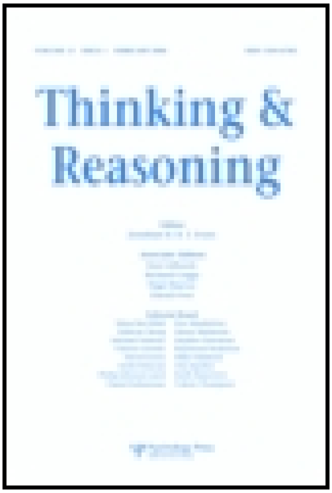

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Convergent and divergent thinking in verbal analogy

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Convergent and divergent thinking in verbal analogy

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Individual differences in convergent and divergent thinking may uniquely explain variation in analogical reasoning ability. Across two studies we investigated the relative influences of divergent and convergent thinking as predictors of verbal analogy performance. Performance on both convergent thinking (i.e., Remote Associates Test) and divergent thinking (i.e., Alternative Uses Task) uniquely predicted performance on both analogy selection (Studies 1 and 2) and analogical generation tasks (Study 2). Moreover, convergent and divergent thinking were predictive above and beyond creative behaviours in Study 1 and a composite measure of crystallised intelligence in Study 2. Verbal analogies in Study 2 also varied in semantic distance, with results demonstrating divergent thinking as a stronger predictor of analogy generation for semantically far than for semantically near analogies. Results thus further illuminate the link between analogical reasoning and creative cognition by demonstrating convergent and divergent thinking as predictors of verbal analogy.

Keywords: Analogy; Convergent thinking; Divergent thinking; Creative cognition.

Analogical reasoning is the identification of a relation between two concepts that also holds between two other concepts (A:B::C:D; e.g., sparrow:bird:: hammer:tool) and is crucial for creative endeavours in business, education, engineering, and science (Dahl & Moreau, 2002; Dunbar, 2001; Gentner et al., 1997; Hey, Linsey, Agogino, & Wood, 2008; Kolodner, 1997; Schunn, Paulus, Cagan, & Wood, 2006; Thompson, Gentner, & Loewenstein, 2000). For instance, successful design and innovation as well as successful bargaining

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in managerial fields frequently entails analogical reasoning in the form of applying features from one domain or product to another (Christensen & Schunn, 2007; Hey et al., 2008; Johnson-Laird, 1989; Thompson et al., 2000). The purpose of our study was to investigate the extent to which creativity, with a focus on convergent and divergent thinking, predicted verbal analogy. Whereas convergent thinking tasks generally entail a narrowing of possible solutions to one optimal answer, divergent tasks are focused on generating several possible "imaginative" answers (Gilhooly, Fioratou, Anthony, & Wynn, 2007; Guilford, 1967; Smith & Ward, 2012). We hypothesised that both types of thinking are important for analogical reasoning, and individual differences in them may uniquely explain some variation in analogical reasoning ability.

ANALOGY, CREATIVITY, AND INTELLIGENCE

Prior studies have investigated individuals' expertise (Ball, Ormerod, & Morley, 2004; Bearman, Ball, & Ormerod, 2007) and creativity (Corkill & Fager, 1995) as predictors of spontaneous transfer in analogical problem-solving and design. In the current study, we instead used verbal analogies as the criterion measure in part based on the ease in measuring and controlling other factors related to the overall difficulty of the analogies, such as distractor salience (i.e., extent to which the incorrect answer options are related to the C term), and the semantic distance between the terms within the analogy (Green, Kraemer, Fugelsang, Gray, & Dunbar, 2010, 2012; Thibaut, French, & Vezneva, 2010; Vendetti, Wu, & Holyoak, 2014).

Verbal analogy selection tasks typically require selecting one or more terms to complete a given analogy stem. In this study, participants were given the first three terms (A:B::C:__) and had to select the correct answer from among four or five choices (e.g., PLATINUM:NECKLACE::GOLD:________; earring, silver, rich, diamond, metal). Completion of verbal analogies entails five component processes (Sternberg, 1977; Sternberg & Nigro, 1980): (1) Encoding of the analogical terms; (2) inference of the relation between the first two terms (source pair; e.g., a NECKLACE *made of* PLATINUM); (3) mapping between corresponding elements between the first (source) pair and second (target) pair (e.g., PLATINUM and GOLD are precious metals; NECKLACE and EARRING are jewellery); (4) application of the inferred relation (the compositional relation is applied to the target pair, i.e., an EARRING *made of* GOLD); and (5) selection of the correct response (e.g., EARRING) in the presence of semantically closer incorrect choices (e.g., SILVER).

In contrast to the selection of the relationally consistent D term, analogical generation tasks require participants to provide rather than to choose a solution that is structurally consistent with the source analogue (the A:B pair). Though analogical selection tasks are more widely used as a measure of reasoning aptitude in standardised tests such as the Miller Analogies Test and Air Force Officer Qualifying Test, analogical generation tasks are more likely to reflect the type of reasoning involved in more natural settings such as laboratory meetings (e.g., Blanchette & Dunbar, 2000; Dunbar, 2001; Dunbar & Blanchette, 2001; Gentner et al., 1997; Kolodner, 1997; Schunn & Dunbar, 1996; Schunn et al., 2006). Moreover, analogical generation tasks may be particularly related to creativity (Finke, Ward, & Smith, 1992; Vendetti et al., 2014). Hence, we investigated the extent to which convergent and divergent thinking predicted performance in an analogical selection task (Studies 1 and 2) as well as in an analogical generation task (Study 2).

Creativity is a multidimensional construct that encompasses aspects of the person (e.g., traits, behaviours), cognitive processes, and the novelty and usefulness of a final product (Batey, 2012; Caroff & Besançon, 2008; Simonton, 2000; Smith & Ward, 2012). Batey (2012) nicely conceptualised the multidimensional aspect of creativity as a $4 \times 4 \times 3$ heuristic framework consisting of levels (individual, team, organisation, culture), facets (trait, process, press, product), and measurement approaches (objective, self-rating, and other-ratings). Across two studies, we focused on convergent and divergent thinking (at the individual level) as predictors of analogical reasoning—namely, the convergent Remote Associates Test (RAT), and the number of responses generated (fluency) on an Alternative Uses Task (AUT). As detailed further in the next section, the creative cognition approach (Finke et al., 1992; Smith & Ward, 2012; Ward, Smith, & Finke, 1999) posits that some of the same underlying cognitive processes involved in convergent and divergent thinking are important in other areas of cognition such as analogical reasoning. Thus, focusing on these objectively measured cognitive processes of creativity is advantageous given the extensive variability of other raters' creativity judgements, produced by raters' different reliance on various aspects of creativity, characteristics of the raters, and/or different instructions given to the raters (Caroff & Besançon, 2008). Also, in comparison to self-ratings of creativity and creative behaviours, convergent and divergent thinking are more predictive of cognitive processes such as relational reasoning (Batey, Furnham, & Safiullina, 2010; Froehlich & Hoegl, 2012). Moreover, creative behaviours such as writing a short story or producing your own website also are related to divergent thinking and potentially also to relational reasoning (Batey et al., 2010). Thus, in Study 1, we included the *Biographical Inventory of Creative Behaviours* (BICB; Batey, 2007; Batey et al., 2010) to assess whether convergent and divergent thinking predicted verbal analogy performance above and beyond these self-rated behavioural aspects of creativity.

Creativity is also related to intelligence (e.g., Batey et al., 2010; Silvia, 2008). Indeed, innovation requires intelligence to transform a creative idea into a creative achievement (Jauk, Benedek, & Neubauer, 2014; Squalli &

Wilson, 2014). Intelligence is generally conceptualised via two distinct factors of fluid intelligence (Gf), which is essentially the ability to reason logically and solve problems, and crystallised intelligence (Gc), which is essentially one's general world knowledge (Horn & Cattell, 1966). In two direct tests of whether Gf and/or Gc predicted divergent thinking, Batey and colleagues found in one study that both Gf and Gc predicted divergent thinking (Batey et al., 2010), whereas in another study they found that Gc predicted divergent thinking but Gf did not (Batey, Chamorro-Premuzic, & Furnham, 2009). Chermahini and Hommel (2010) also found no relation between Gf and divergent thinking. Yet, others have found robust relationships between creativity and Gf (Benedek, Jauk, Sommer, Arendasy, & Neubauer, 2014; Jauk, Benedek, Dunst, & Neubauer, 2013; Nusbaum & Silvia, 2011). Given that Gc appears to be more reliably related to divergent thinking than is Gf, in Study 2 we assessed whether convergent and divergent thinking predicted verbal analogy performance above and beyond Gc.

