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The contributions of convergent thinking, divergent thinking, and schizotypy to solving insight and non-insight problems

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ABSTRACT

The ability to generate diverse ideas (divergent thinking) is valuable in solving creative problems (e.g., insight problems); yet, however advantageous, this ability is insufficient to solve the problem alone and requires the ability to logically deduce an assessment of correctness of each solution (convergent thinking). Positive schizotypy may help isolate the aspects of divergent thinking prevalent in insight problem solving. Participants were presented with a measure of schizotypy (Oxford-Liverpool Inventory of Feelings and Experiences), divergent and convergent thinking tasks, insight problems, and non-insight problems. We found no evidence for a relationship between schizotypy and insight problem solving. Relationships between divergent thinking and insight problem solving were also surprisingly weak; however, measures of convergent thinking had a stronger relationship with problem solving. These results suggest that convergent thinking is more important than divergent thinking in problem solving.

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Introduction

Links between psychoticism and creativity are often justified through reference to the mythical mad genius (Acar & Sen, 2013; Carson, 2011). Although the ability to perceive a hitherto unseen association between diverse concepts (e.g., a stairwell and biology[1]) may be valuable in creative problem solving, such associations might seem bizarre without the further capacity to assess the "fit" or accuracy of a solution for the problem (Holt, 2015; Mohr, Graves, Gianotti, Pizzagalli, & Brugger, 2001). To wit, the cognitive processes underpinning creative thinking involve both divergent thinking (the generation of many and diverse ideas and concepts from a single start point; Batey & Furnham, 2008) and convergent thinking (logically building

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[1]Spiral staircases provided that *aha!* sensation of revelatory confirmation for Watson during the discovery of the helical structure of DNA (Watson, 1968, p. 16).

associations and linearly moving towards the single, best, conclusion; Claridge & McDonald, 2009). These creative processes have often been investigated through insight problem solving (DeYoung, Flanders, & Peterson, 2008).

Insight problems are, by design, simple but not straightforward, requiring consideration of the problem in a diverse number of ways and filtration of these options to find the correct solution. Consider the following insight problem:

> A man married 20 women. He and the women are still alive, he had no divorces, he is no bigamist and broke no law. How can this be? (Gick & Lockhart, 1995)

The answer (the man is the priest) may not be immediately apparent but may seem obvious once known. Such problems often result in an impasse if problem solvers fixate on an incorrect cue (e.g., the typical meaning *marry* implies that the man is the one getting married). In contrast, a non-insight problem typically requires the *incremental* application of known problem-solving rules (e.g., arithmetic or logic) (Cunningham, Macgregor, Gibb, & Haar, 2009). Contrast the following non-insight problem:

> Mary won't eat fish or spinach, Sally won't eat fish or green beans, Steve won't eat shrimp or potatoes, Alice won't eat beef or tomatoes, and Jim won't eat fish or tomatoes. If you are willing to give such a bunch of fussy eaters a dinner party, which items from the following list can you serve: green beans, creamed codfish, roast beef, roast chicken, celery, and lettuce. (Schooler, Ohlsson, & Brooks, 1993)

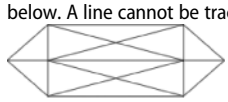
The answer (roast chicken, celery, and lettuce) is obtainable through a process of systematic elimination. Both problems are examples of *classic* problems; that is, they are examples of the most frequently used riddles, brainteasers, and puzzles drawn from the literature of insight problem solving before 1990 (for a comprehensive review, see Sternberg & Davidson, 1995). In Table 1, we have listed classic problems and solutions used in this study, as well as their solution rates.

More contemporary research mixes the use of these classic problems with other tasks such as anagrams, rebus puzzles, Remote Associates Tasks (also known in contemporary insight research as Compound Remote Associates or CRAs[2]), and matchstick arithmetic (see Cunningham et al., 2009, for a review of the use of these problems). Although we recognise that many of these task types have been used for similar amounts of time as the "classic" problems, their use in insight problem-solving literature is relatively recent; hence, we refer to these tasks as *contemporary insight problems*.

An important point raised by the work described here and elsewhere (Webb, Little, & Cropper, 2016) is that it is unclear whether the cognitive processes underlying performance on so-called insight and non-insight problems

[2]Compound Remote Associates (CRAs; Bowden & Jung-Beeman, 2003) are a variant of the Remote Associates Task (Mednick & Mednick, 1967) in which three words are presented to the participant (e.g., age, mile, sand) with the task being to find the fourth word that meaningfully relates to the others (*stone*-age, mile*stone*, sand*stone*). In the Remote Associates Task, participants have to generate a word linking three concepts, but the solutions are not necessarily compounds.

Table 1. Insight and non-insight problems and between-person solution rates across studies. The first three in each category are from Karimi et al. (2007)*.

