letter) and word fluency (generating words based on orthographic constraints). Letter fluency tasks use orthographic constraints and thus conceptually fit within the first-level word fluency factor, but many applications of Gr tasks use only letter fluency tasks, such as the use of *F–A–S* tasks in neuropsychological assessment. Exploring relationships of letter fluency itself thus seemed worthwhile.

Table 1
Descriptions of the verbal fluency tasks.

First-level factor	Task	Description	Standardized CFA loading
Word fluency	End TION	List words that end with *TION*	.452
Word fluency	Start CON	List words that start with *CON*	.541
Word fluency	No ER	List words that don't contain the letters *E* or *R*	.543
Word fluency	No HU	List words that don't contain the letters *H* or *U*	.440
Word fluency	Five letters	List words with exactly five letters	.521
Associational fluency	Good	List synonyms for *good*	.575
Associational fluency	Hot	List synonyms for *hot*	.672
Associative flexibility	Music chain	Write a series of linked words, in which each word is related to the prior word, starting with *music*	.785
Associative flexibility	Cold chain	Write a series of linked words, in which each word is related to the prior word, starting with *cold*	.825
Ideational fluency	Jobs	List occupations	.742
Ideational fluency	Names	List people's first names	.676
Ideational fluency	Fake words	Write neologisms: words that can be pronounced in English but aren't real words (e.g., *zeffle*, *raglate*)	.528
Letter fluency	Letter F	List words that begin with *F*	.757
Letter fluency	Letter M	List words that begin with *M*	.731
Dissociative ability	Random baby	Write a list of random unrelated words starting with *baby*	.756
Dissociative ability	Random table	Write a list of random unrelated words starting with *table*	.880

Gr tasks draw upon crystallized verbal knowledge (Horn & Blankson, 2005), we measured vocabulary knowledge to appraise the unique effects of Gr after controlling for vocabulary. Second, Carroll (1993) noted that research using timed ideational tasks should attempt to control for writing speed, so we included a typing speed task as an additional covariate.

5. Method

5.1. Participants

A total of 147 people enrolled in psychology courses at the University of North Carolina at Greensboro volunteered to participate and received credit toward a research participation option. Because of the project's substantial language component, we excluded a priori participants who didn't speak English as a native language ($n = 13$); three additional participants were excluded for extensive missing data or for misunderstanding the instructions. This left a final sample of 131 people. The sample consisted mostly of women (110 women, 21 men) and young adults (mean age = 19.71, $SD = 4.92$, with a range from 18 to 53). Regarding self-reported race and ethnicity, the sample was approximately 70% European American, 23% African American, 6% Asian, and 5% Hispanic or Latino. (People could choose more than one option or decline to state any.)

5.2. Procedure

People participated in group sessions that ranged from 1 to 8 people. After completing an informed consent form, people learned that the study was about how people generate ideas. MediaLab 2010 was used to present the tasks and collect responses.

5.3. Divergent thinking assessment

The first two tasks assessed divergent thinking. People were asked to generate creative and unusual uses for two common objects: a *rope* and a *box*. People had three minutes for each task. As in our past work, we emphasized that the tasks assessed creativity and that people should try to be creative in their responses (Nusbaum & Silvia, 2011; Silvia et al., 2008). The experimenter noted that there were many common and obvious ways to use these objects, but that people should try "to come up with *creative ideas*, which are ideas that strike people as clever, unusual, interesting, uncommon, humorous, innovative, or different." The experimenter also noted that people could enter as many ideas as they wished during the three minutes, but that "it is more important to come up with creative ideas than a lot of ideas." Past research shows that instructing people to "be creative" yields better responses (Harrington, 1975; Niu & Liu, 2009). In addition, we have argued that omitting "be creative" instructions turns divergent thinking tasks into verbal fluency tasks, so "be creative" instructions are central to valid score interpretations (Silvia et al., 2008).

We scored the divergent thinking tasks using subjective scoring methods, which involve using raters to score each individual response, subsets of responses, or the set of responses as a whole (Silvia et al., 2008). As in our past research (Nusbaum & Silvia, 2011), we used "snapshot scoring" (Silvia et al., 2009), which involves giving a single holistic score to each person's set of responses (e.g., all the uses for a rope) rather than a score for each individual response. This method allows raters to take relations within the set into account—such as responses that build off each other or refer to prior responses—and it has worked well in prior research (Mouchiroud & Lubart, 2001; Nusbaum & Silvia, 2011; Runco & Mraz, 1992). Global snapshot scores correlate highly with item-level ratings. In one study (Silvia, Martin, et al., 2009), snapshot scores correlated highly ($r = .66$) with "top two scores," which are ratings of the two responses that participants chose as their best (Silvia et al., 2008). In another study (Nusbaum & Silvia, 2011, Study 2), snapshot scores correlated highly with ratings of individual responses that the participants said they generated themselves on the spot ($r = .74$).