CONVERGENT AND DIVERGENT THINKING IN VERBAL ANALOGY

Measures of convergent and divergent thinking

Across several recent studies, convergent and divergent thinking have been measured respectively via the RAT and AUT (e.g., Chermahini & Hommel, 2010, 2012; Dewhurst, Thorley, Hammond, & Ormerod, 2011; Lee & Therriault, 2013). In a remote associates task (RAT; Mednick, 1962), participants must generate an associate that can be related to or combined with each of three seemingly disparate items (e.g., SAME/TENNIS/HEAD; solution = MATCH). The compound RAT (Bowden & Jung-Beeman, 2003) consists of items in which the solution is related by the formation of a compound or two-word phrase with each word in the triad (LIGHT/BIRTHDAY/STICK; solution = CANDLE) and has frequently been used as a measure of convergent thinking in problem-solving studies (e.g., Jarosz, Colflesh, & Wiley, 2012).[1] In the alternative uses test (AUT; a.k.a. Unusual Uses Test), participants are typically given 2 or 3 minutes to generate novel uses for common objects such as a brick (Benedek, Muhlmann, Jauk, & Neubauer, 2013; Guilford, 1967; Jauk et al., 2013; Silvia, 2008, 2011; Smith & Ward, 2012). Though responses may be rated for creativity or uniqueness, perhaps the most common scoring method used in prior studies of divergent thinking and

[1] The compound RAT could be and has been used as a measure of insight problem-solving (e.g., Jung-Beeman et al., 2004) given the sudden rather than gradual nature of deriving the solution. Yet it is also appropriate to classify it as a convergent creativity task because each item has one correct answer.

relational reasoning was to assess fluency, which reflects the number of alternative uses generated. Indeed, Batey et al. (2010) found that the simpler measure of fluency correlated very strongly with the rated creativity of those generated uses ($r = +.79$). However, correlations between fluency and creativity were much weaker in other studies (e.g., $r = .27$, Silvia, Beaty, & Nusbaum, 2013; $r < .14$, Nusbaum & Silvia, 2011) and near zero or negative in studies considering each participant's top two most creative responses (Benedek et al., 2013; Silvia et al., 2008). We therefore use divergent fluency as our divergent thinking measure in both studies, but additionally use a more subjective "snapshot scoring" measure of overall creativity in Study 2.

Common underlying processes

Both the RAT and verbal analogy entail activation of the superior temporal gyrus, which is associated with the relational integration of verbal material such as in sentence or story comprehension and insight problems (Green et al., 2010, 2012; Jung-Beeman et al., 2004). In verbal analogy, relational integration entails the retrieval and maintenance of an analogical relation between the first pair of words and the subsequent transfer of that relation onto the second pair (Bunge, Wendelken, Badre, & Wagner, 2005). Likewise the RAT also entails retrieval and maintenance of relations—in this case three separate relations, one for each of the words in a given triad (CREAM/SKATE/WATER) with the solution (ICE). Moreover, both the RAT and verbal analogy require interference control or the inhibition of initial possible responses. For example, for the triad APPLE/HOUSE/FAMILY, initial responses such as GREEN may be related to only one or two of the words in the triad (e.g., green house; green apple) rather than to all three words as with the solution TREE (Smith & Ward, 2012). Likewise, for verbal analogies, possible responses (e.g., SILVER) may be associated with or similar to one of the terms in the analogy stem (typically the C term; e.g., GOLD) but may lack the same relation with that term as that of the source pair (e.g., necklace *made of* platinum). Thus, better performance on the RAT should be related to better verbal analogy performance. Recent studies have indeed shown convergent thinking (measured using a RAT) to be reliably related to accuracy on the non-verbal Raven's Advanced Progressive Matrices (RAPM; $r = .47$, Chermahini, Hickendorff, & Hommel, 2012; $r = .37$, Chermahini & Hommel, 2010; $r = .32$, Lee & Therriault, 2013).

Results are more mixed, however, for the relationship between divergent thinking (at least as measured by AUT-Fluency) and relational reasoning. AUT-Fluency and RAPM were positively related in some studies ($r = .27$, Batey et al., 2010), but not others ($r = -.14$, Chermahini et al., 2012; $r = -.21$, Chermahini & Hommel, 2010; $r = -.002$, Nusbaum & Silvia, 2011). Notably, the relational reasoning tasks in most of these studies were non-verbal tasks such as the RAPM or number series. Verbal analogy and divergent thinking both require a broadening of conceptual scope, in that they entail the retrieval or generation of responses that are in domains distant from the given concept or beyond the typical use for the object. For instance, in a given analogy stem (e.g., LEATHER:SADDLE::GOLD:______) the missing term (e.g., EARRING) may belong to a conceptually distant category from the analogous term in the base pair (i.e., the B term, SADDLE). Likewise, in an AUT, participants are encouraged to think of the target object in novel and conceptually distant ways from its typical use. Stated conversely, individuals who exhibit a narrow conceptual scope are unlikely to excel at either verbal analogy or divergent thinking.

In sum, verbal analogy likely entails both divergent and convergent processes—an initial generation or retrieval of possible responses for the missing term upon presentation of the analogy stem followed by selection of one of the presented or generated responses that meets the relational constraint of the analogy (i.e., produces the same relation in the C:D pair as in the A:B pair). Given the distinction between convergent and divergent thinking (Guilford, 1967), these underlying factors are likely to account for unique proportions of variance in analogical reasoning. Indeed, prior studies have found no reliable relationship between the convergent RAT and the divergent AUT (e.g., $r = -.07$, Chermahini et al., 2012; $r = -.04$, Chermahini & Hommel, 2010; $r = .02$, Dewhurst et al., 2011; $r = .06$, Lee & Therriault, 2013). Notably, prior studies used either a non-verbal relational reasoning task like the RAPM or an analogical problem-solving task; none has used a verbal analogy task. Moreover, with the exception of Corkill and Fager (1995), prior studies required only selecting rather than generating a correct response. Thus, in addition to our use of a verbal analogy task rather than the non-verbal RAPM, a novel aspect of our study is the inclusion of an analogy selection task in Studies 1 and 2 as well as a generation task in Study 2.

STUDY 1

Study 1 provided a first test of whether convergent and divergent thinking are related to analogy skill. Convergent and divergent thinking were assessed via the RAT and AUT, respectively, and analogy skill was assessed via a multiple-choice analogical selection task. For comparison, Study 1 additionally tested whether analogy skill is related to everyday creative behaviour (e.g., writing a short story or producing a short film), as measured by the BICB. We hypothesised that higher analogy accuracies would be predicted by creative cognition (higher scores on the RAT and AUT) but not by creative behaviour (BICB; cf Batey et al., 2010).

Method

Participants. University of Warwick undergraduates participated voluntarily as part of a class demonstration ($N = 155$; 125 females and 30 males; age $M = 19$ years, SD = 2). Most were native English speakers (82%), and all non-native speakers exhibited a high degree of English language proficiency (IELTS score > 7.0, or TOEFL score > 100). The pattern of statistically significant results was identical regardless of whether the non-native speakers were included or excluded, so for completeness they are included in all results reported below.

Measures. The verbal analogy selection task consisted of 20 items, with three of the four concepts presented in the analogy stem (e.g., ARRIVAL: DEPARTURE::________:DEATH). Participants were instructed to choose the correct item (e.g., BIRTH) from among four answer options (A, B, C, and D), and to write the letter corresponding to their answer on a response sheet that had 20 numbered blanks. Items were sampled from the McGraw-Hill Higher Education website (Verbal Analogies Exercise 1), which provides student resources for verbal analogy training. See Appendix A for stimuli.

The BICB consisted of 34 items, each describing a creative behaviour (e.g., "drawn a cartoon", "composed a poem"). Participants were instructed to "place a cross next to the activities you have been actively involved in during the past *12 months*." Participants responded by marking on a response sheet with numbered blanks any of the activities in which they had been involved, and scores were calculated as the sum of those activities (Batey, 2007).

The RAT consisted of 20 items sampled from Bowden and Jung-Beeman (2003) varying in difficulty as assessed by the per cent of participants in their sample who could solve the item within 7 seconds (for these 20 items: $M =$ 59.65%, SD = 12.10%; range: 42%–84%). Participants were instructed to "generate a fourth word that, when combined with each of the three given words, would result in common compound words or phrases." After three practice trials, participants completed 20 experimental trials by writing their answers on a response sheet that had 20 numbered blanks.

The AUT consisted of two items: A wooden pencil and a wire coat hanger. Participants were instructed "On each trial, you will have 2 minutes to list as many uses as possible for each given object. For example, you might be asked to list as many uses as possible for a candle. Please number each different use for the object so that we can tell them apart clearly," and they wrote their responses on a response sheet that included separate blank spaces for each of the two items. Scores were the sum of each participant's listed uses, combined across both items (Batey et al., 2010; Hocevar, 1979).

Procedures

The study was presented via PowerPoint slides projected onto a large screen at the front of a lecture theatre. Participants first completed the analogy task, in which each analogy was presented on a separate slide, and each slide advanced automatically after 5 seconds. Exactly one week later the same students completed the BICB, RAT, and AUT (in that order) in the same lecture theatre.

The BICB was presented across two slides, with each item presented one at a time. The RAT and AUT were administered approximately 30 minutes later. Each RAT trial was presented on a separate slide that advanced automatically after 10 seconds. Participants then completed the AUT, in which they were given 2 minutes for each item (e.g., Batey et al., 2009).