	Classic problems (riddles and puzzles)	Solution rate (%)	
	Presumed insight problems	Study 1	Study 2
1*	*Egg problem*. Using only a 7-minute and an 11-minute hourglass, how will you be able to time the boiling of an egg for exactly 15 minutes?	44.9	43.6
2*	Triangle of coins problem. Moving only three coins make the triangle point downwards. 	50	62.4
3*	*Socks problem*. If you have black socks and brown socks in your drawer, mixed in a ratio of 4 to 5, how many socks will you have to take out to make sure that you have a pair the same color?	41	40.2
4	*Water lilies*. Water lilies double in area every 24 hours. At the beginning of summer there is one water lily on the lake. It takes 60 days for the lake to become completely covered with water lilies. On which day is the lake half covered?	46.1	51.3
5	*Coin problem*. A dealer of antique coins received an offer to buy a beautiful bronze coin by an unknown man. The coin had an emperor's head on one side and the date 544 BC stamped on the other side. The dealer examined the coin, but instead of buying it, he called the police to arrest the man. What made him realise that the coin was fake?	28.1	22.2
	Presumed non-insight problems		
6*	*Card problem*. Three cards from an ordinary deck are lying on a table, face down. The following information is known about those three cards: To the left of a queen there is a jack To the left of a spade there is a diamond To the right of a heart there is a king To the right of a king there is a spade Can you assign the proper suit to each picture card?	47.7	46.2
7*	*Water jug problem*. Given a source of unlimited water and four containers of different capacities (99, 14, 25 and 11 L) obtain exactly 86 L of water.	41	56.4
8*	*Trace Problem*. Without lifting pencil from paper, trace the figure provided below. A line cannot be traced more than once. 	46	NA
9	*Dinner*. Dinner Mary won't eat fish or spinach, Sally won't eat fish or green beans, Steve won't eat shrimp or potatoes, Alice won't eat beef or tomatoes, and Jim won't eat fish or tomatoes. If you are willing to give such a bunch of fussy eaters a dinner party, which items from the following list can you serve: green beans, creamed codfish, roast beef, roast chicken, celery, and lettuce.	88	81.2
10	*Police*. The police were convinced that either A, B, C or D had committed a crime. Each of the suspects, in turn, made a statement, but only one of the four statements was true. A said, "I didn't do it." B said, "A is lying." C said, "B is lying." D said, "B did it." Who is telling the truth? Who committed the crime?	38	39.3

are different (Weisberg, 2014), despite the contrast of insight and non-insight problems in the literature on individual differences (e.g., Karimi, Windmann, Güntürkün, & Abraham, 2007). In other words, just because an insight problem is termed as such, does not necessitate a feeling of insight in the solution (Danek, Wiley, & Öllinger, 2016; Webb et al., 2016).

Divergent thinking

One proposed difference between insight and non-insight problems revolves around the ideational process of divergent thinking, with insight problems able to uniquely elicit divergent thinking compared to non-insight problems (DeYoung et al., 2008). Divergent thinking is used to generate a broad set of associated concepts and categories, encompassing the abilities of forming loose associations, and fluency and flexibility of thought (Jones, Caulfield, Wilkinson, & Weller, 2011) and is considered a fundamental characteristic of creative ability (Acar & Runco, 2012; Kenett, Anaki, & Faust, 2014). Divergent thinking is often measured by creative tasks (Beaty, Nusbaum, & Silvia, 2014) such as the Alternative Uses Task (Guildford, Christensen, Merrifield, & Wilson, 1978), in which participants are required to generate as many and varied uses for an everyday object (e.g., a brick) within a time limit. A possible reason for the relationship between divergent thinking and insight problem solving is the fluency and flexibility of thought required in divergent-thinking tasks: as the number and variety of potentially relevant concepts retrieved is increased, too, so does the likelihood of hitting upon a fitting solution (Ansburg, 2000).

Another possible factor underlying the relationship between divergent thinking and problem solving is the nature of the semantic networks in highly creative individuals. Creative ideas are thought to arise from the ability to connect distal concepts in more loosely structured semantic networks (Nusbaum & Silvia, 2011). Evidence indicates that highly creative individuals perceive less semantic distance between unrelated word pairs as compared to less creative subjects (Kenett et al., 2014; Rossmann & Fink, 2010). Kenett et al. (2014) investigated the semantic networks of high creative vs. low creative individuals and found that the former group had wider interconnected semantic networks. Mohr et al. (2001) similarly found that individuals high in positive schizotypy tended to perceive less semantic distance between remote concepts compared to individuals low in positive schizotypy.

Schizotypy and divergent thinking

Schizotypy is a personality dimension (comprising four sub-dimensions) often associated with and used to measure individual differences in creativity (Acar & Sen, 2013; Batey & Furnham, 2008). The significant relationships between schizotypy, originality and flexibility of thinking (Green & Williams, 1999;

Tsakanikos & Claridge, 2005; Woody & Claridge, 1977) may also be indicative of these underlying differences in semantic network configurations. There are several reliable and valid measures of schizotypy, including the O-LIFE (Oxford–Liverpool Inventory of Feelings and Experiences; Mason & Claridge, 2006) and the SPQ (Schizotypal Personality Questionnaire; Raine, 1991). The O-LIFE is derived from factor analyses of non-clinical measures (Mason & Claridge, 2006), and the SPQ is based on DSM-III-R criteria for schizotypal personality disorder (Cochrane, Petch, & Pickering, 2010; Raine, 1991). For both, schizotypy is measured across several dimensions, including positive, negative and disorganised schizotypy.[3] The dimension most consistently associated with creativity is positive schizotypy, which assesses, among other traits, apophenia, magical thinking, unusual perceptual aberrations and hallucinatory experiences (Acar & Sen, 2013). The link between positive schizotypy and creativity is possibly due to its links with inner experiences and traits (such as apophenia, the tendency to perceive a meaningful pattern in noise; Partos, Cropper, & Rawlings, 2016) that give rise to unconventional thinking and perception (Claridge & McDonald, 2009; Mohr & Claridge, 2015). These aspects of positive schizotypy which are likely to promote divergent thinking may also result in an inability to inhibit inappropriate answers (Claridge & McDonald, 2009).

