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Examining the Relationships among Working Memory, Creativity, and Intelligence

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A thesis submitted to the Department of Psychology

in partial fulfillment of the requirements for the degree of

Master of Arts in General Psychology

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COLLEGE OF ARTS AND SCIENCES

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Abstract

In this study we investigated the relationships among working memory, creativity (measured as divergent thinking and creative achievement) and nonverbal intelligence. Furthermore, this study examined the roles of working memory and intelligence in the creative process. In order to examine this, participants were evaluated using a variety of cognitive tasks that included the Alternative Uses Test, the Consequences Task, the Creative Achievement Questionnaire, the Alloway Working Memory Assessment, and the matrix test from the Wechsler Abbreviated Scale of Intelligence. The results of this study indicate that verbal working memory was related to divergent thinking over and beyond intelligence and creative achievement. Nonverbal intelligence was found to be related to divergent thinking over and beyond working memory. Finally, according to the model used in this study, creative achievement was the best predictor of divergent thinking. The findings of this study expand on the previous literature pertaining to the relationships between working memory, creativity and intelligence.

Keywords: creativity, working memory, intelligence

Examining the Relationships between Working Memory, Creativity, and Intelligence

Two cognitive skills that are associated with creativity are intelligence and working memory. Currently, there are studies that have found relationships among these constructs (Silva, 2008; Vandervert, Schimpf, & Liu, 2007; De Dreu, Nijstad, Baas, Wolsink; & Roskes, 2012; Colom, Abad, Quiroga, Shih, & Flores-Mendoza, 2008), but it is still unclear how intelligence and working memory are involved in the creative process. The aim of the present research is to further explore the nature of the relationships between working memory, creativity, and nonverbal intelligence, in addition to the role intelligence and working memory each play in the creative process.

Creativity

There are many different ways to define and measure creativity. It can be assessed through divergent thinking, associations, performance, and self-report, just to name a few. Divergent thinking is a key component of creativity and has been defined by Guilford and Guilford (1980) as “the efficient generation of a variety of ideas to met a given question or problem” (as cited in Jones, et al., 2009, p. 324). A divergent thinking task requires individuals to generate original and appropriate answers to open ended, vague problems (e.g., “What would be the results if none of us needed food anymore in order to live?”) (Benedek, Konen, & Neubauer, 2012; Jones et al., 2009; Sternberg & Lubart, 1996) and is one of the most often used measures for creativity (Furnham & Bachtiar, 2008). Divergent thinking is comprised of features such as fluency (e.g. the number of responses a person provides to a given question or problem), flexibility of thinking (e.g. the number of categories their responses fall into), originality (e.g. how uncommon a response is within the population sample) and figural or verbal elaboration (e.g. the amount of detail the participant provides in their response) (Batey & Furnham, 2006; "Creativity Test," n.d.).