Results and discussion

Descriptive statistics and inter-correlations for the four measures are shown in Table 1. The RAT and AUT correlated significantly, but more critically for the present purposes, both of those measures correlated significantly with analogy performance (see Table 1 for statistics). The more remote associates and alternative uses a participant identified, the more verbal analogies he or she solved correctly. Interestingly, BICB scores correlated significantly with AUT scores but not with RAT scores. This relationship between creative behaviour (BICB) and divergent thinking (AUT) corroborates prior research (Batey et al., 2010), whereas the lack of relationship between creative behaviour (BICB) and convergent thinking (RAT) is novel.

TABLE 1
Study 1, descriptive statistics and correlations for all measures

	1.	*2.*	*3.*	*4.*
1. Analogy accuracy (proportion correct)	–			
2. RAT (proportion correct)	.32**	–		
3. AUT-Fluency	.25**	.25**	–	
4. BICB	.03	.01	.22**	–
Mean	.56	.49	14.40	9.62
SD	.14	.19	4.74	4.35
Minimum	.15	.00	4.00	.00
Maximum	.90	.95	29.00	24.00
Skewness	−.24	−.34	.34	.46
Kurtosis	.12	−.34	.20	.33

**$p < .01$; *$p < .05$.

Importantly, BICB scores did not predict analogy performance: Creative achievements, such as writing poems and inventing recipes, were unrelated to analogy skill. Thus, as expected, analogy skill was related to creative cognition but not creative behaviour.

To examine the relative and unique contributions of RAT and AUT performance, we entered both simultaneously as predictors of analogy performance. The overall model was significant, $R^2 = .13$, $F(2, 152) = 11.97$, $p < .001$, with both RAT scores ($\beta = .28$, $t = 3.58$, $p < .001$) and AUT scores ($\beta = .18$, $t = 2.34$, $p < .05$) explaining significant amounts of unique variance in analogy skill. Although analogy skill was better predicted by RAT scores than by AUT scores, the difference in slopes failed to approach significance ($p = .44$). In sum, Study 1 provided initial evidence that both convergent and divergent thinking contribute uniquely to analogy skill.

STUDY 2

Study 2 extended Study 1 in four ways: (1) Assessing the impact of creativity above and beyond crystallised intelligence (Gc), (2) adding a more subjective measure of response creativity in the AUT, (3) investigating the effects of creativity in an analogical generation task as well as analogical selection task, and (4) examining the relation between creativity and analogy skill using analogies varying in semantic distance.

Crystallised intelligence (Gc) is related to divergent thinking (Batey, et al., 2009, 2010; Benedek et al., 2014; Chermahini & Hommel, 2010; Jauk et al., 2013). Particularly relevant to our study, verbal analogy is also related to crystallised intelligence measures of general knowledge (e.g., Unsworth, 2010, $r = .40$) and verbal aptitude including vocabulary—both current vocabulary (Unsworth, 2010, $r = .31$), and vocabulary at age 54 months (Richland & Burchinal, 2013, $r = .46$). Thus, Study 2 additionally included measures of crystallised intelligence—a vocabulary task and a general knowledge test—in order to assess whether convergent and divergent thinking influenced verbal analogy reasoning above and beyond crystallised intelligence.

Importantly, the strength of the correlation between Gc and creativity is lower for fluency measures of divergent thinking in comparison to originality or creativity measures (Jauk et al., 2013; Silvia et al., 2013). So we added an additional more subjective measure to the AUT that assessed the creativity of the overall set of responses. We also included the AUT-Creativity measure to determine if the previously mentioned discrepant findings for a relationship between fluency and creativity in the AUT would in turn lead to different results for fluency versus creativity as predictors of verbal analogy. The fluency of responses reflects not only the creativity in an AUT but also a broad retrieval ability (Gr; Silvia et al., 2013) that is found in other verbal fluency tasks such as word fluency (e.g., list words that end with TION) and letter fluency (e.g., list words that start with M). Thus, AUT-Creativity measures may produce purer and hence stronger effects than fluency in predicting verbal analogy performance. Indeed, performance on the RAPM, which is a purely non-verbal task, was more strongly related to AUT-Creativity than to AUT-Fluency (Nusbaum & Silvia, 2011, Table 1).

Semantic distance, or the similarity between the source and target domains, may also influence the extent to which creativity predicts verbal analogy performance, with semantically distant analogies potentially requiring more divergent thinking due to their "less obvious" and consequently "more novel" mappings (Green et al., 2012, p. 265; see also Vendetti et al., 2014). Moreover, the type of task may also influence the extent to which convergent and divergent thinking are related to analogy. Vendetti and colleagues (2014) found that participants generated more relational responses in a picture-mapping analogy task after first completing a verbal analogical generation task consisting of semantically distant or "far" rather than near analogies. However, the effect did not transfer following a validity judgement task in which participants judged whether the first and second pairs in the analogy shared the same relation. Accordingly, in Study 2 we also systematically varied semantic distance and included an analogical generation task in order to investigate the robustness of the effects across both types of analogy tasks (see also Blanchette & Dunbar, 2000).

Method

Participants. Wayne State University undergraduates ($N = 182$; 132 females and 50 males) participated for partial course credit towards their psychology course. Participants were native or fluent speakers of English and ranged in age from 18 to 55 ($M = 21.70$, SD = 5.43).

Analogy selection task. This task included 18 items, half of which were semantically distant and half of which were semantically near. For each different domain analogy, a same domain analogy was created by changing the A:B pair of the different analogy to reflect the same domain as the C:D pair (see Appendix B). Thus, the C term and five answer choices were identical for the same and different domain analogies. Latent semantic analysis (LSA; Landauer, Foltz, & Laham, 1998) cosines, which are based on textual co-occurrence, were used as a measure of semantic distance with higher LSA cosines indicating a nearer semantic distance. Independent-samples t-test results confirmed a nearer semantic distance between the A:B and C:D pairs for the same domain (M = .47, SD = .17) than for the different domain (M = .11, SD = .05) analogies, $t(34) = 8.49$, $p < .001$. Likewise, semantic distance was also nearer for the same domain than the different domain analogies between the A and C terms (same: $M = .37$, SD = .17; different: $M = .10$, SD = .07), $t(34) = 6.02$, $p < .001$, and between the B and D terms (same: $M = .32$, SD = .22; different: $M = .08$, SD = .09), $t(34) = 4.08$, $p < .001$. The association between the C and D terms can also facilitate analogy performance (Thibaut et al., 2010), so we also used LSA to assess the semantic distance between the C term with each answer option (D terms). LSA cosines between the C term and the correct D term ($M = .31$, SD = .21) were slightly but not reliably less than that between the C term and the average of all four distractor D terms ($M = .39$, SD = .19), $t(88) = 1.14$, $p = .16$. However, for nearly all the analogies, at least two of the distractors were much more strongly related to the C term in comparison to the correct answer. In comparison to the correct D term, the LSA cosines for the two closest distractors on each item were far greater (reflecting greater association) for the average of each item's two most semantically similar distractors ($M = .51$, SD = .17), $t(52) = 3.62$, $p = .001$.

The analogy selection task was run on computers using DirectRT software. Participants were told that response times (RTs) would be recorded and thus they should answer each item as quickly as possible without sacrificing accuracy. As in Jones (2011), each trial began with presentation of the three-term analogy stem in ALL CAPS for 750 ms, which remained centred on the screen during presentation of the answer choices. Numbered answer choices were centred below the analogy stem with each choice presented on a separate line for 500 ms prior to presentation of the next choice. This was done to increase the likelihood that participants would read each answer choice prior to selecting a response. After presentation of the fifth choice, participants were prompted to "Enter the number of your answer." RTs were recorded from this point until an answer was provided. Presentation order of the 18 items was randomised across participants, but the order of answer options was consistent across all participants.

Analogy generation task. This task included 40 items sampled from Bunge et al. (2005), 20 of which were semantically distant and 20 of which were semantically near (see Appendix C). LSA cosines were again used to measure semantic distance between the pairs, with higher LSA cosines indicating a nearer semantic distance. Although participants could and did generate a relationally consistent response that did not match the exact D term of Bunge et al.'s completed analogy stem, 71% of relationally consistent responses were identical to the anticipated D term. Most other responses were very similar to their D term (e.g., for the analogy BUTCHER:MEAT::BAKER:______, several participants responded with "cake" rather than "bread"). LSA cosines were again used as the measure of semantic distance between the A:B and C:D pairs of the complete analogy stem as well as between the corresponding terms from each pair. Independent-samples *t*-test results confirmed a nearer semantic distance between the pairs of the same domain (M = .51, SD = .10) than the different domain (M = .09, SD = .04) analogies, $t(38) = 17.84$, $p < .001$. Likewise, semantic distance was also nearer for the near than for the far analogies between the A and C terms (near: M = .40, SD = .17; far: M = .07, SD = .06), $t(38) = 8.00$, $p < .001$, and between the B and D terms (near: M = .42, SD = .12; far: M = .09, SD = .09), $t(38) = 11.28$, $p < .001$. Because stronger association strengths between the A and B terms as well as between the C and D terms also facilitate ease of solving an analogy (Thibaut et al., 2010), we equated the near and far analogies on the semantic distance between these terms. LSA cosines between the A and B terms for the near analogies (M = .46, SD = .18) did not differ from those for the far analogies (M = .47, SD = .22), p = .96. Likewise, the semantic distance between the C and D terms was nearly identical for the near (M = .43, SD = .17) and far (M = .43, SD = .26) analogies, p = .98.