Although various studies indicate a positive relationship between positive schizotypy and creativity, it is necessary to note here that the evidence for the relationship between schizotypy and creativity is somewhat inconsistent, with a series of studies reporting non-significant associations (e.g., Folley & Park, 2005; Suzuki & Usher, 2009). These disparate findings may be a consequence of an interactive process between divergent thinking and convergent thinking in creativity and creative acts, in which facilitation of spreading activation within semantic networks occurs in individuals high in positive schizotypy. However, those same individuals are unable to find fitting solutions unless they are also able to control that chaotic activation with convergent-thinking processes (Jones et al., 2011; Kyriacou, Weniger, & Brugger, 2003).

Convergent thinking

Convergent thinking comprises processes of discerning the most fitting solution through deductive reasoning (Jones et al., 2011; Lee & Therriault, 2013). Within the domain of convergent thinking are measures of intelligence, including both crystallised and fluid intelligence, which are positively correlated with

[3]The dimensions of the SPQ are positive, negative and disorganised schizotypy, whereas the O-LIFE is measured along four dimensions: Unusual Experiences, Social Anhedonia, Cognitive Disorganisation and Impulsive Non-conformity (Mason & Claridge, 2006). In the O-LIFE, positive schizotypy is a combination of the Unusual Experiences and Cognitive Disorganisation dimensions.

success on both insight (Davidson, 2003; Schooler & Melcher, 1995) and non-insight problems (Ansburg, 2000). DeYoung et al. (2008) argued that the associations between working memory and insight problem solving (Ansburg, 2000; Ash & Wiley, 2006) are also a function of fluid intelligence: the more an individual is able to simultaneously manipulate various parts of information about a question, the more variations of solutions they can develop and the faster they are able to weigh alternatives and generate a correct solution.

Problem solving, in general, and insight problems, in particular, arguably require both convergent thinking and divergent thinking in order to provide multiple ideas leading to a single correct conclusion (Lee & Therriault, 2013). Success in a convergent-thinking task, as in insight problems, is determined by whether or not a problem solver is able to identify the correct solution.

Problem solving and schizotypy

Investigations using Remote Associate Tasks as a convergent-thinking tool have demonstrated a positive relationship between positive schizotypy and accuracy for these problems (Gianotti, Mohr, Pizzagalli, Lehmann, & Brugger, 2001; Mohr & Claridge, 2015; Mohr et al., 2001). However, few studies have investigated insight problem solving and schizotypy (Karimi et al., 2007; Mohr, et al., 2001), and the evidence supporting a relationship between the two is mixed (Batey & Furnham, 2008; Suzuki & Usher, 2009). This ambiguity may be a consequence of failing to dissociate convergent- and divergent-thinking styles (Jones et al., 2011).

Only one study has investigated schizotypy and insight problem solving: Karimi et al. (2007) found that high schizotypy scores (according to the SPQ) were associated with better insight problem solving on classic insight but not non-insight problems. This implies the tendency towards a more loosened associative thinking process in the high schizotypy group generated a creative advantage. However, the study used a limited number of problems, did not examine different types of creativity, did not differentiate the dimensions of schizotypy and did not ensure that their insight problems actually elicited insight.

Number of problems used

In the present study, we expanded the problem set of Karimi et al. (2007) by adding additional classic problems, as well as including CRAs, which are increasingly used as insight problems in contemporary research (e.g., Bowden, Jung-Beeman, Fleck, & Kounios, 2005; Chein & Weisberg, 2014; Salvi, Bricolo, Bowden, Kounios, & Beeman, 2016). CRAs, as well as anagrams and matchstick arithmetic, have been increasingly used to alleviate the limitations of using only classic insight problems (Bowden et al., 2005). We selected CRAs as they have been used to test the relationship between thinking styles in schizotypy

(see e.g., Suzuki & Usher, 2009), but there is little research investigating how comparable CRAs are to classic insight problems (Ansburg, 2000). Hence, in the present study, we also examine a larger set of insight and non-insight problems in order to facilitate this comparison and to be able to generalise our data.

Creativity and insight

Insight problems have been used as tests of creativity (Hedblom, 2013), but there are questions regarding the ability of insight problems to predict productive creativity (see e.g., Beaty, Nusbaum, et al., 2014). Although insight problem solving and divergent thinking are positively associated, there is often a greater relationship between creativity and working memory and inhibition of inappropriate responses (Beaty, Silvia, Nusbaum, Jauk, & Benedek, 2014; Benedek, Jauk, Sommer, Arendasy, & Neubauer, 2014; DeYoung et al., 2008). Insight also correlates positively with convergent thinking (Jones et al., 2011). Karimi et al. aimed to investigate whether the link between schizotypy and insight problem solving was due to divergent-thinking processes but did not examine this directly. We investigate this issue using tests of divergent and convergent thinking.

Differentiating dimensions

Positive schizotypy is the dimension most consistently predictive of creativity (Acar & Sen, 2013). Hence, it is important to differentiate the dimensions of schizotypy. In the present study, we use the O-LIFE to extract the positive schizotypy scores (i.e., using the Unusual Experiences/Cognitive Disorganisation scales) and examine their relation to divergent thinking. We use a modified version of the standard O-LIFE questionnaire where the response is a Likert scale of 0–6 rather than yes/no, in order to increase sensitivity of the measure (Cropper, Johnston, & Groot, 2015).