Two raters independently gave snapshot scores for each task for each participant. Each set of responses was rated on a 5-point scale (1 = *not at all creative*, 5 = *very creative*). The raters were instructed, based on Guilford's writings (Wilson, Guilford, & Christensen, 1953), that creative responses typically have three features: originality (they occur infrequently in the sample), remoteness (they are conceptually distant from obvious and common uses), and cleverness (they are interesting, funny, or intriguing). The raters were unaware of each other's scores as well as all information about the participants, including their responses to the other divergent thinking task.

5.4. Typing speed

To evaluate and control for differences in typing speed, we administered a brief typing speed task. People had 30 s to type as many words as possible from a list of 30 English words. The task was scored for the number of words typed correctly during that time.

5.5. Verbal fluency assessment

After the typing speed task, people completed a series of 16 verbal fluency tasks. Table 1 lists the tasks according to their lower-order Gr factor. Most of the tasks represented the most consistently replicated verbal fluency factors in Carroll's (1993) analysis of the Gr domain (word fluency, associational fluency, and ideational fluency) and that frequently appear in research on verbal fluency (e.g., letter fluency). In addition, we included several tasks from Benedek, Könen, et al.'s (2012) recent study of associative abilities and creativity. The associative flexibility tasks (music chain and cold chain) involve creating a chain of linked words: people are given a target word (e.g., summer) and then must create a series in which each word is associated with the prior word (e.g., "beach, sand, castle, knight, horse…"). The dissociative ability tasks (random baby, random table) involve creating a series of unrelated words in response to a prompt: each new word must be unrelated to the prompt and to all prior words.

As in our other research that measured both divergent thinking and verbal fluency (Nusbaum & Silvia, 2011), the experimenter emphasized the difference between the goal of the divergent thinking tasks (i.e., to be creative) and the goal of the verbal fluency tasks (i.e., to generate as many words as possible). All participants completed the verbal fluency tasks in the same fixed order (Letter M, Letter F, Names, Music Chain, Cold Chain, Five Letters, Random Baby, Random Table, Start CON, End TION, Good, Hot, Fake Words, No ER, No HU, and Jobs). Prior to each task, the experimenter read aloud the task's instructions, which were also presented on each participant's monitor. People had 60 s for each task. After the fifth and tenth task, people completed simple self-report scales for brief breaks. Each task was scored for the number of valid responses (e.g., excluding repetitions, incorrect responses, and roots).

5.6. Vocabulary knowledge

After the verbal fluency tasks, people completed two measures of vocabulary knowledge, a key component of crystallized intelligence (Kan, Kievit, Dolan, & van der Mass, 2011). People had 7 min to complete 42 vocabulary items from the Advanced Vocabulary Test and Extended Range Vocabulary Test from the ETS Kit of Factor-Referenced Cognitive Tests (Ekstrom, French, Harman, & Dermen, 1976). The task was scored for the total number of problems correctly solved during the time limit.

6. Results

6.1. Analysis plan and model specification

All models were estimated with maximum likelihood with robust standard errors, using Mplus 7. There was relatively little missing data: covariance coverage was at least 94% and was typically greater than 99%. All indicators were centered at the sample's grand mean (Kline, 2011). The models were evaluated for outlying and influential cases using Mahalanobis's distance, Cook's distance, and individual contributions to the log-likelihood.[3] All estimates are standardized. Table 2 lists descriptive statistics and correlations. In the spirit of Wichert and Bakker's (2012) call for data publishing, the raw data are included as an online appendix.

6.2. Divergent thinking

We conducted a confirmatory factor analysis (CFA) of divergent thinking that specified two factors: creativity and fluency. For creativity, we estimated a higher-order creativity factor that was indicated by two lower-order factors: scores on the rope task ($\beta = .847$) and the box task ($\beta = .847$). For identification, these loadings were constrained to be equal, and the variance of the higher-order creativity factor was fixed to 1. Each lower-order factor, in turn, was indicated by the two raters' scores; the variances of the lower-order factors were fixed to 1. For fluency, a latent fluency variable was formed using the rope fluency ($\beta = .852$) and box fluency ($\beta = .849$) scores as indicators, which were constrained to be equal for identification. Fig. 1 displays the model.

The model's fit was good on most fit indices: $\chi^2(8\ df) = 17.63$, $p = .024$; CFI = .949; RMSEA = .096 (90% CI: .033, .158); SRMR = .033. Estimates of construct reliability (also known as maximal reliability) for latent variables (Drewes, 2000; Hancock & Mueller, 2001) were good for creativity ($H = .835$) and for fluency ($H = .839$). The latent creativity and fluency factors correlated only modestly, $r = .27$, $p = .013$, which replicates our past work on how subjective scoring methods effectively dissociate quality and quantity.

6.3. Gr tasks

We conducted a CFA of the 16 Gr tasks to specify its lower-order structure; Fig. 2 displays the model. The 16 tasks were assigned to lower-order latent variables as shown in Table 1. The latent variables' scales were set by fixing a path to 1; the variances were freely estimated. When a latent variable had only two indicators, we constrained both paths to equal 1.