The analogy generation task was run on computers using DirectRT software. Participants were told that RTs would be recorded and thus they should answer each item as quickly as possible without sacrificing accuracy. Each trial began with a fixation "+" for 250 ms followed by presentation of the three-term analogy stem centred on the computer screen in lower-case font (e.g., scarf:neck::belt:_____). Once participants had thought of their response, they pressed the space bar. Upon pressing the space bar, they typed their response into a textbox. The time between the onset of the analogy stem and pressing of the space bar served as the RT measure. Presentation order of the 40 items was randomised across participants. Both the analogy generation RT and the proportion of relationally consistent responses (i.e., D term responses such that the resulting C:D pair shared the same analogical relation as the A:B pair) served as the dependent measures.

Convergent thinking—RAT. The RAT consisted of 25 items sampled from Bowden and Jung-Beeman (2003) varying in difficulty as assessed by the per cent of participants in their sample who could solve the item within 15 seconds (for these 25 items: M = 51.56%, SD = 23.08%; range: 12%–92%).[2] Participants were first given a practice problem (COTTAGE/CREAM/CAKE; solution = CHEESE) with feedback regarding the correct answer to ensure that

[2] The items in Study 1 were selected on the basis of accuracy at 7 seconds (Bowden & Jung-Beeman, 2003) because in that study participants were given only 10 seconds to respond. The items in Study 2 instead were selected on the basis of accuracy at 15 seconds because in this study participants were given 15 seconds to respond. In terms of the 7-second metric reported in Study 1, the selected 25 items used in Study 2 were more difficult and variable (M = 40.76%, SD = 21.23%) in order to produce greater variability in our Study 2 participants' performance. As noted by the *M*s and SDs in Tables 1 and 2, though the mean proportion correct for the RAT was lower in Study 2 than in Study 1, the standard deviations were nearly equivalent.

they fully understood the task. They were instructed that the items were arranged in order of difficulty from easy to most difficult, but that they could complete the items in any order. They were given up to 6 minutes and 25 seconds (based on 15 seconds for each of the 25 items) to complete the RAT by writing the answer in the blank next to each triad. Prior to starting, they were further informed that the goal was to answer as many items as possible and not to spend too long on any one item. Proportion correct served as the score on this measure.

Divergent thinking—AUT. Participants wrote down alternative uses for a brick and a wooden pencil. Instructions are shown below:

> Produce as many different uses as you can think of, which are different from the normal use. For example, the common use for a newspaper is for reading, but it could also be used for swatting flies, to line drawers, to make a paper hat and so on. You will have **2 minutes** on each object. Its common use will be stated but you are to try to produce possible uses that are different from the normal one and different in kind from each other.

Duplicated responses and responses consisting of common uses for each object (e.g., "building a house" or "fireplace" for BRICK) were crossed off and not included in the fluency measure. In a few cases, there were some responses reflecting the same general novel use of the object. For instance, one participant listed four nearly identical responses for PENCIL ("eye test," "check for cross eye," "check for eye movement," and "check for eye restriction"). Another participant, for BRICK, had included both "to get someone's attention by throwing it at them" and "to get a girl's attention by throwing it at her." In these and other such cases, only one of the nearly identical responses was considered to be a unique response and included in the fluency score.

In addition to the fluency measure (i.e., number of items produced) used in Study 1, we included a more subjective "snapshot scoring" measure of creativity (Silvia, 2011; Silvia, Martin, & Nusbaum, 2009; Silvia et al., 2013). For this "AUT-Creativity" measure, we followed the procedures described in Silvia et al. (2013). Two research assistants independently rated the overall set of responses for the brick and the pencil on a scale from 1 (not at all creative) to 5 (very creative) with the instruction 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). Raters were unaware of each other's scores as well as all information about the participants. They were additionally instructed not to base their judgements on the number of items generated by each participant. Inter-rater reliabilities for the AUT were intraclass correlation coefficient (ICC) = .70 for the pencil and ICC = .62 for the brick. The correlation of $r = .57$ between fluency and creativity was consistent with that of prior studies using subjective scoring (i.e., Silvia et al., 2008) though higher than that found in more recent studies (Silvia et al., 2013).

Crystallised intelligence measures. A composite score for crystallised intelligence (henceforth, Gc) was created by averaging the z-transformed proportion correct for each of the following two measures. As can be seen in Table 2, the correlation between these measures was moderately high.

Vocabulary. For each of the 40 target words on the Shipley vocabulary measure (Shipley, 1940), which were shown in ALL CAPS (e.g., MASSIVE), participants circled the answer choice that had the most similar meaning to the target word (e.g., bright, large, speedy, low).

General knowledge. The general knowledge test was adapted from that used in Unsworth (2010) and included 24 multiple-choice questions on literature, science, history, government, geography, and the arts with four answer choices per item.

Procedures. Participants first completed the analogy selection task followed by the Shipley vocabulary measure, AUT, analogy generation task, RAT, then the general knowledge test.[3]

Results and discussion

As in Study 1, the primary question of interest was whether both divergent and convergent creativity predicted verbal analogy performance. With the computerised analogy task in Study 2, we were also able to test RTs in addition to accuracies. Moreover, we assessed whether each type of creativity predicted analogy performance above and beyond crystallised intelligence.

[3] A potential methodological concern with Study 1 is the order in which participants completed the various measures. For instance, in Study 1, participants completed the RAT before the AUT. This is potentially important because the RAT and AUT have differing effects on mood—the RAT decreases mood, whereas the AUT increases mood (Chermahini & Hommel, 2012)—and mood has wide-ranging effects on behaviour. Thus, in Study 1, participants' completion of the RAT may have affected their subsequent performance on the AUT, which in turn could have implications for the reliability of the AUT scores and their ability to predict analogy performance. Study 2 therefore addressed this concern by reversing the order of the two measures, so that participants in Study 2 completed the AUT before the RAT. If the same general pattern of results is observed in both studies, then evidently the order of the measures did not have a substantial effect in this case. Indeed, as reported next, the same significant relationships among RAT, AUT, and analogy performance were observed in both studies, thereby indicating that the observed results were not substantially affected by the order of the tasks.

TABLE 2
Study 2, descriptive statistics and correlations for all measures

		1.	*2.*	*3.*	*4.*	*5.*	*6.*	*7.*	*8.*	*9.*	*10.*
1.	Analogy acc.−selection task	–									
2.	Analogy RT−selection task	−.02	–								
3.	Analogical responses−gen. task	.71**	−.20**	–							
4.	Analogy RT−generation task	−.13	.63**	−.28**	–						
5.	RAT (proportion correct)	.46**	−.31**	.50**	−.34**	–					
6.	AUT-Fluency	.20**	−.27**	.19**	−.35**	.14*	–				
7.	AUT-Creativity	.22**	−.09	.19**	−.19*	.05	.57**	–			
8.	Gc (composite measure)	.47**	−.30**	.58**	−.45**	.53**	.26**	.25**	–		
9.	Vocabulary	.47**	−.22**	.61**	−.37**	.52**	.24**	.28**	.86**	–	
10.	General knowledge	.33**	−.29**	.38**	−.41**	.39**	.21**	.15*	.86**	.48**	–
Mean		.66	4210	.85	3534	.41	13.61	2.55	0.00	.67	.47
SD		.18	2669	.13	1873	.18	4.98	.66	.86	.12	.15
Minimum		.10	446	.13	295	.04	3	1.25	−2.42	.20	.08
Maximum		.90	16536	1.00	12639	.84	35	4.25	2.57	.95	.88
Skewness		−1.21	1.59	−2.33	1.69	−.17	.83	.30	.15	−.73	.31
Kurtosis		1.06	3.55	8.41	3.94	−.57	1.97	−.49	−.03	1.76	−.09

$^{**}p < .01$; $^{*}p < .05$.