Aims and hypotheses

The aim of this paper is to investigate problem solving using a number of task types (insight problems, non-insight problems and CRAs) and measures of processes proposed to be underlying problem solving (convergent thinking, divergent thinking). We explored whether it is the generative and unusual response aspect of divergent thinking that is helpful in problem solving by incorporating a measure of positive schizotypy, which has been associated with unusual responses due to chaotic activation of semantic networks.

We investigate Karimi and colleague's (2007) study using Mason and Claridge's (2006) O-LIFE, and further explore the validity of insight problems

as a measure of creativity through comparison with a well-known creativity task. Following Karimi et al. (2007), we predict (1) positive schizotypy will be a significant predictor of insight problem solving, but not of non-insight problem solving. We further predict that (2) positive schizotypy have a positive relationship with divergent-thinking processes (particularly flexibility and originality of thought), (3) convergent thinking will be a significant predictor of both insight and non-insight problem types, and (4) divergent thinking will be a significant predictor of insight, but not of non-insight problems.

Experiment 1

In this experiment, we aimed to replicate Karimi and colleagues' (2007) study using Mason and Claridge's (2006) O-LIFE, and further examine the relationship between insight and creativity, divergent and convergent thinking, and between divergent thinking and positive schizotypy.

Method

Participants

University of Melbourne students (N = 193: 118 female; age range: 17–52; mean: 19.639) completed the study for course credit. Nine participants were removed for errors on more than 20% of the tasks.

Materials

Problem-solving tasks

We used a mixture of "classic" insight problems, non-insight problems and CRAs (Bowden & Jung-Beeman, 2003) in order to investigate problem solving.

"Classic" insight and non-insight problems. We used the same insight and non-insight problems as Karimi et al. (2007), supplementing these with others drawn from the existing insight problem-solving literature (e.g., Schooler & Melcher, 1995); see Table 1 for problems used and their solution rates. Participants were given four minutes per problem. Accuracy and response time were recorded.

Compound Remote Associates. Participants were given 30 seconds to generate a fourth word to complete the given three words. Accuracy and response time were recorded (cf. Bowden & Jung-Beeman, 2003). We ranked problems in terms of solution rates and pseudo-randomly chose five questions from

each quantile ensuring that the solutions were likely to be familiar and not duplicated across problems (see Appendix for CRAs used in this study).

Schizotypy

Schizotypy was measured using the O-LIFE (Mason & Claridge, 2006). The questionnaire comprises 159 items for four measures of schizotypy: "Unusual Experiences" (positive: assesses magical thinking, unusual perceptual aberrations and hallucinatory experiences), "Cognitive Disorganisation" (disorganised: assesses difficulty with concentration, decision-making and social anxiety), "Introvertive Anhedonia" (negative: assesses the lack of enjoyment from social contact, emotional and physical intimacy) and "Impulsive Nonconformity" (psychoticism: assesses impulsive, antisocial and aggressive behaviour). We used an adapted Likert scale where subjects responded from 0 (strongly disagree) to 6 (strongly agree) (Cropper et al., 2015).

Divergent thinking

Divergent thinking was measured using an adaptation of the Alternative Uses Task (Guildford, Christensen, Merrifield, & Wilson, 1978). The task consists of five two-minute trials in which participants were presented with common household items (i.e., *brick*, *paperclip*, *newspaper*, *ice tray*, *rubber band*) and asked to generate as many uses for that item as possible. The task was scored on fluency (number of responses), flexibility (number of different categories used) and originality. *Flexibility* was scored as the number of different categories used by participants (e.g., using a brick as a planting tray and a paperweight is two different categories, but as a paperweight and to hold down a balloon was a single category). We scored *originality* following the methodology of DeYoung et al. (2008): scores depended on how frequently a response was obtained within that sample, with one point awarded to responses given by between 3% and 10% of respondents, two points for responses by less than 3% of the sample and three points to unique responses (e.g., using paperclips as Barbie doll tap shoes).

Two researchers independently rated all responses. Inter-rater reliabilities were calculated using Cronbach's alpha, with brick $\alpha = 0.750$, paper clip $\alpha = 0.821$, rubber band $\alpha = 0.721$, ice tray $\alpha = 0.925$ and the newspaper $\alpha = 0.743$.

Convergent thinking

Convergent thinking was measured using Raven's Advanced Progressive Matrices (Raven, 1985) as common indicator of deductive logic (Jones & Estes, 2015; McGrew & Flanagan, 1998) which has already been tested alongside insight problems (e.g., Gilhooly, Fioratou, & Henretty, 2010; Lee & Therriault, 2013; Paulewicz, Chuderski, & Nęcka, 2007).

Procedure

Each participant was tested individually. Participants were given no information about the problem type. No solutions (feedback) were given.

First, the six problems from Karimi et al. (2007) were randomly interleaved with two additional "insight" and "incremental" (or "non-insight") problems, drawn from Schooler and Melcher (1995). In the next phase, 20 CRAs (Bowden, Jung-Beeman, Fleck, & Kounios, 2005) were presented in random order, with 5 practice trials preceding the set. In the last phase, a series of individual differences measures were presented in counterbalanced order across participants. These included the O-LIFE, Raven's, a verbal fluency measure (adapted from Lezak, 2004), a suggestibility measure (Gudjonsson, 1984), and an adaptation of the Alternative Uses Task. Of these, only the O-LIFE, Raven's Matrices and the Alternative Uses Task are reported.

Results and discussion

We used a series of regression analyses in order to investigate the data. Although Karimi et al. performed a median split on the combined Unusual Experiences and Cognitive Disorganisation scores for their analyses, we used regression and correlation in order to investigate the continuous variables with more sensitivity, and to maximise the use of the Likert scale response. A direct replication of the analyses used by Karimi et al. (2007) can be found in Supplementary Materials.