[3] Specifically, we examined both the univariate distributions of these variables, scatterplots of their relationships with each other (e.g., scatterplots of Cook's D and log-likelihood values), and scatterplots with the major latent variables. We decided a priori to drop cases that appeared deviant on two of the three variables. No cases were dropped based on these analyses. A couple cases had elevated Cook's D scores for models involving Gr, but they were retained because they were not deviant on the other two metrics and dropping them had essentially no effect.

Table 2
Correlations and descriptive statistics.

	M	*SD*	Min, max	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1. Rope: Rater 1	1.75	.84	1, 5	1																							
2. Rope: Rater 2	2.19	.71	1, 4	.39	1																						
3. Box: Rater 1	1.93	.96	1, 5	.34	.36	1																					
4. Box: Rater 2	2.07	.74	1, 5	.31	.31	.55	1																				
5. Rope: Fluency	7.53	3.95	1, 22	.09	.19	.11	.18	1																			
6. Box: Fluency	7.87	3.97	1, 22	.03	.04	.22	.13	.72	1																		
7. End TION	6.28	2.47	1, 12	.11	.15	.18	.16	.08	.05	1																	
8. Start CON	7.64	2.18	2, 13	.18	.25	.19	.18	.27	.16	.33	1																
9. No ER	11.36	3.74	4, 22	.09	.05	.13	.08	.10	.13	.27	.21	1															
10. No HU	13.65	3.79	6, 28	.18	.01	.20	.12	.12	.18	.21	.24	.40	1														
11. Five letters	9.21	3.97	2, 25	.08	.11	.16	.05	.15	.10	.21	.19	.24	.21	1													
12. Good	7.18	2.73	3, 17	.18	.11	.15	.11	.15	.13	.17	.26	.35	.17	.32	1												
13. Hot	5.27	2.32	1, 12	.11	.26	.28	.21	.36	.26	.13	.34	.20	.26	.35	.38	1											
14. Music Chain	12.46	4.69	1, 30	.15	.18	.14	.21	.14	.14	.08	.24	.33	.31	.19	.24	.36	1										
15. Cold chain	12.24	4.33	3, 25	.15	.12	.29	.23	.28	.28	.16	.18	.34	.15	.28	.28	.40	.65	1									
16. Jobs	12.67	3.18	6, 23	.07	.04	.03	.15	.21	.16	.31	.33	.44	.28	.33	.32	.28	.43	.40	1								
17. Names	21.40	4.48	11, 33	−.02	.12	.16	.14	.16	.12	.29	.30	.32	.21	.41	.32	.40	.36	.35	.56	1							
18. Fake words	5.76	3.09	0, 15	.27	.30	.20	.27	.25	.20	.19	.24	.23	.27	.24	.33	.36	.31	.35	.38	.21	1						
19. Letter F	13.91	3.44	6, 26	.19	.08	.11	.25	.23	.19	.25	.42	.23	.25	.33	.20	.26	.24	.13	.31	.36	.35	1					
20. Letter M	13.68	3.69	2, 23	.19	.09	.17	.23	.23	.26	.37	.34	.37	.18	.27	.27	.27	.35	.30	.43	.31	.36	.55	1				
21. Random baby	12.21	4.33	4, 28	.07	.15	.05	.15	.15	.15	.10	.18	.25	.18	.21	.15	.33	.43	.34	.31	.33	.39	.30	.37	1			
22. Random table	12.05	3.60	6, 27	.00	−.01	.06	.14	.19	.15	.12	.15	.37	.28	.14	.20	.29	.42	.39	.35	.31	.29	.37	.38	.67	1		
23. Typing speed	10.95	3.09	2, 22	.01	.00	−.02	.05	.10	−.05	.13.	.08	.11	.18	.18	.05	.04	.16	.14	.28	.25	.01	.25	.06	.09	.23	1	
24. Vocabulary	17.19	5.02	7, 30	.18	.15	.06	.19	−.08	−.19	.25	.34	.19	.14	.11	.03	.07	.15	.00	.35	.14	.19	.35	.35	.12	.11	.21	1

Note. $n = 131$. Descriptions of the verbal fluency tasks (rows 7 through 22) are in Table 1.

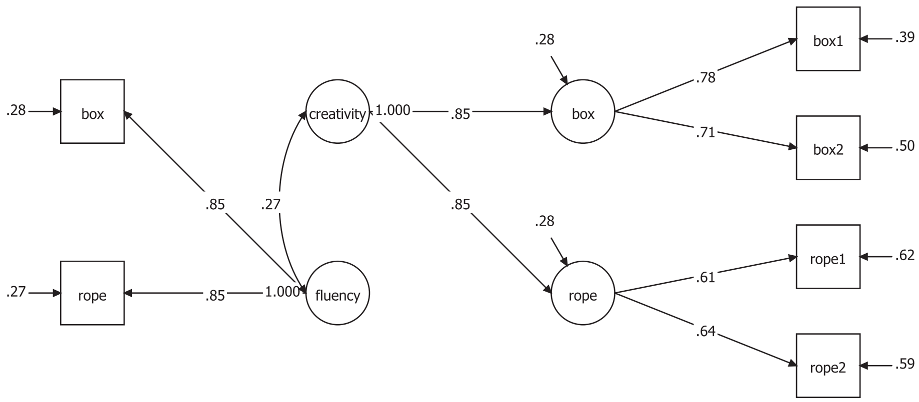

Fig. 1. The divergent thinking measurement model.