TABLE 3
Study 2, results of regression analyses

Task	*DV*	*Block*	*Predictor*	*Beta*	*t*	*p*
Analogy selection	Accuracy	1	Gc	.47	7.09	<.01
			Overall model: $R^2 = .21$, $F(1, 180) = 50.33$, $p < .01$			
		2	Gc	.27	3.49	<.01
			RAT	.32	4.27	<.01
			AUT-C	.14	2.11	<.05
			R^2 change = .08, $F = 10.59$, $p < .01$			
			Overall model: $R^2 = .29$, $F(3, 178) = 25.62$, $p < .01$			
	RT	1	Gc	−.30	4.20	<.01
			Overall model: $R^2 = .08$, $F(1, 180) = 17.60$, $p < .01$			
		2	Gc	−.13	1.57	.12
			RAT	−.22	2.68	<.01
			AUT-F	−.20	2.86	<.01
			R^2 change = .07, $F = 8.32$, $p < .01$			
			Overall model: $R^2 = .15$, $F(3, 178) = 11.45$, $p < .01$			
Analogy generation	Responses	1	Gc	.58	9.42	<.01
			Overall model: $R^2 = .33$, $F(1, 179) = 88.81$, $p < .01$			
		2	Gc	.41	5.73	<.01
			RAT	.28	4.03	<.01
			AUT-C	.07	1.19	.23
			R^2 change = .05, $F = 8.46$, $p < .01$			
			Overall model: $R^2 = .38$, $F(3, 177) = 37.71$, $p < .01$			
	RT	1	Gc	−.45	6.80	<.01
			Overall model: $R^2 = .20$, $F(1, 177) = 46.22$, $p < .01$			
		2	Gc	−.32	4.10	<.01
			RAT	−.14	1.85	.07
			AUT-F	−.25	3.74	<.01
			R^2 change = .07, $F = 8.84$, $p < .01$			
			Overall model: $R^2 = .27$, $F(3, 175) = 22.67$, $p < .01$			

Adjusted R^2 and standardised beta coefficients are shown here. AUT-F = AUT-Fluency; AUT-C = AUT-Creativity.

Descriptive statistics are shown in Table 2 for the predictors and all analogy measures. Results of all regression analyses are shown in Table 3.

Analogy selection task

Semantic distance. Consistent with prior research (Green et al., 2010, 2012; Vendetti et al., 2014), accuracies were higher for the semantically near analogies (M = .69, SD = .18) than for the semantically far analogies (M = .64, SD = .21), $F(1, 181) = 20.46$, $p < .001$, $\eta_p{}^2 = .10$. Likewise, the semantically near analogies ($M = 3962$, SD = 3229) also had faster RTs than the semantically far analogies ($M = 4459$, SD = 2758), $F(1, 181) = 5.92$, $p < .05$, $\eta_p{}^2 = .03$. To determine whether semantic distance moderated the relationship between our verbal analogy measures and creativity, we conducted an analysis of variance (ANCOVA) each for the accuracies and RTs with semantic distance (near vs. far) as the within-participants independent variable and our predictors as covariates (Gc, RAT, AUT-Fluency, AUT-Creativity). However, semantic distance did not interact with any of the predictors for either the accuracies (ps $\geq .19$) or for the RTs (ps $\geq .43$). So we collapsed across semantic distance for all remaining analyses.

Does creativity predict analogy selection performance above and beyond Gc?
As shown from the zero-order correlations in Table 2, each of our measures was related to both analogy accuracies and RTs. We conducted hierarchical linear regression analyses to test the hypothesis that creativity predicted analogy performance above and beyond the crystallised intelligence measures. Gc was included in the first block and the creativity measures (RAT and AUT) in the second block with either analogy accuracy or RTs as the criterion measure. Given the high correlation between AUT-Fluency and AUT-Creativity ($r = .57$), we included only one of these divergent thinking measures in our analyses for each criterion measure. As previously noted, AUT-Fluency and AUT-Creativity measure different aspects of divergent thinking (Benedek et al., 2013; Jauk et al., 2013; Nusbaum & Silvia, 2011; Silvia et al., 2013). AUT-Fluency reflects retrieval (including speed of retrieval), and therefore we included it as a predictor of the RT measure. In contrast, AUT-Creativity reflects the remoteness of the response, and we therefore included it as a predictor of analogy accuracies.[4] As shown in Table 3, both our convergent and divergent creativity measures predicted analogy accuracies (RAT $\beta = .32$, AUT-Creativity $\beta = .14$, $\Delta R^2 = .08$) and analogy RTs (RAT $\beta = -.22$, AUT-Fluency $\beta = -.20$, $\Delta R^2 = .07$) to a reliable extent above and beyond Gc. Thus, results extend those of Study 1 by showing that convergent and divergent creativity measures reliably predicted performance in an analogical selection task even beyond the more robust predictor of crystallised intelligence.

Analogy generation task
Responses were coded by the first author as relationally consistent (i.e., generation of a D term such that the C:D pair shared the same relation as

[4] When AUT-Fluency was included in the regression analysis instead of AUT-Creativity, it was not a reliable predictor of analogy accuracies. Likewise, AUT-Creativity did not predict overall analogy selection RTs.

the A:B pair; 84.01% of responses), semantically related to the C term (13.24%), semantically related to the A or B term (1.02%), or other (1.73%), which included "don't know" responses.

Semantic distance. Consistent with the analogy selection task results and prior studies using an analogical generation task (e.g., Vendetti et al., 2014), the proportion of relationally consistent responses, henceforth "analogical responses," was higher for the semantically near analogies ($M = .88$, SD = .13) than for the semantically far analogies ($M = .82$, SD = .16), $F(1, 178) = 50.87$, $p < .001$, $\eta_p^2 = .22$. Likewise, the semantically near analogies ($M = 3296$, SD = 1774) also had faster RTs than the semantically far analogies ($M = 3876$, SD = 2253), $F(1, 178) = 34.14$, $p < .001$, $\eta^2 = .16$.

Next, as done in the analogy selection task, we conducted ANCOVAs for each dependent measure (proportion of analogical responses and RTs) to determine whether the semantic distance factor (near vs. far) interacted with our creativity measures. As before Gc, RAT, AUT-Fluency, and AUT-Creativity were included as covariates. For the analogical responses, semantic distance interacted with crystallised intelligence, $F(1, 174) = 7.40$, $p < .01$, $\eta_p^2 = .04$. Notably, semantic distance interacted with AUT-Fluency for the analogical responses, $F(1, 174) = 3.75$, $p = .05$, $\eta_p^2 = .02$, and for the RTs, $F(1, 174) = 5.53$, $p < .05$, $\eta_p^2 = .03$. This interaction between our AUT-Fluency and generated analogical responses corroborates Vendetti and colleagues' (2014) finding of a greater transfer in relational thinking for far but not for near analogies. (We will return to this point in the "General Discussion" section.) There were no interactions with semantic distance for the RAT (ps > .55) or for AUT-Creativity (ps > .35). We first collapsed across semantic distance for the correlation and regression analyses as done for the analogical selection task analyses. Then, given these interactions between semantic distance and our predictor variables, we conducted separate regression analyses for the near and far analogies where appropriate.

Does creativity predict analogy generation performance above and beyond Gc? As shown from the zero-order correlations in Table 2, each of our measures was related to both analogical responses and RTs. Moreover, the analogical response measure in the analogy generation task was strongly related to analogy accuracies in the analogy selection task, and the RTs to select a response were strongly related to RTs to generate an analogical response. Hierarchical linear regression analyses again were conducted to test the hypothesis that creativity predicted analogy performance (proportion of analogical responses and then analogical generation RTs) above and beyond crystallised intelligence. As before, crystallised intelligence was included in the first block with convergent (RAT) and divergent (AUT) creativity measures in the second block. As before, AUT-Creativity was a predictor for the proportion of analogical responses and AUT-Fluency served as a predictor for the RTs. Results were mostly consistent with those found for the analogical selection task (see Table 3). RAT scores significantly predicted analogical responses, but only marginally predicted RTs. Although there was only a trend for the AUT-Creativity measure in predicting the proportion of analogical responses generated, AUT-Fluency significantly predicted faster RTs to generate such a response. Most crucially, just as in the analogy selection task, these two creativity measures did predict a significant amount of residual variance in both analogical responses (RAT $\beta = .28$, AUT-Creativity $\beta = .07$, $\Delta R^2 = .05$) and RTs (RAT $\beta = -.14$, AUT-Fluency $\beta = -.25$, $\Delta R^2 = .07$) above and beyond crystallised intelligence.

How does semantic distance moderate creativity as a predictor? Because semantic distance interacted with AUT-Fluency for both the proportion of analogical responses generated and the RTs to generate them, we conducted separate regression analyses for the near and far analogies with AUT-Fluency as a predictor. Consistent with the strong relationship between semantic distance and creativity (i.e., with far analogies rated as more creative than near analogies; Green et al., 2010), AUT-Fluency was a reliable predictor of analogical responses for the far analogies ($\beta = .24$, $t = 3.26$, $p = .001$), yet not for the near analogies ($\beta = .11$, $t = 1.47$, $p = .14$). However, fluency strongly predicted the RTs for generating both the far analogies ($\beta = -.35$, $t = 5.00$, $p < .001$) and the near analogies ($\beta = -.31$, $t = 4.40$, $p < .001$).

Overall, results for convergent and divergent thinking as predictors were consistent across the analogical selection and generation tasks. As shown in Table 2, both types of thinking were reliably related to performance in the selection and generation analogy tasks. However, as shown in Table 3, results varied slightly as to the extent to which each type of thinking predicted performance above and beyond Gc. Convergent thinking (RAT) generally predicted accuracies and RTs in the analogical selection task as well as the analogical responses and RTs in the analogical generation task. Divergent thinking (AUT) was also a reliable predictor of RTs across both tasks, though no longer a reliable predictor of analogical responses in the analogical generation task. Moreover, analogy accuracy was predicted by AUT-Creativity, whereas analogy RTs were predicted by AUT-Fluency.