After initial analyses, we filtered the data so that the sample comprised only students with English as their first language ($N = 132$; see Supplementary Materials for results and discussion of unfiltered data).

Schizotypy

Consistent with our predictions, and the literature, there was evidence for a positive relationship between Unusual Experiences and divergent-thinking measures (fluency, flexibility and originality of thought, see Table 2). Consistent with prior research and hypotheses regarding lower cognitive inhibition facilitating chaotic firing of semantic networks, and consequent activation of many concepts through to more distal points of a semantic network.

Problem solving

Pearson correlations conducted between problem-solving variables (insight problems, non-insight problems and CRAs) demonstrated a significant

positive relationship between classic insight and non-insight problem solving: $r(130) = 0.372$, $p < 0.001$, and a weak relationship between CRAs and non-insight problems: $r(130) = 0.228$, $p = 0.009$, but *not* between CRAs and classic insight problems: ($r(130) = 0.095$, $p = 0.277$. This was surprising and contrasts with several papers using Remote Associate Tasks as insight problems since they are highly related to CRAs (e.g., Ansburg, 2000; Cunningham et al., 2009; Schooler & Melcher, 1995). While the observed results may be a reflection of the different task type (e.g., the long vignettes of the classic insight problems compared to the three words of the CRAs), Remote Associate Tasks have indicated unreliable (i.e., both positive and negative) relationships with insight tasks. Our results may reflect the multi-step nature of classic insight and non-insight problems, suggesting that the processes underlying classic insight and non-insight problems are more related than the processes underlying classic insight problems and CRAs (cf. Schooler & Melcher, 1995).

Insight problem solving and individual differences

Insight problem solving was significantly correlated with all divergent-thinking measures (flexibility: $r(132) = 0.225$, $p = 0.010$, originality: $r(130) = .252$, $p = 0.004$; and fluency: $r(130) = .183$, $p = 0.037$), as well as measures of convergent thinking (Raven's: $r(130) = .372$, $p < .001$); however, contrary to the findings of Karimi et al. (2007), there was no evidence of a relationship between insight problem solving and any subsets of schizotypy (see Table 2 for correlations). The absence of a relationship between insight problem solving and schizotypy may be an indication of the convergent nature of insight problems.

Regressing convergent- and divergent-thinking measures onto insight problem solving indicated that originality and flexibility were significant predictors of insight problem solving in the ESL1 sample: $F(4, 129) = 7.822$, $p < 0.001$, with an R^2 of 0.200, flexibility: $\beta = -1.23$, $p = 0.048$, originality: $\beta = 1.34$, $p = 0.03$. Raven's Advanced Progressive Matrices: $\beta = 0.33$, $p < 0.001$. Fluency was not a significant predictor of insight problem solving (see Table 3). These results imply that the ability to generate many ideas was not as important as the ability to generate original ideas, which are better predictors of divergent thinking, and are congruent with literature indicating a relationship between creativity and insight problem solving (e.g., DeYoung et al., 2008). The negative relationship between flexibility and insight problem solving may imply that the tendency to generate many diverse categories of response impairs insight problem solving, which may reflect the necessity of focused, convergent thinking for successful solution of insight problems.

Non-insight problem solving and individual differences

Only convergent thinking was a significant predictor of non-insight problem solving in another linear regression: $F(4, 129) = 5.486$, $p < 0.001$, with an R^2 of

Table 2. Pearson correlations between problem solving and individual difference measures in filtered data-set ($N = 132$).

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
1. Insight problems	–	**0.372** ***	**0.095**	**0.372*****	**0.225****	**0.183***	**0.252****	−0.001	0.027	−0.014	−0.045
2. Non-insight problems		–	**0.228****	**0.275****	**0.156**	**0.130**	**0.166**	0.021	0.071	−0.110	0.025
3. CRAs			–	**0.004**	**0.051**	**0.094**	**0.050**	0.065	0.091	0.066	0.115
4. Raven's				–	0.108	0.006	0.126	0.040	0.047	−0.083	0.148
5. DT: Flexibility					–	0.828***	0.992***	**0.216***	0.006	0.028	-0.035
6. DT: Fluency						–	0.831***	**0.185***	0.025	−0.054	0.016
7. DT: Originality							–	**0.212***	0.019	0.038	-0.029
8. O-LIFE: UE								–	0.333***	0.493***	0.441***
9. O-LIFE: IA									–	0.177*	0.208*
10. O-LIFE: CD										–	0.356***
11. O-LIFE: INC											–

$^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$

Note: DT, divergent thinking; CRA, Compound Remote Associates; Raven's, Raven's Advanced Progressive Matrices; O-LIFE truncations: UE, Unusual Experiences; IA, Introverted Anhedonia; CD, Cognitive Disorganisation; INC, Impulsive Non-conformity.

Relationships discussed in text are emphasised in bold.

Table 3. Linear regression of convergent and divergent thinking measures against problem solving variables.

Independent variable	Dependent variable								
	Insight composite			Non-insight composite			CRA composite		
	βWt	t	R^2	βWt	t	R^2	βWt	t	R^2
intercept		0.244	0.200		2.889	0.092		5.967	0.032
Raven's	0.332***	4.028		0.260**	2.961		0.021	0.231	
DT: Flexibility	−1.227*	−1.995		−0.308	−0.469		−0.107	−0.158	
DT: Fluency	0.082	0.563		0.103	0.661		0.328*	2.039	
DT: Originality	1.341*	2.144		0.337	0.506		−0.175	−0.254	

*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.
Note: DT, divergent thinking.