The model fit well: χ^2(93 *df*) = 139.23, $p = .0014$; CFI = .929; RMSEA = .062 (90% CI: .039, .082); SRMR = .056.

6.4. Divergent thinking and lower-order factors

How did the lower-order Gr factors predict divergent thinking? Because of the high correlations between the lower-order factors—exceeding .80 in many cases and .90 in one case (see Table 3)—entering all six factors as predictors in a regression analysis would be problematic. We thus conducted six multivariate regression models in which one lower-order Gr factor was the predictor and divergent thinking creativity and fluency scores were the two outcomes. Table 4 displays the effects, *p*-values, and confidence intervals.

For creativity, many of the factors had large or moderate effects. In descending effect size order, creativity was significantly predicted by associational fluency (β = .505), word fluency (β = .463), associative flexibility (β = .390), and

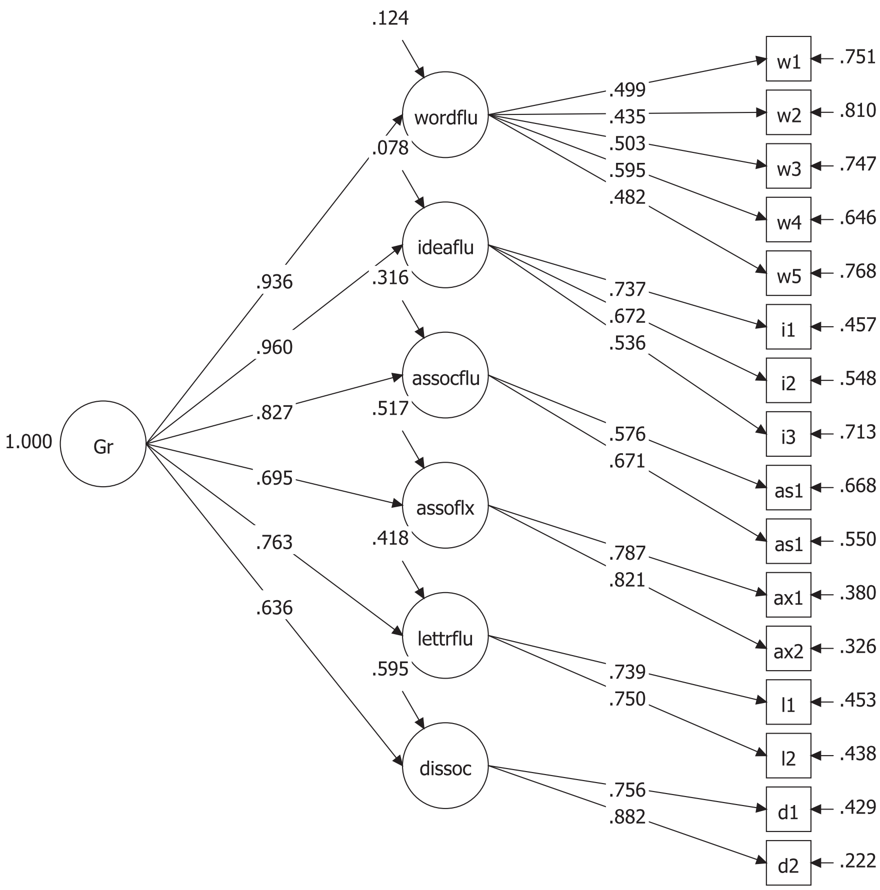

Fig. 2. The higher-order Gr measurement model.

Table 3
The lower-order factors' intercorrelations and loadings on the higher-order Gr factor.

	Word fluency	Associational fluency	Associative flexibility	Ideational fluency	Letter fluency	Dissociative ability	High-order Gr factor loading
Word fluency	1						.94
Associational fluency	.83	1					.83
Associative flexibility	.57	.66	1				.70
Ideational fluency	.92	.78	.69	1			.96
Letter fluency	.82	.54	.41	.71	1		.76
Dissociative ability	.49	.49	.58	.58	.58	1	.64

Table 4
Summary of the effects of Gr factors on divergent thinking creativity and fluency.

	DT creativity			DT fluency		
	β	*p*	95% CI	β	*p*	95% CI
Word fluency	.463	.001	.201, .725	.317	.005	.096, .537
Associational Fluency	.505	.001	.297, .730	.454	.001	.235, .672
Associational flexibility	.390	.001	.178, .602	.325	.001	.142, .509
Ideational fluency	.228	.157	−.088, .544	.284	.011	.066, .503
Letter fluency	.388	.003	.133, .643	.359	.001	.175, .542
Dissociative ability	.138	.275	−.110, .386	.224	.024	.029, .420
Higher-order Gr	.443	.001	.256, .631	.399	.001	.231, .567

Note. Coefficients are standardized regression weights.

letter fluency (β = .388); non-significant effects appeared for ideational fluency (β = .228) and dissociative ability (β = .138). For divergent thinking fluency, significant effects were found for associational fluency (β = .454), letter fluency (β = .359), associative flexibility (β = .325), word fluency (β = .317), ideational fluency (β = .284), and dissociative ability (β = .224).