GENERAL DISCUSSION

Across two studies, both convergent and divergent thinking predicted verbal analogy performance in an analogical selection task and an analogy generation task. In Study 1, convergent and divergent thinking predicted verbal analogy performance above and beyond a behavioural measure of creativity (the BICB). In Study 2, results demonstrated a role for convergent and divergent thinking above and beyond crystallised intelligence in both accuracy and RT in both an analogical selection task and analogical generation task. Thus, our results corroborate prior research showing a relationship between convergent thinking and non-verbal relational reasoning tasks (e.g., RAPM; Chermahini et al., 2012) and extend the importance of convergent thinking to verbal analogy. Consistent with recent studies (Green et al., 2012; Vendetti et al., 2014), semantic distance of the analogy moderated the predictive strength of divergent thinking (AUT-Fluency).

These results provide several theoretical insights regarding the relation between analogy and creativity. We have shown that convergent and divergent thinking, which are primary mental abilities that support other cognitive processes like creative thinking, also predict analogy skill. Furthermore, analogy skill is related to these two forms of creative *cognition* (e.g., Smith & Ward, 2012) but not to everyday creative *behaviour* (cf. Batey et al., 2010). That is, analogy skill was predicted by one's ability to think convergently and divergently, but not by one's propensity to engage in creative behaviours such as writing poems and designing websites. We also demonstrated that this relation between creative cognition and analogy skill was not simply due to their mutual relations with intelligence. Rather, even after statistically controlling for crystallised intelligence, both convergent and divergent thinking still significantly predicted both the accuracy and the speed of analogical thinking on most of our measures.

As previously stated, fluency measures reflect broad retrieval ability (Gr), which in our study predicted the speed and retrieval in selecting or generating an analogical response. This finding is consistent with the role of Gr in creative thought described in Silvia et al. (2013, p. 330). High AUT-Fluency scores entail being able to quickly retrieve characteristics of the item (e.g., the heaviness of a brick) that can then serve as cues for retrieving other uses for that item (e.g., paper weight). In turn, being able to selectively generate or retrieve such alternative uses requires interference control (Unsworth, Brewer, & Spillers, 2013; Unsworth, Spillers, & Brewer, 2011), in this case by resisting interference from much more strongly associated common uses (e.g., building a house) or from previously generated uses (Nusbaum & Silvia, 2011). Likewise, both analogical selection and generation tasks also require interference control in the form of resisting interference from a presented or retrieved distracter that are more semantically similar to other concepts in the analogy but that do not produce the same relation as that in the first pair.

Implications for analogical processes: Semantic distance and task as moderators

Results of recent verbal analogy studies (Green et al., 2012; Vendetti et al., 2014) suggest that "creative thinking" is most likely related to the processes of abstracting the relation in the first pair and then applying or transferring that relation onto the second pair. As described in prior studies (Green et al., 2012; Jones, 2011; Vendetti et al., 2014), semantically distant analogies entail generating more abstract or higher order relations between the A:B pair, whereas semantically near analogies can be completed based on the semantic similarity between the corresponding A and C terms. Results investigating individual differences in analogical problem-solving further suggest that divergent thinking was related to analogical or relational transfer. Corkill and Fager (1995) found that divergent thinking, measured using the unusual (alternative) uses test of the Torrance Test of Creative Thinking, predicted analogical transfer from a source problem in one domain to a target problem in a different (i.e., semantically distant) domain. The interaction found in our Study 2 between AUT-Fluency and semantic distance in the analogical generation task corroborates these prior findings of divergent thinking as a stronger predictor of generating a relationally consistent response for far analogies than for near analogies.

Analogical selection tasks require inferring possible relations between the A and B terms followed by selection of an answer that meets the constraint of having the same relation as in the A:B pair. Both surface similarity (i.e., the similarity between the corresponding terms in each pair) and structural similarity (i.e., the relational similarity between the pairs) are important in these processes (Gentner & Markman, 1997; Holyoak & Thagard, 1995, 1997; Krawczyk, Holyoak, & Hummel, 2004). Likewise, the RAT entails inferring relations between each concept and a potential solution followed by an evaluative process in the selection of an answer that is related to each of the terms in the triad. Notably, convergent thinking predicted performance to an equal extent for near and far analogies and in both the analogical selection and generation tasks. Thus, this common underlying process of relational inference in the RAT and verbal analogy occurs regardless of surface similarity.

Limitations and future directions

As is the case in many psychology studies, our samples reflected the high proportion of psychology students who are female (81% and 72% females in Studies 1 and 2, respectively). It is entirely possible that some forms of creativity may be more predictive of verbal analogy performance for one sex than for the other. Given the relatively small samples of male participants in our studies ($n = 30$ and 50 in Studies 1 and 2, respectively), we were not able to conclusively determine whether sex moderated the relationship between our various measures of creativity and verbal analogy, but preliminary analyses suggest it may. In Study 2 for instance, controlling for Gc, the relationship between convergent thinking (performance on the RAT) and the proportion of analogical responses in the generation task was stronger for males ($r = .35$) than for females ($r = .16$). In contrast, the relationship between AUT-Creativity and this proportion of generated analogical responses was reliable only for the female participants ($r = .18$) with no such relationship found for the males ($r = -.015$). Thus, given these preliminary findings, one future avenue of research would be to investigate sex as a moderator in the relationship between creativity and verbal analogy.

Another potential limitation was that our participants were not explicitly instructed to come up with "creative" responses on the AUT. For the given objects we instructed our participants to list "as many uses as possible" (Study 1) or "possible uses that are different from the normal one and different in kind from each other" (Study 2), but we did not instruct them to generate "creative" uses. As noted by Silvia and colleagues (Silvia et al., 2009, 2013), explicitly instructing participants to be creative increases the validity of the measure as a creativity rather than fluency measure. In turn, this results in lower correlations between fluency and creativity. Yet despite the high correlation between our fluency and creativity measures ($r = .57$), each measure predicted distinct aspects of verbal analogy performance.

One final future direction will be to investigate the influence of individual differences in creative thinking along with differences in executive functions (EF) that impact relational transfer such as working memory and updating, which entails the monitoring and revision of working memory. Given the association between EF and divergent thinking (Gilhooly et al., 2007), it is likely that such EF may mediate the connection between creative thinking and verbal analogy. Indeed, in a latent variable model, updating accounted for a significant part of the shared variance between Gf and divergent thinking (Benedek et al., 2014). Another study found that the effect of Gf on divergent thinking was mediated by executive switching (i.e., the extent to which participants switched categories in the AUT; Nusbaum & Silvia, 2011). Much research has also focused on the role of EF such as working memory and inhibitory control in analogical reasoning (e.g., Cho, Holyoak, & Cannon, 2007; Krawczyk et al., 2008; Morrison et al., 2004; Richland & Burchinal, 2013; Richland, Morrison, & Holyoak, 2006; Thibaut, et al., 2010; Viskontas, Morrison, Holyoak, Hummel, & Knowlton, 2004; Waltz, Lau, Grewal, & Holyoak, 2000). For example, participants with better inhibitory control are less prone to select a more salient distracter rather than the correct answer (Krawczyk et al., 2008; Morrison et al., 2004; Richland et al., 2006; Thibaut et al., 2010; Viskontas et al., 2004). Likewise, as previously discussed, AUT-Fluency measures entail interference control. Thus, interference control may also explain some of the shared variance between divergent thinking and verbal analogy, particularly in an analogical selection task that includes highly salient distracters.

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REFERENCES

Ball, L. J., Ormerod, T. C., & Morley, N. J. (2004). Spontaneous analogizing in engineering design: A comparative analysis of experts and novices. *Design Studies, 25*, 495–508.

Batey, M. (2007). *A psychometric investigation of everyday creativity* (Unpublished doctoral thesis). University College, London.

Batey, M. (2012). The measurement of creativity: From definitional consensus to the introduction of a new heuristic framework. *Creativity Research Journal, 24*, 55–65.

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

Batey, M., Furnham, A., & Safiullina, X. (2010). Intelligence, general knowledge and personality as predictors of creativity. *Learning and Individual Differences, 20*, 532–535.

Bearman, C. R., Ball, L. J., & Ormerod, T. C. (2007). The structure and function of spontaneous analogizing in domain-based problem solving. *Thinking & Reasoning, 13*, 273–294.

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

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

Blanchette, I., & Dunbar, K. (2000). How analogies are generated: The roles of structural and superficial similarity. *Memory & Cognition, 29*, 730–735.

Bowden, E. M., & Jung-Beeman, M. (2003). Normative data for 144 compound remote associate problems. *Behavior Research Methods, Instruments, and Computers, 35*, 634–639.