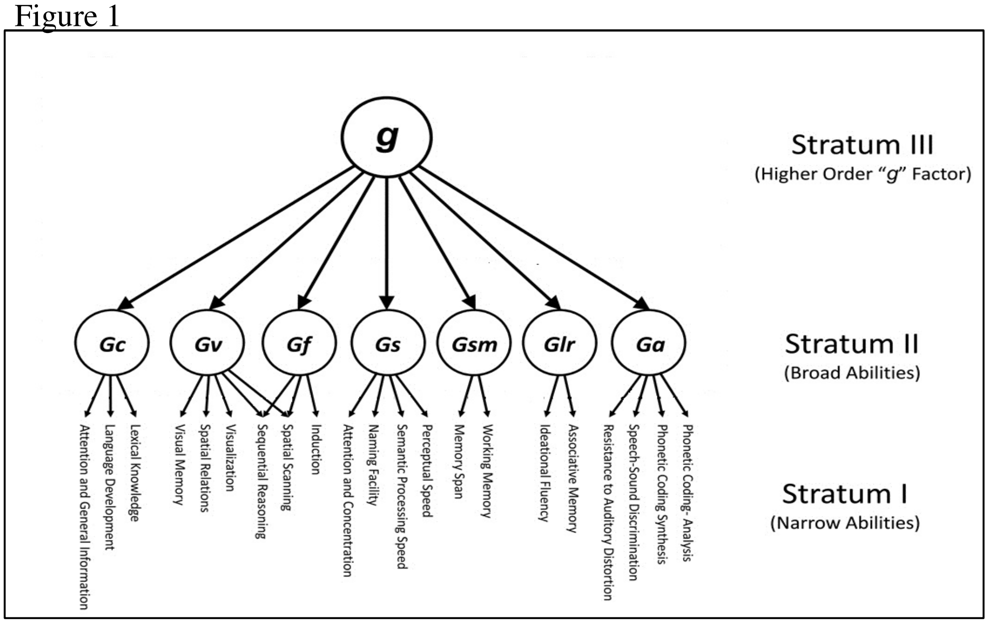
Creative achievement appears to be moderately related (r= .47) to divergent thinking (Carson, Peterson, & Higgins, 2005). Creative achievement is defined as the total amount of creative products (musical composition, poem, medical cure, etc.) that are generated by a person during his/ her lifetime. This type of assessment allows for the measurement of significant, observable accomplishments and also allows researchers to measure general creativity in both domain specific and domain general areas (Silvia, Wigert, Reiter-Palmon, & Kaufman, 2012; White & Shah, 2011). Domain specific creativity refers to creativity that is specific to one area; in contrast, domain general creativity suggests that a person who is creative in one capacity is also creative in other areas as well (Silvia, Kaufman, & Pretz, 2009).

Intelligence

Definitions of intelligence vary from very specific to very broad; Sternberg and Detterman (1986) define intelligence as "a person's ability to adapt to the environment and to learn from experience" (as cited in Sternberg, 2005, p.189). Sternberg's theory of intelligence divides intelligence into three interrelated parts: analytic intelligence, creative intelligence, and practical intelligence (Ekinci, 2014). Analytical intelligence is typically used when the problem at hand is familiar and the decisions made are theoretical (e.g. academic problems). Creative intelligence is used for more novel problems; people who are strong in this type of intelligence are better able to generate new ideas. Lastly, practical intelligence is used for problems that arise in daily life (e.g. issues at work or at home); individuals who score highly for this type of intelligence are best at the application of ideas (Sternberg, 2005; Ekinci, 2014).

An alternate theory of intelligence is the Cattell-Horn-Carroll (CHC) theory. This theory is a combination of the Cattell-Horn theory, which divided intelligence into fluid and crystallized intelligence and is based on of an eight factor model, and Carroll's Three-Stratum Theory, which divided abilities into narrow, broad, and general (Flanagan, 2007). Narrow abilities are identified as abilities that require in-depth knowledge; they are typically specific in the way that they reflect knowledge or performance approaches. Broad abilities are basic characteristics of a person that could influence a variety of behaviors in an area (e.g. the broad ability of fluid intelligence is made up of more narrow abilities such as recognizing relationships within patterns or deductive reasoning). While general abilities are composed of both narrow and broad abilities, this general factor is used for more complex cognitive processes (see Figure 1) (Flanagan, 2007). For the purpose of this study, the focus is on the general aspect of nonverbal intelligence, using a nonverbal form of intelligence decreases the chance for language differences and certain disabilities (e.g., hearing loss) to influence performance (De Thorne & Schaefer, 2004).

Figure 1



Modified from Fig. 4, Tucker-Drob, 2010

Creativity and Intelligence.