0.093, fluency: $\beta = 0.25$, $p = 0.08$, flexibility: $\beta = -0.01$, $p = 0.99$, originality: $\beta = -0.01$, $p = 0.99$ (see Table 3). Raven's Advanced Progressive Matrices: $\beta = 0.23$, $p = 0.002$. This finding is consistent with research indicating that divergent thinking independently predicts insight problem solving (DeYoung et al., 2008). The relationship between insight and non-insight problems and the ability of convergent thinking to predict solution accuracy on both may simply be a reflection on the necessity of individuals to respond with fitting solutions.

Compound Remote Associates and individual differences

There was no indication of significant relationships between CRAs and either insight problems or any of the measures of divergent thinking (see Table 2). The regression using the measures of convergent and divergent thinking as predictors was not significant $F(4, 129) = 1.046$, $p < 0.386$ (see Table 3 for beta weights). Within a non-significant regression, only divergent-thinking fluency (number of ideas generated) was a significant predictor of solution, possibly indicating that the more words an individual is able to generate within a short time frame, the more likely they are to stumble upon an answer to a verbal question.

Summary

Although our analyses indicated relationships between positive schizotypy and creativity, and between creativity and insight problems, no facets of schizotypy were predictive of problem-solving accuracy. Thus, the current study did not replicate the results of Karimi et al. (2007) despite a larger sample and larger problem set. This calls for caution in the use of insight problems as a measure of creativity without accounting for convergent-thinking processes. Our results further indicate that though the ability to generate many and diverse ideas, particularly atypical ideas, may be helpful in problem solving, the ability to selectively focus on the merits of possible solution to generate a logical and meaningful response is more important. This is further

reflected by the moderate relationship between the Raven's Matrices and both classic problem-solving tasks (insight and non-insight alike). There was a similarly strong relationship between classic insight and non-insight problems, perhaps indicative of the common role of convergent-thinking processes for both types of problems. Despite the moderately positive relationship between classic non-insight/insight problems, there was no evidence for a relationship between CRAs and classic insight problems (cf. Ansburg, 2000).

Experiment 2

We sought in Experiment 2 to replicate our Experiment 1 results using a sample that was explicitly selected with English as the first language. A further aim of Experiment 2 was to investigate the effect of feedback on reported insight. These data are not reported here, as we are focusing on solution accuracy rather than reported insight; hence, we only report analysis of the responses taken before the feedback was revealed for each problem. (Investigations of reported insight can be found in Webb et al., 2016.)

Method

Participants

Undergraduates from the University of Melbourne (N = 129: 88 female; age range: 17–45; mean: 19.059) completed the tasks for course credit. Twelve participants were removed for errors in more than 20% of the tasks.

Materials, procedure, and design

The materials and procedure were identical to Experiment 1, except that participants were given the solution to the problem after their initial attempt.

Results and discussion

The directions and strengths of correlations between variables were largely replicated (see Table 4). Insight and non-insight problems remained strongly positively correlated. The strong positive relationship between Raven's and both classic insight and non-insight problems was also replicated. Convergent thinking remained most important in predicting the relationship in both insight and non-insight classic problem-solving tasks, while not being predictive of the ability to solve CRAs (see Table 5). As in Experiment 1, there were no significant predictors of CRA solution accuracy: $F(4, 102) = 0.963$, $p = 0.431$.

Table 4. Pearson correlations between problem solving and individual difference measures in filtered data-set ($N = 119$).

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
1. Insight problems	–	**0.342** ***	**0.243** **	**0.370** ***	**0.209** *	**0.187**	**0.073**	0.097	0.058	0.068	0.040
2. Non-insight problems		–	**0.158**	**0.309** ***	**0.263** **	**0.103**	**0.224** *	0.073	0.009	0.041	0.021
3. CRAs			–	**0.107**	**0.194** *	**0.176**	**0.114**	0.060	−0.010	0.050	−0.071
4. Raven's				–	**0.239** *	0.101	0.178	0.165	−0.031	0.128	0.057
5. Flexibility					–	0.793 ***	0.719 ***	**−0.042**	0.053	0.015	−0.068
6. Fluency						–	0.604 ***	**0.048**	0.071	0.019	0.011
7. Originality							–	**0.074**	0.032	0.105	0.061
8. O-LIFE: UE								–	0.673 ***	0.772 ***	0.679***
9. O-LIFE: IA									–	0.639 ***	0.505***
10. O-LIFE: CD										–	0.699***
11. O-LIFE: INC											–

*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$

Note: DT, divergent thinking; CRA, Compound Remote Associates; Raven's, Raven's Advanced Progressive Matrices; O-LIFE truncations: UE, Unusual Experiences; IA, Introverted Anhedonia; CD, Cognitive Disorganisation; INC, Impulsive Non-conformity.

Relationships discussed in text are emphasised in bold.

Table 5. Linear regression of convergent and divergent thinking measures against problem-solving variables ($N = 119$).