6.5. Divergent thinking and the higher-order Gr factor

Viewed alone, several lower-order factors predicted creativity. The natural next question is how the general Gr factor predicts the quality and quantity of divergent thinking responses. Our first model of the general Gr factor used a conventional higher-order specification: the six lower-order latent variables were indicators of a higher-order Gr factor, and the path from Gr to Word Fluency was fixed to 1. The model fit well: $\chi^2(102\ df) = 158.33$, $p = .0003$; CFI = .913; RMSEA = .065 (90% CI: .044, .084); SRMR = .062. The factor loadings are shown in Table 3; the model is depicted in Fig. 2. The construct reliability of the higher-order Gr factor was high ($H = .959$), consistent with the high loadings.

How did the higher-order Gr factor predict divergent thinking? We estimated a multivariate structural equation model in which Gr was the sole predictor and divergent thinking creativity and fluency scores were the two outcomes. Gr had statistically significant effects with notable effect sizes for both creativity (β = .443, $p < .001$) and for fluency (β = .399, $p < .001$; see Table 4).

Gr's effects on creativity and fluency were robust when additional predictors were considered. Vocabulary knowledge, for example, was correlated with Gr ($r = .36$, $p < .001$), but the effects of Gr on creativity (β = .414, $p < .001$) and fluency (β = .514, $p < .001$) didn't decline when it was added as a predictor. Vocabulary knowledge had a small effect on creativity (β = .088, $p = .477$) and a moderate (and negative) effect on fluency (β = −.335, $p < .001$).[4]

When a model with age and gender as additional predictors was estimated, Gr's effect on creativity (β = .452, $p < .001$) and fluency (β = .393, $p < .001$) changed only slightly. The effects of age and gender on creativity (age β = .111, gender β = −.162) and fluency (age β = −.100, gender β = −.104) were small in size and not statistically significant.[5]

Similarly, the effects of Gr on creativity and fluency were largely unchanged when typing speed was added. Gr's effect on creativity (β = .473, $p < .001$) and fluency (β = .424, $p < .001$) were slightly higher. Typing speed had small effects on divergent thinking creativity scores (β = −.112, $p = .393$) and fluency scores (β = −.092, $p = .385$).[6]

6.6. Divergent thinking and the bifactor Gr factor

Our second model of the general Gr factor used a bifactor specification. As discussed earlier, a bifactor model allows one to model specific and general effects simultaneously. In the higher-order model, general Gr affects the indicators indirectly via the specific factors. In a bifactor model, the general Gr factor and specific factors each predict the indicators (Chen et al., 2006, 2012; Reise, 2012). The observed task scores are thus modeled as a function of direct contributions from a general factor and from a specific factor, along with residual error. Both the general factor and the specific factors can then serve as predictors.

The final bifactor model of Gr is shown in Fig. 3. We first specified a complete bifactor model that included Gr as the

[4] The negative relationship between vocabulary knowledge and divergent thinking fluency probably stems from instructing people to "be creative" in the divergent thinking tasks. Research shows that telling people to be creative both boosts creative quality and reduces overall output (e.g., Carson & Carson, 1993; Harrington, 1975). Factors such as Gf and Gc, inasmuch as they enable people to enact strategies that favor quality over quantity (Gilhooly et al., 2007), can thus positively predict quality but negatively predict quantity. Regardless, we should emphasize that this negative effect is for divergent thinking fluency (the number of uses for ropes and boxes), not for the Gr verbal fluency tasks. Vocabulary knowledge, as one would expect, correlates positively with nearly all the Gr tasks (see Table 2).

[5] Researchers interested in gender and age effects should keep in mind that age and gender were fairly homogeneous in our sample, which consisted primarily of college-aged women.

[6] For the curious, typing speed had a moderate correlation with the higher-order Gr factor ($r = .29$, $p = .005$) and mostly moderate correlations with the lower-order word fluency ($r = .26$, $p = .020$), associational fluency ($r = .07$, $p = .560$), associative flexibility ($r = .18$, $p = .182$), idea fluency ($r = .32$, $p = .026$), letter fluency ($r = .21$, $p = .007$), and dissociative ability ($r = .23$, $p = .001$) factors.

general factor and the six lower-order factors as specific factors. The path from the general factor to the "five letters" task was fixed to 1. Two of the specific factors—ideational fluency and word fluency—could not be identified in a bifactor model. This isn't surprising for several reasons: these two factors loaded close to 1 with the higher-order Gr factor (see Fig. 2); the two factors had non-significant variances; none of the paths from the specific ideational fluency and word fluency factors were statistically significant; and one of the ideational fluency indicators had a negative variance. These are all typical signs that a specific factor cannot be identified in a bifactor model (Chen et al., 2006). As a result, in our final model word fluency and ideational fluency tasks were absorbed into the general Gr factor. The fit of this final model was good: $\chi^2(100\ df) = 157.02$, $p = .0002$; CFI = .912; RMSEA = .066 (90% CI: .045, .085); SRMR = .059. Our final model—known as an incomplete bifactor model—is analogous to Gustafsson's (2001) analyses of general intelligence. That line of research found that Gf is absorbed into *g* (e.g., Gustafsson & Balke, 1993; Kvist & Gustafsson, 2008), which suggests that Gf is equivalent to *g* (Gustafsson, 1984).