Bunge, S. A., Wendelken, C., Badre, D., & Wagner, A. D. (2005) Analogical reasoning and prefrontal cortex: Evidence for separable retrieval and integration mechanisms. *Cerebral Cortex, 15*, 239–249.

Caroff, X., & Besançon, M. (2008). Variability of creativity judgments. *Learning and Individual Differences, 18*, 367–371.

Chermahini, S. A., Hickendorff, M., & Hommel, B. (2012). Development and validity of a Dutch version of the Remote Associates Tests: An item-response theory approach. *Thinking Skills and Creativity, 7*, 177–186.

Chermahini, S. A., & Hommel, B. (2010). The (b)link between creativity and dopamine: Spontaneous eye blink rates predict and dissociate divergent and convergent thinking. *Cognition, 115*, 458–465.

Chermahini, S. A., & Hommel, B. (2012). Creative mood swings: Divergent and convergent thinking affect mood in opposite ways. *Psychological Research, 76*, 634–640.

Cho, S., Holyoak, K. J., & Cannon, T. D. (2007). Analogical reasoning in working memory: Resources shared among relational integration, interference resolution, and maintenance. *Memory & Cognition, 35*, 1445–1455.

Christensen, B. T., & Schunn, C. D. (2007). The relationship of analogical distance to analogical function and preinventive structure: The case of engineering design. *Memory & Cognition, 35*, 29–38.

Corkill, A. J., & Fager, J. J. (1995). Individual differences in transfer via analogy. *Learning and Individual Differences, 7*, 163–187.

Cropley, A. J. (2000). Defining and measuring creativity: Are creativity tests worth using? *Roeper Review, 23*, 72–79.

Dahl, D. W., & Moreau, P. (2002). The influence and value of analogical thinking during new product ideation. *Journal of Marketing Research, 39*, 47–60.

Dewhurst, S. A., Thorley, C., Hammond, E. R., & Ormerod, T. C. (2011). Convergent, but not divergent, thinking predicts susceptibility to associative memory illusions. *Personality and Individual Differences, 51*, 73–76.

Dunbar, K. (2001). The analogical paradox: Why analogy is so easy in naturalistic settings, yet so difficult in the psychology laboratory. In D. Gentner, K. J. Holyoak, & B. Kokinov (Eds.), *Analogy: Perspectives from cognitive science* (pp. 313–334). Cambridge, MA: MIT Press.

Dunbar, K., & Blanchette, I. (2001). The in vivo/in vitro approach to cognition: The case of analogy. *Trends in Cognitive Sciences, 5*, 334–339.

Finke, R., Ward, T., & Smith, S. M. (1992). *Creative cognition*. Cambridge, MA: MIT Press.

Froehlich, J. K., & Hoegl, M. (2012). Thematic ideation—antecedents and consequences of individuals' thematic similarity recognition. *Creativity and Innovation Management, 21*, 443–456.

Gentner, D., Brem, S., Ferguson, R., Wolff, P., Markman, A. B., & Forbus, K. (1997). Analogy and creativity in the works of Johannes Kepler. In T. B. Ward, S. M. Smith, & J. Vaid (Eds.), *Creative thought: An investigation of conceptual structures and processes* (pp. 403–459). Washington, DC: American Psychological Association.

Gentner, D., & Markman, A. B. (1997). Structure-mapping in analogy and similarity. *American Psychologist, 52*, 45–56.

Gilhooly, K. J., Fioratou, E., Anthony, S. H., & Wynn, V. (2007). Divergent thinking: Strategies and executive involvement in generating novel uses for familiar objects. *British Journal of Psychology, 98*, 611–625.

Green, A. E., Kraemer, D. J. M., Fugelsang, J. A., Gray, J. R., & Dunbar, K. N. (2010). Connecting long distance: Semantic distance in analogical reasoning modulates frontopolar cortex activity. *Cerebral Cortex, 10*, 70–76.

Green, A. E., Kraemer, D. J. M., Fugelsang, J. A., Gray, J. R., & Dunbar, K. N. (2012). Neural correlates of creativity in analogical reasoning. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 38*, 264–272.

Guilford, J. P. (1967). *The nature of human intelligence*. New York, NY: McGraw-Hill.

Hey, J., Linsey, J., Agogino, A. M., & Wood, K. L. (2008). Analogies and metaphors in creative design. *International Journal of Engineering Education, 24*, 283–294.

Hocevar, D. (1979). Ideational fluency as a confounding factor in the measurement of originality. *Journal of Educational Psychology, 71*, 191–196.

Holyoak, K. J., & Thagard, P. (1995). *Mental leaps: Analogy in creative thought*. Cambridge, MA: MIT Press.

Holyoak, K. J., & Thagard, P. (1997). The analogical mind. *American Psychologist, 52*, 35–44.

Horn, J. L., & Cattell, R. B. (1966). Refinement and test of the theory of fluid and crystallized intelligence. *Journal of Educational Psychology, 57*, 253–270.

Jarosz, A. F., Colflesh, G. J. H., & Wiley, J. (2012). Uncorking the muse: Alcohol intoxication facilitates creative problem solving. *Consciousness and Cognition, 21*, 487–493.

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

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

Johnson-Laird, P. N. (1989). Analogy and the exercise of creativity. In S. Vosniadou & A. Ortony (Eds.), *Similarity and analogical reasoning* (pp. 313–331). Cambridge, MA: Cambridge University Press.

Jones, L. L. (2011). Relational constraint and format in verbal analogy. In B. Kokinov, A. Karmiloff-Smith, & N. J. Nersessian (Eds.), *European perspectives on cognitive science*. Sofia: New Bulgarian University Press. Retrieved from http://nbu.bg/cogs/eurocogsci2011/proceedings/

Jung-Beeman, M., Bowden, E. M., Haberman, J., Frymiare, J. L., Arambel-Liu, S., Greenblatt, R., . . . Kounios, J. (2004). Neural activity when people solve verbal problems with insight. *PLoS Biology, 2*, 500–510.

Kolodner, J. (1997). Educational implications of analogy: A view from case-based reasoning. *American Psychologist, 52*, 57–66.

Krawczyk, D. C., Holyoak, K. J., & Hummel, J. E. (2004). Structural constraints and object similarity in analogical mapping and inference. *Thinking & Reasoning, 10*, 85–104.

Krawczyk, D. C., Morrison, R. G., Viskontas, I., Holyoak, K. J., Chow, T. W., Mendez, M. F., . . . Knowlton, B. J. (2008). Distraction during relational reasoning: The role of prefrontal cortex in interference control. *Neuropsychologia, 46*, 2020–2032.

Landauer, T. K., Foltz, P. W., & Laham, D. (1998). Introduction to latent semantic analysis. *Discourse Processes, 25*, 259–284.

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

Mednick, S. A. (1962). The associative basis of the creative process. *Psychological Review, 69*, 220–232.

Morrison, R. G., Krawczyk, D. C., Holyoak, K. J., Hummel, J. E., Chow, T. W., Miller, B. L., & Knowlton, B. J. (2004). A neurocomputational model of analogical reasoning and its breakdown in frontotemporal lobar degeneration. *Journal of Cognitive Neuroscience, 16*, 260–271.

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

Richland, L. E., & Burchinal, M. R. (2013). Early executive function predicts reasoning development. *Psychological Science, 24*, 87–92.

Richland, L. E., Morrison, R. G., & Holyoak, K. J. (2006). Children's development of analogical reasoning: Insights from scene analogy problems. *Journal of Experimental Child Psychology, 94*, 249–273.

Schunn, C. D., & Dunbar, K. (1996). Priming, analogy, and awareness in complex reasoning. *Memory & Cognition, 24*, 271–284.

Schunn, C. D., Paulus, P. B., Cagan, J., & Wood, K. (2006). *Final report from the NSF innovation and discovery workshop: The scientific basis of individual and team innovation and discovery*. Washington, DC: National Science Foundation.