Independent variable	Dependent variable								
	Insight composite			Non-insight composite			CRA composite		
	βWt	t	R^2	βWt	t	R^2	βWt	t	R^2
intercept		0.014	0.210		3.857	0.093		7.855	0.036
Raven's	0.359***	4.009		0.251**	2.669		0.061	0.613	
DT: Flexibility	0.319	1.924		0.252	1.447		0.037	0.204	
DT: Fluency	0.043	0.298		−0.174	−1.140		0.183	1.139	
DT: Originality	−0.234	−1.854		0.088	0.668		−0.073	−0.525	

*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

Interestingly, in Experiment 2, only scores on Raven's Advanced Progressive Matrices were a significant predictor of insight problem solving: $F(4, 102) = 6.775$, $p < 0.001$, with an R^2 of 0.210 (see Table 5 for beta weights). This again reflects the role of convergent thinking for the solution of insight problems.

There was again no evidence for a relationship between any facets of schizotypy and problem solving; these results are inconsistent with those of Karimi et al. (2007), yet fit with the findings of Mohr et al. (2001), who posited that convergent-thinking ability mediates chaotic activation in individuals high in positive schizotypy in order to solve convergent tasks.

We were unable to replicate the positive relationship between divergent-thinking measures and positive schizotypy (see Table 5). This is reflective of the unreliability of the findings in the literature regarding this relationship (Batey & Furnham, 2008), and we urge caution in the use and interpretation of these variables.

The positive relationship observed in Experiment 1 between CRAs and non-insight problems was *not* replicated; rather, in Experiment 2, there was a significant positive relationship between CRAs and classic insight problems: $r(118) = 0.243$, $p = 0.008$). Inspection of CRA scores with individual classic insight problems (see Table 6) indicated that the relationship was driven by two of the insight problem riddles used in Schooler and Melcher (1995) in Experiment 2, and one of the non-insight problems in Experiment 1 (see Supplementary Materials for full correlation matrices of individual problems and individual difference measures). This finding highlights the problem of using restricted problem sets (Bowden et al., 2005).

Table 6. Pearson correlations between classic insight problems and CRAs ($N = 119$).

	1.	2.	3.	4.	5.	6.
1. Egg timer	–	0.192*	0.164	0.447***	0.279**	0.162
2. Triangle of coins		–	0.247**	0.205*	0.165	0.070
3. Socks			–	0.384***	0.110	0.073
5. Lilies				–	0.318***	0.184*
5. Antique Coin					–	0.306***
6. CRAs						–

*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

General discussion

Two experiments explored the relationship between facets of schizotypy, convergent thinking, divergent thinking and insight problem solving. There was no evidence for a relationship between any facets of schizotypy and any of the problem-solving tasks (classic insight, non-insight or CRAs). While our results contrast with the conclusions of Karimi et al. (2007), they are consistent with the speculation of Mohr et al. (2001) regarding a positive relationship between loose associative thinking and positive schizotypy, mediated by general intelligence or convergent thinking ability. Indeed, convergent thinking was a reliable significant predictor of both classic insight and non-insight problem solving; however, surprisingly, this relationship was not observed between convergent thinking and CRAs.

We found no relationship between convergent thinking (as measured by Raven's Matrices) and positive schizotypy, nor any other facets of schizotypy (cf. Claridge & McDonald, 2009). These results are consistent with evidence indicating that individuals scoring high in positive schizotypy have loosened associative language processing (Tonelli, 2014) and have lower cognitive inhibition (Green & Williams, 1999) relative to individuals low in positive schizotypy. Thus, individuals high in positive schizotypy may activate more distal points of semantic networks and so perceive more words as being related while performing no better on focused tasks (Kyriacou et al., 2003; Mohr et al., 2001). Furthermore, these individuals may generate a lot of ideas but require higher levels of fluid intelligence in order to solve the problems (Mohr et al., 2001). This result also aligns with the observation that high schizotypy individuals scored better on divergent problems, while low-scoring individuals performed better than their counterparts on convergent problems (Jones et al., 2011). Overall these results reflect the convergent and focused nature of insight tasks.

In Experiment 1, there was a positive relationship between flexibility and originality of thought and positive schizotypy, possibly reflecting the activation of distal semantic network points (Carson, Peterson, & Higgins, 2003; Claridge & McDonald, 2009; Mohr et al., 2001; Peterson, Smith, & Carson, 2002); however, the lack of reliability in our results also reflects an inconsistency in the published data (e.g., Suzuki & Usher, 2009; Vartanian, 2009). Vartanian (2009), in particular, found the opposite direction of effect with a positive relationship between creativity and the *strengthening* of inhibition functions. Along these lines, Batey and Furnham (2008) note that there may be a difference between reported creativity and creativity measured by a divergent-thinking task, possibly as real creative achievement requires convergent, as much as divergent, thinking. Guilford (1981) proposed that above a certain threshold of intelligence, the degree of creativity has little effect on performance. It is therefore possible that there is a diversity of schizotypy and

creativity in the current sample but that intelligence mediates any variation in levels of schizotypy.

Flexibility and originality were shown to have relationships with, but unreliable predictive power for, the solution of both classic insight and non-insight problem solving. This is consistent with findings in the literature, such as those of Gilhooly and Murphy (2005), who similarly found a correlation between the Alternative Uses Task (fluency scores) and both insight and non-insight problem solving, as well as the lack of predictive power of fluency to predict solutions. Lee and Therriault (2013) found an unreliable relationship between divergent-thinking measures and two classic insight problems they used. This may be seen as further evidence of spreading activation being helpful, but not necessary in insight problem solving; rather, the moderate positive relationship between convergent thinking and classic problem solving may reflect that insight and non-insight problems are solved with similar processes (Fleck & Weisberg, 2013), and that both may require, on average, equal amounts of restructuring and creativity.