How did the general and specific factors predict divergent thinking? As before, we included creativity and fluency scores from the divergent thinking tasks as outcomes. The five predictors were the general Gr factor and the specific associational fluency, associational flexibility, letter fluency, and dissociative ability factors. Table 5 displays the effect sizes along with their confidence intervals and *p*-values. All told, the bifactor model explained 37.4% of the variance in creativity and 27.9% of the variance in divergent-thinking fluency.[7]

Overall, the model found that the general Gr factor was more important than the specific factors. General Gr significantly predicted both the creativity ($\beta = .380$, $p < .001$) and number ($\beta = .327$, $p < .001$) of responses, and the effect sizes were at least medium in size. Many of the specific factors had notable effect sizes, but none of the effects was statistically significant (see Table 5). As a result, the bifactor model suggests that the individual verbal fluency tasks significantly predicted creativity by virtue of the general Gr factor rather than from variance specific to the lower-order factors.

7. Discussion

7.1. Creativity and the CHC model

The present research explored how divergent thinking fits within the second-level factor of broad retrieval ability (Gr). Divergent thinking tasks involve open-ended idea production, like most verbal fluency tasks, but they are scored for the creativity of the ideas. Because common scoring methods essentially equate idea quality and quantity (Silvia et al., 2008), much research on divergent thinking is largely or solely measuring quantity of idea production. As a result, the relationship between divergent thinking and Gr may have been overestimated in past analyses of the Gr domain.

Using contemporary scoring methods that can distinguish between creative quality and quantity (Silvia et al., 2008; Silvia, Martin, et al., 2009), we examined how six first-level factors and the second-level Gr factor—estimated with both higher-order and bifactor models—predicted divergent thinking. At the first level, many of the six factors significantly predicted creative quality, and all of them predicted quantity. At the second level, consistent with the CHC model's view of creativity as a first-level factor within Gr (Carroll, 1993; McGrew, 2005), we found significant and large effects of Gr on both the creative quality and the quantity of divergent thinking responses. These effects were robust after covarying age, gender, vocabulary ability, and typing speed, and they appeared for both higher-order and bifactor specifications of the general Gr factor.

The present research illustrates the value of using the CHC model of cognitive abilities as a framework for couching the ongoing debate about the relationship between creativity and intelligence. The dominant view in creativity research is that these represent distinct, weakly-related abilities (Kaufman & Plucker, 2011; Kim et al., 2010). A CHC perspective, however, allows a more refined view of what one might mean by "intelligence." A CHC lens on past research on intelligence and creativity reveals that most of it has not measured intelligence in a way that easily corresponds to modern models of cognitive abilities. In Kim's (2005) meta-analysis, for example, the three most common intelligence tests—accounting for over half of all effect sizes—were the California Test of Mental Maturity, the Sequential Tests of Educational Progress, and the Wechsler Intelligence Scale for Children. (If available, the data could probably be reanalyzed using a cross-battery approach; Flanagan, Ortiz, & Alfonso, 2007).

In our past work, we have suggested that a CHC approach provides a conceptual framework for revisiting the debate over whether creativity and intelligence are unrelated. Recent work has shown large effects of Gf on the creativity of divergent thinking responses (Nusbaum & Silvia, 2011) and the creativity of metaphors (Beaty & Silvia, 2013; Silvia & Beaty, 2012). The present work expands this program to include both Gr and many of its lower-level factors. As in our past work, we found substantial relationships between cognitive abilities and creativity, and the effect sizes are large enough that it is hard to sustain the conventional interpretation of creativity and intelligence as unrelated abilities (Kim, 2005).

An important issue for future research is to examine the role of crystallized intelligence (Gc). Few studies have measured creativity and several CHC abilities, but they suggest that Gc has relatively weaker effects than Gf and Gr (Beaty & Silvia, 2013). Consistent with this pattern, the present study found stronger effects for Gr than for vocabulary knowledge, a central indicator of Gc. Studying Gc and creativity is interesting in its own right, but it could also clarify why past work found small relationships between intelligence and creativity. The assessment of intelligence in past research has been heterogeneous: many

[7] As before, controlling for typing speed, vocabulary knowledge, age, and gender did not substantially change the effects. For creativity, the effects were essentially the same, except for a larger effect of associational fluency: general Gr ($\beta = .381$, $p = .007$), associational fluency ($\beta = .473$, $p = .045$), associational flexibility ($\beta = .180$, $p = .268$), letter fluency ($\beta = .176$, $p = .429$), and dissociative ability ($\beta = -.222$, $p = .116$). Likewise, divergent thinking fluency was essentially the same: general Gr ($\beta = .370$, $p < .001$), associational fluency ($\beta = .213$, $p = .364$), associational flexibility ($\beta = .113$, $p = .361$), letter fluency ($\beta = .275$, $p = .026$), and dissociative ability ($\beta = .024$, $p = .848$). The bifactor model with typing speed, vocabulary knowledge, age, and gender explained 54.3% of the variance in creativity and 34.5% of the variance in divergent-thinking fluency.