Shipley, W. C. (1940). A self-administering scale for measuring intellectual impairment and deterioration. *The Journal of Psychology, 9*, 371–377.
Silvia, P. J. (2008). Another look at creativity and intelligence: Exploring higher-order models and probable confounds. *Personality and Individual Differences, 44*, 1012–1021.
Silvia, P. J. (2011). Subjective scoring of divergent thinking: Examining the reliability of unusual uses, instances, and consequences tasks. *Thinking Skills and Creativity, 6*, 24–30.
Silvia, P. J., Beaty, R. E., & Nusbaum, E. C. (2013). Verbal fluency and creativity: General and specific contributions of broad retrieval ability (Gr) factors to divergent thinking. *Intelligence, 41*, 328–340.
Silvia, P. J., Martin, C., & Nusbaum, E. C. (2009). A snapshot of creativity: Evaluating a quick and simple method for assessing divergent thinking. *Thinking Skills and Creativity, 4*, 79–85.
Silvia, P. J., Winterstein, B. P., Willse, J. T., Barona, C. M., Cram, J. T., Hess, K. I., … Richard, C. A. (2008). Assessing creativity with divergent thinking tasks: Exploring the reliability and validity of new subjective scoring methods. *Psychology of Aesthetics, Creativity, and the Arts, 2,* 68–85.
Simonton, D. K. (2000). Creativity: Cognitive, personal, developmental, and social aspects. *American Psychologist, 55*, 151–158.
Smith, S. M., & Ward, T. B. (2012). Cognition and the creation of ideas. In K. Holyoak & R. Morrison (Eds.), *Oxford handbook of thinking and reasoning* (pp. 456–474). New York: NY: Oxford University Press.
Squalli, J., & Wilson, K. (2014). Intelligence, creativity, and innovation. *Intelligence, 46*, 250–257.
Sternberg, R. J. (1977). Component processes in analogical reasoning. *Psychological Review, 84*, 353–378.
Sternberg, R. J., & Nigro, G. (1980). Developmental patterns in the solution of verbal analogies. *Child Development, 51*, 27–38.
Thibaut, J.-P., French, R., & Vezneva, M. (2010). Cognitive load and semantic analogies: Searching semantic space. *Psychonomic Bulletin & Review, 17*, 569–574.
Thompson, L., Gentner, D., & Loewenstein, J. (2000). Avoiding missed opportunities in managerial life: Analogical training more powerful than individual case training. *Organizational Behavior and Human Decision Processes, 82*, 60–75.
Unsworth, N. (2010). Interference control, working memory capacity, and cognitive abilities: A latent variable analysis. *Intelligence, 38*, 255–267.
Unsworth, N., Brewer, G. A., & Spillers, G. J. (2013). Working memory capacity and retrieval from long-term memory: The role of controlled search. *Memory & Cognition, 41*, 242–254.
Unsworth, N., Spillers, G. J., & Brewer, G. A. (2011). Variation in verbal fluency: A latent variable analysis of clustering, switching, and overall performance. *Quarterly Journal of Experimental Psychology, 64*, 447–466.
Vendetti, M. S., Wu, A., & Holyoak, K. J. (2014). Far-out thinking: Generating solutions to distant analogies promotes relational thinking. *Psychological Science, 25*, 928–933.
Viskontas, I. V., Morrison, R. G., Holyoak, K. J., Hummel, J. E., & Knowlton, B. J. (2004). Relational integration, inhibition, and analogical reasoning in older adults. *Psychology and Aging, 19*, 581–591.
Waltz, J. A., Lau, A., Grewal, S. K., & Holyoak, K. J. (2000). The role of working memory in analogical mapping. *Memory & Cognition, 28*, 1205–1212.
Ward, T. B., Smith, S. M., & Finke, R. A. (1999). Creative cognition. In R. Sternberg (Ed.), *Handbook of creativity* (pp. 189–212). New York, NY: Cambridge University Press.

APPENDIX A

Study 1, stimuli in analogy selection task

A:B pair	*C:D pair*	*Distracters*
ARRIVAL:DEPARTURE	BIRTH:DEATH	life, person, train
ELBOW:ARM	KNEE:LEG	walking, finger, nose
CAR:ROAD	TRAIN:TRACK	vehicle, fast, wheel
BAITING HOOK:FISHING	LOADING GUN:HUNTING	firing gun, stalking game, aiming gun
VIOLENCE:ACTIVITY	MELANCHOLY:MOOD	evening, cruelty, silence
MAN:TROUSERS	WOMAN:SKIRT	clothing, hat, blanket
UNIVERSITY:INSTITUTION	MAYOR:OFFICIAL	town, law, councilman
GRASS:SOIL	SEAWEED:WATER	salty, river, fish
TRUTHFULNESS:COURT	CLEANLINESS:BATH	virtue, restaurant, pig
EGG:FISH	SEED:PLANT	leaf, root, stem
LION:ANIMAL	FLOWER:PLANT	grass, roots, rose
WAVE:CREST	MOUNTAIN:PEAK	water, top, moving
FALLING:GRAVITATION	COLLAPSE:PRESSURE	balloon, electricity, destruction
PROFESSOR:INSTRUCTION	MUSICIAN:ENTERTAINMENT	pupils, school, homework
GRAINS:SAND	DROPS:RAIN	snow, surf, flood
WAVE:TIDE	MOMENT:TIME	ocean, tardiness, clock
WIFE:WOMAN	HUSBAND:MAN	father, groom, boy
BOOK:PAGE	COMB:TOOTH	title, library, knowledge
BOY:CHILD	MAN:ADULT	father, uncle, person
FLOWER:WEED	SWAN:BUZZARD	plant, bird, vulture

APPENDIX B

Study 2, stimuli in analogy selection task

A:B pair semantically far	*A:B pair semantically near*	*C:D pair*	*Distracters*
STRONG:WEAK	DAY:NIGHT	MORNING:EVENING	dawn, sunrise, early, dew
SUN:MOON	POLITE:RUDE	KIND:CRUEL	nice, gentle, sweet, caring
QUESTION:ANSWER	TIRED:AWAKE	SICK:HEALTHY	ill, doctor, hospital, medicine
DARK:LIGHT	MAN:WOMAN	BOY:GIRL	son, male, scout, father
TREE:BRANCH	TURTLE:FLIPPERS	FISH:FIN	trout, swim, tank, sea
HUMAN:HEART	PEACH:PIT	APPLE:CORE	fruit, orange, red, pie
BOOK:COVER	ORANGE:RIND	BANANA:PEEL	coconut, yellow, apes, island
FLOWER:PETALS	SWEATER:ZIPPER	COAT:BUTTONS	hat, jacket, cold, winter
FLUTE:INSTRUMENT	SOUP:APPETIZER	JUICE:BEVERAGE	milk, orange, cup, breakfast

(*continued*)

(*continued*)

A:B pair semantically far	*A:B pair semantically near*	*C:D pair*	*Distracters*
SWORD:WEAPON	PEAR:FRUIT	PUMPKIN:VEGETABLE	pie, patch, seed, squash
BEAR:MAMMAL	KITCHEN:ROOM	BED:FURNITURE	pillow, sleep, sofa, sheets
BEE:INSECT	OHIO:STATE	SWEDEN:COUNTRY	Stockholm, Italy, Scandinavia, snow
DOLL:PUZZLE	MOUSE:SQUIRREL	ROBIN:CANARY	wings, nest, bird, red
STOMACH:LIVER	FRIDAY:TUESDAY	MAY:JULY	month, vacation, hot, beach
LEATHER:SADDLE	PLATINUM:NECKLACE	GOLD:EARRING	silver, diamond, rich, metal
GLASS:BOTTLE	ALUMINUM:GUN	STEEL:RACK	strong, hard, metal, iron
STRAW:HAT	SNOW:CASTLE	ICE:SCULPTURE	skate, cold, water, pick
COTTON:BALL	PLASTIC:TABLE	WOOD:CHAIR	burn, chop, fire, tree

APPENDIX C

Study 2, stimuli in analogy generation task

Semantically far	*Semantically near*
OX:PLOW::HORSE:CARRIAGE	WALL:BRICKS::ROOF:SHINGLES
LAMP:LIGHT::SPEAKER:SOUND	BUTCHER:MEAT::BAKER:BREAD
PENCIL:WRITING::BINOCULARS:SEEING	KANGAROO:HOP::SNAKE:SLITHER
BEAR:HONEY::MONKEY:BANANAS	TADPOLE:FROG::CATERPILLAR:BUTTERFLY
SURGEON:SCALPEL::WRITER:PEN	BEEF:COW::PORK:PIG
PAINTER:BRUSH::MECHANIC:WRENCH	BED:SLEEPING::CHAIR:SITTING
MONEY:BANK::CAR:GARAGE	GLARE:ANGER::SMILE:HAPPINESS
LANGUAGE:WORDS::MUSIC:NOTES	BLIND:SIGHT::DEAF:HEARING
EAGLE:BIRD::APPLE:FRUIT	SCARF:NECK::BELT:WAIST
PLAYER:TEAM::SINGER:CHOIR	OCTOPUS:TENTACLES::CRAB:CLAWS
SCIENTIST:LAB::TEACHER:CLASSROOM	HAT:HEAD::BRACELET:WRIST
ARMOR:KNIGHT::BARK:TREE	LEMON:SOUR::GRAPE:SWEET
TUTOR:STUDENT::COACH:ATHLETE	ARROGANT:HUMILITY::FOOLISH:WISDOM
CENTURY:DECADE::GALLON:QUART	CANDLE:WAX::WINDOW:GLASS
PIRANHA:FISH::OAK:TREE	TRAIN:TRACK::CAR:ROAD
HAMSTER:CAGE::PRISONER:CELL	ARRIVAL:DEPARTURE::BEGINNING:END
PHARMACIST:DRUGS::CHEF:FOOD	SHALLOW:DEEP::SHORT:TALL
HORSE:HAY::DOLPHIN:FISH	FEAR:TERROR::SADNESS:MISERY
PHOTOGRAPHER:CAMERA::DENTIST:DRILL	SCALE:WEIGHT::RULER:LENGTH
LIFEGUARD:BEACH::RANGER:FOREST	SHOE:FOOT::GLOVE:HAND