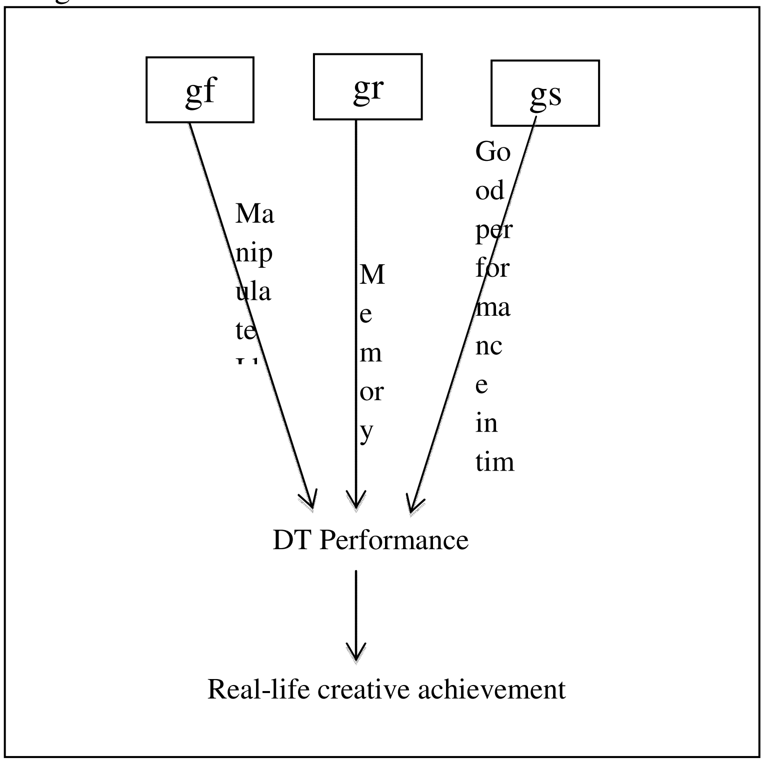
Researchers have suggested that some minimum level of intelligence is required for the creation of a new idea or product to occur (Silva, 2008). However, opinions on the type of relationship that exists and the strength of this relationship differ. Following a review of the literature, Batey and Furnham (2006) suggest that there is a modest correlation between intelligence and creativity typically ranging between r= .20 and r= .40. Sternberg provided a few different possibilities for how creativity and intelligence could be related. One view of this relationship is that creativity is a subset of intelligence, while others think the inverse is true and intelligence is a subset of creativity. An alternate theory about this relationship is that creativity and intelligence are overlapping sets, because in order to shape an environment to suit oneself, a person must have the imagination to visualize what the environment could be and how to turn that vision into a reality. Even at a minimum it seems that creativity involves certain aspects of intelligence (Sternberg & O'Hara, 1999; Kaufman & Plucker, 2011).

Furnham, Crump, Batey, and Chamorro-Premuzic (2009) were interested in further examining the relationship between creativity and intelligence. They chose to measure creativity as divergent thinking through the Consequences test, and intelligence was measured through both the Graduate and managerial assessment and The Watson-Glaser critical thinking appraisal. The results of this study showed a positive relationship between divergent thinking and intelligence, but the correlation was low (r= .12). The researchers further explored this relationship through step-wise regressions and found that intelligence was a significant predictor of divergent thinking, however, it only accounted for a very small portion of the variance (1.5% to 3.3%) (Furnham, et al., 2009).

Creativity can be measured by both fluency and originality, as discussed above. However, there is a stronger relationship between creativity and intelligence when creativity is measured as fluency than when creativity is measured as originality. Batey, Furnham, and Safiullina (2010) examined the relationship between creativity, measured through rated divergent thinking, fluency of divergent thinking, creative achievement, self-rated creativity, and a total score of these creativity tests, and intelligence, measured through fluid intelligence and general knowledge. The researchers found that only the fluency component of divergent thinking (r=. 27), and rated divergent thinking (r= .26) were related to fluid intelligence. When the creativity tests were combined for a total score, it was also found to be significantly related to fluid intelligence (r= .29). However, general knowledge did not seem to be significantly related to any of the creativity tests used in this study (Batey, et al., 2010).

This relationship between fluency and intelligence could be a result of the use of timed creativity tests (Batey & Furnham, 2006). The neural abilities that are part of intelligence are needed to support a high fluency score. Under timed conditions faster neural performance tends to lead to improved performance on divergent thinking tasks. The fluency score of a task partially relies on cognitive speed and the ability to retrieve information from memory, in addition to fluid intelligence (see Figure 2) (Carroll, 1993; Batey & Furnham, 2006).