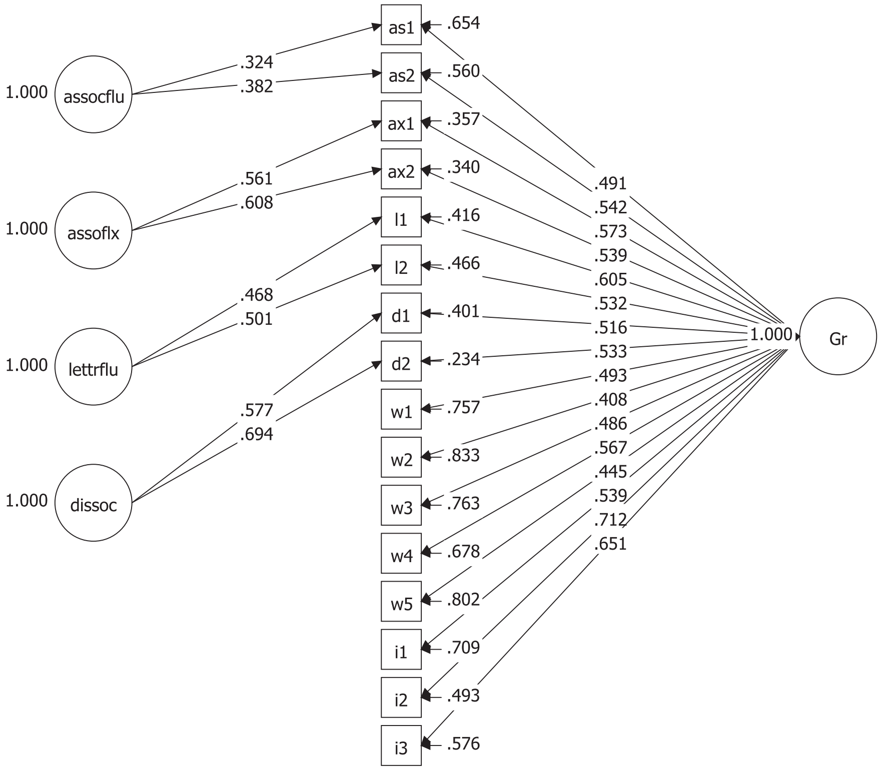

Fig. 3. A bifactor model of the 16 Gr tasks.

studies in Kim's meta-analysis used measures of academic achievement and measures that combine Gf and Gc. As with the assessment of creativity, the assessment of intelligence could explain why past work found relatively small effects.

7.2. Specific and general Gr factors and creativity

The mechanism underling verbal fluency was long attributed to a passive process of spreading activation in semantic memory (e.g., Bousfield & Barclay, 1950; Bousfield & Sedgewick, 1944). While memory research remains grounded in the associative tradition, modern theories of verbal fluency tend to emphasize the importance of controlled processes that guide retrieval in a top-down, strategic manner (Rosen & Engle, 1997; Troyer et al., 1997; Unsworth, Brewer, & Spillers, 2013; Unsworth et al., 2011). The contemporary shift to an executive framework is reflected by the increasing number of studies focusing on the controlled aspects of retrieval ability and divergent thinking (e.g. Benedek, Könen, et al., 2012; Benedek, Franz, et al., 2012; Gilhooly et al., 2007; Nusbaum & Silvia, 2011, Study 1).

Table 5
Summary of the bifactor model effects on divergent thinking creativity and fluency.

	DT creativity			DT fluency		
	β	*p*	95% CI	β	*p*	95% CI
Bifactor Gr	.380	.001	.161, .598	.327	.001	.141, .513
Associational fluency	.324	.106	−.069, .718	.328	.124	−.090, .746
Associational flexibility	.220	.152	−.081, .520	.136	.250	−.095, .367
Letter fluency	.212	.272	−.167, .591	.214	.054	−.003, .432
Dissociative ability	−.177	.219	−.460, .105	−.005	.968	−.235, .226

Note. Coefficients are standardized regression weights.