Benedek, Jauk, Sommer, Arendasy, and Neubauer (2014) conducted latent modelling of *updating*, *inhibition* and *switching*, which are processes proposed to underlie both divergent and convergent thinking. Updating was measured by how accurate comparisons were with consistently and swiftly updating information; inhibition was measured by Stroop tasks, and switching by the ability to change between tasks. Benedek et al. found that updating was important for both divergent and convergent thinking, while inhibition was more important for creativity. The ability to inhibit unproductive trains of thought may, therefore, underlie problem-solving success for both classic insight and non-insight problems, yet that same process inhibits excessive semantic activation.

Links between creativity and psychopathology remain hotly debated in the literature (for reviews and meta-analyses, see Acar & Runco, 2012; Acar & Sen, 2013). The current study considers the processes underlying schizotypy in a high-functioning, healthy sample, and finds no relationship between any facets of schizotypy and problem-solving ability. This possibly reflects the protective nature of high intelligence against an inability to inhibit irrelevant information (Batey & Furnham, 2006), and consequently results in the observed differences in divergent-thinking tasks, but not in convergent-thinking tasks.

Problem-solving tasks and Compound Remote Associates

Evidence of a positive relationship between divergent-thinking scores and CRAs was not reliable across studies, with evidence for a positive relationship between flexibility and CRA solution Experiment 2, but no evidence in Experiment 1. Although there is evidence for a relationship between divergent thinking and CRA solution in the literature (e.g., Jones & Estes, 2015), the lack

of reliability aligns with a literature that struggles to replicate the finding of divergent-thinking requirements in both CRAs and remote associates (Lee, Huggins, & Therriault, 2014; Suzuki & Usher, 2009).

Though both classic insight problems and CRAs indicated relationships with creativity, the relationship between these problem types was not as reliable as expected. This was a surprising result, as CRAs are commonly used as insight problems in the current literature (Jung-Beeman et al., 2004; Kounios et al., 2008; Salvi, Collier, Bricolo, Kounios, & Beeman, 2012). Indeed, though Ansburg (2000) found a positive relationship between CRAs and insight problems, this finding was unreliable in Cunningham, Macgregor, Gibb, and Haar's (2009) study, who also investigated insight questions and Remote Associate Task scores and found a relationship between Remote Associate Tasks and in one group of insight questions, but not in a second group. In the current study, the relationship between insight problems and non-insight problems was both more reliable and stronger than between the classic insight problems and CRAs, which may indicate simply the similarity of cognitive processing behind longer vignettes within individual problems. This calls for investigation regarding the validity of using CRAs interchangeably with classic insight problems (particularly given the way individual problems drove the relationship between classic problem solving and CRAs, see Table 6), as the assumptions made from a literature using the classic insight riddles may not generalise, and urges caution in generalising research and theories developed using classic insight problems to CRAs. However, it is important to note that these were CRAs developed in America used in an Australian sample, and that there was a lower accuracy rate in the current sample. Further studies may investigate the relationship between classic vignette riddles and CRAs, and their cultural specificity (e.g., Salvi et al., 2016).

Despite careful data collection and analyses, there are some aspects of the current methodology that could be improved upon. Though some of these are typical of the insight literature, others are particular to our research question: (1) the unreliable relationships between individual differences and insight problem-solving tasks, particularly when using a small problem set. Although we extended the problem set of Karimi et al. (2007), we only used 10 classic problems (5 insight; 5 non-insight). Given the diverse types of insight problems (Cunningham et al., 2009; Gilhooly & Fioratou, 2009; Gilhooly & Murphy, 2005), it is possible that some insight problem types or tasks are improved by divergent thinking, while others are not (see, for instance, Lee & Therriault, 2013, who used two insight problems, and found distinct results regarding intelligence and creativity for each problem). For instance, predicament problem solving (see e.g., Puccio, Murdock, & Mance, 2007) has been shown to benefit from divergent-thinking processes. (2) It is possible that it is loose *associative* thinking, rather than divergent thinking, that is underlying the relationship between schizotypy and insight. (This is congruent with the

loose cognitive style found by Partos et al. (2016).) As the Alternative Uses Task measures verbal and creative fluency and flexibility, rather than associative thoughts, future investigations may benefit from word association tests (e.g., the Controlled Oral Word Association Test; Benton, Hamsher, & Sivan, 1994; see also Ruff, Light, Parker, & Levin, 1996). (3) Finally, we used a measure of convergent thinking which is also a measure of fluid intelligence (Raven's Matrices); however, as intimated by the filtering of students without English as the first language, classic insight problems and CRAs alike require high levels of crystallised verbal knowledge. This is congruent with the findings of Batey and Furnham (2006) in their investigation of CRAs, indicating that these problems may be more related with verbal fluency than flexibility of thought (Ansburg, 2000).

Conclusion

Although schizotypy may be related to divergent thinking, divergent thinking is not sufficient to solve insight problems. Rather, it is possible that verbal fluency, divergent thinking and convergent thinking all interact to predict ability to solve insight problems. Despite the use of insight problems to investigate creativity, and the contrast of insight and non-insight problems to access differing underlying processes, there still remains a debate regarding whether these problems are reliably solved with those underlying processes (Fleck & Weisberg, 2013), and thus whether insight and non-insight problems are reliably different (Danek et al., 2016). Our results call into question a number of previous investigations that showed significant relationships but with smaller samples or restricted sets of questions. Given the ongoing concerns regarding replicability in Psychology (Open Science Collaboration, 2015), we offer these studies as a clarification of a complex pattern of relationships between schizotypy and problem solving.

Disclosure statement

No potential conflict of interest was reported by the authors.

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