In the present study, the effects of lower-order Gr variables on the creative quality and fluency of divergent thinking showed wide differences. Regarding creative quality, structural equation models that evaluated the factors separately revealed statistically significant effects of associational fluency, word fluency, associative flexibility, and letter fluency (in descending magnitude). These tasks place greater semantic constraints on the search process (e.g., word fluency; "list words that end with *TION*") compared to simpler tasks that require retrieving instances from broad and familiar categories (e.g., ideational fluency; "list occupations"). Ideational fluency did not predict creativity in our analysis, although like all the verbal fluency tasks, it predicted divergent thinking fluency. Interestingly, a similar pattern of relations between the different fluency tasks and divergent thinking appeared in our past work (Nusbaum & Silvia, 2011, Study 1): two letter fluency tasks had higher relationships with divergent thinking creativity scores than did two ideational fluency tasks. In a similar vein, Gilhooly et al. (2007) found that the frequency of responses identified as novel in a divergent thinking task correlated more strongly with letter fluency than with ideational fluency. It thus appears that the relatively more executively demanding Gr factors were more strongly related to creative quality, which is consistent with the emerging literature on how executive abilities influence creative thought (Beaty & Silvia, 2012, 2013; Benedek, Franz, et al., 2012; Nusbaum & Silvia, 2011; Silvia & Beaty, 2012; Zabelina & Robinson, 2010; Zabelina, Robinson, Council, & Bresin, 2012).

Of the six first-level factors, two were relatively new factors proposed by Benedek, Könen, et al. (2012): associative flexibility (generating a chain of associative links) and dissociative ability (generating a string of unrelated, random words). Our findings for associative flexibility replicated their findings: it was a substantial predictor of both divergent thinking quality and fluency. However, we didn't find a statistically significant effect of dissociative ability on creativity. Similar studies have found mixed results for dissociative ability and divergent thinking (Benedek, Franz, et al., 2012; Benedek, Könen, et al., 2012). Benedek, Könen et al. (2012), for example, reported a large correlation between dissociative ability and divergent thinking ($r = .57$). In a subsequent study (Benedek, Franz, et al., 2012), however, dissociative ability correlated with divergent thinking fluency ($r = .56$) but not with subjective ratings of creativity ($r = .08$). The present research found a similar pattern—higher relationships with fluency than creativity—although the correlation with fluency was appreciably lower than in the studies by Benedek and his colleagues.

One notable difference between the present study and those of Benedek and colleagues is the scoring method of divergent thinking responses. In their initial work (Benedek, Könen, et al., 2012), composite divergent thinking scores were formed by summing the originality scores, rather than averaging, which caused fluency and creativity to be highly correlated. The high correlation between dissociative ability and divergent thinking thus likely reflects the confounding of quantity and quality. When those are separated, as in Benedek, Franz, et al.'s (2012) study and the present study, dissociative ability appears relatively unimportant for generating creative responses. Taken together with the present results, dissociative ability is an interesting trait that appears to predict the quantity but not quality of divergent thinking.

This discussion of the specific Gr factors, however, shouldn't overshadow the role of the general Gr factor in divergent thinking. The specific factors were evaluated separately, so their relationships with each other and with the general Gr factor were not accounted for in those models. We ran two models to illuminate the role of the second-level Gr factor in divergent thinking. There are two traditions for estimating general factors—a higher-order latent variable with the lower-order factors as indicators, and a bifactor model. Both specifications have long traditions, and they offered a different look at how variance common to the verbal fluency tasks influences divergent thinking.

The higher-order model found statistically significant and medium-to-large effects of Gr on both the creativity and quantity of divergent thinking responses. The bifactor model was consistent with the higher-order model but extended it in some interesting ways. First, two of the lower-order factors—ideational fluency and word fluency—were absorbed into the general Gr factor. This finding alone is noteworthy for researchers interested in verbal fluency. These tasks are among the most widely used verbal fluency tasks and emerged among the highest loading factors in Carroll's (1993) analysis, so it isn't surprising that they were not identified as unique specific factors. Just as Gf is often absorbed into *g* (Gustafsson, 1984, 2001), suggesting that Gf tasks essentially capture variance due to g rather than variance specific to Gf, it appears that word fluency and ideational fluency may essentially be markers of Gr.

Second, the bifactor model suggested that the general Gr factor was more important than the specific factors for creativity. The general factor significantly predicted both the creativity and quantity of divergent thinking responses, and its effect sizes were medium in size. The specific factors, however, did not significantly predict either creativity or quantity. The effect sizes for the specific factors varied substantially, and some were notable in size, but none of them was significant. The bifactor model thus offers a different perspective on how the verbal fluency tasks influence creativity. Viewed singly, the lower-order factors have different effects on creativity, but when the contribution of the general factor is modeled, divergent thinking is largely due to general Gr.

8. Conclusion

The present research examined the role of the CHC Gr factor in divergent thinking. Because past assessment methods have confounded creative quality and quantity—or assessed only quantity—the role of Gr in divergent thinking may have been exaggerated. When new assessment and scoring methods are used—ones that emphasize to participants that they should try to be creative and that use subjective scoring to dissociate creativity and fluency—a significant role for the second-level Gr factor appears for both the creative quality and the amount of ideas. Taken together, the findings extend the emerging CHC approach to creative abilities (Nusbaum & Silvia, 2011; Silvia & Beaty, 2012) and further suggest that intelligence and creativity are more closely linked than creativity theories acknowledge.

Appendix A. Supplementary data

Supplementary data to this article can be found online at http://dx.doi.org/10.1016/j.intell.2013.05.004.

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