Figure 2



Modified from Fig. 1, Batey & Furnham, 2006, p. 380

Working Memory

Working memory is the combination of multiple mental tasks some of which include the ability to focus attention, mental rehearsal, and manipulation of information (Colom, Rebollo, Palacios, Juan-Espinosa, & Kyllonen, 2004). Traditionally it consists of the central executive, as well as two additional storage systems, the phonological loop and the visuospatial sketchpad (Baddely, 2003). While there is little that is understood about the role of the central executive component of working memory is mostly thought of as a supervisory component that utilizes the frontal lobe and is responsible for activation, decision making and planning in regards to working memory and long term memory systems (Baddeley, 1996; Baddeley, 2000; Baddeley, 2003; Sauseng, Klimesch, Schabus, & Doppelmayr, 2005).

The phonological loop consists of a phonological store, which holds language and sound memory traces for a limited time, usually a few seconds, before the memory fades away. The fading of the memory traces can be delayed through rehearsal of the information that is being stored. The visuo-spatial sketchpad is responsible for temporary storage of visual information; it is usually limited to three to four objects at a time (Baddely, 2000; Baddely, 2003). A fourth component, which is thought to be controlled by the central executive component, is the episodic buffer. The episodic buffer is an important addition because it is thought to be responsible for integrating information from multiple sources or systems into one memory episode that can be consciously retrieved (Baddely, 2000).

According to De Dreu et al. (2012), working memory is the system that keeps information available for complicated cognitive activity; this would include activities like language comprehension, planning, and reasoning. There are two basic responsibilities of working memory; the first is to keep new information in an enhanced state of activity and the second is to differentiate between information that is task-relevant or task-irrelevant (Unsworth & Engle, as cited in De Dreu et al., 2012, p.657). Because working memory requires not only the retention of information but also the manipulation of information, tasks that measure this are characterized as dual tasks. This is because a person must shift their attention between the list items and the processing component of the task at hand (e.g. mentally rehearsing the directions, while driving to a location) (Engle, Tuholski et al., as cited in Colom, et al., 2008, p.585; Alloway & Copello, 2013).

Creativity and Working Memory.

Vandervert et al. (2007) are some of the few researchers to examine the relationship between creativity and working memory. They believe that working memory is where creativity and invention begin. This could be because working memory is a system that allows people to piece together different ideas and thoughts, and is sometimes referred to as the "blackboard of the mind" (Vandervert et al., 2007, p. 3). De Dreu et al. (2012) suggests that creative ability is affected by a person's ability to maintain focused attention and executive control. This type of executive control includes working memory, which led to their hypothesis that creativity and working memory capacity are positively correlated. Furthermore, it has been suggested that the two basic functions (maintain new information and identify relevant information) of working memory discussed previously are vital to creative performance. To be creative a person must override habitual tendencies in order to be able to combine information into new ideas. The authors of this study found that working memory predicts fluency and originality. Also, working memory was related to creativity beyond general intelligence.

However, not all researchers agree upon this view. An alternate perspective is that a high working memory might hinder creativity. Takeuchi et al. (2011) were interested in how training working memory could affect the performance of other cognitive functions. They found that when participants used mental calculations to train their working memory their verbal working memory scores and their performance on other cognitive tasks improved. However, their creative ability, measured through divergent thinking, was reduced.

A study involving children with hyperactivity provides further support for how improving working memory can hinder creativity. Hyperactive children tend to perform poorly on working memory tasks, but they also possess many of the characteristics that are used to describe a creative person (Kuntsi, Oosterlaan, & Stevenson, 2001; Shaw, 1992). When hyperactive children were placed on medication for their hyperactive behaviors their working memory capacity, when measured through visual search and attentional-set shifting, improved

(Mehta, Goodyer, & Sahakian, 2004). However, while on the medication their performance on creative tasks was impaired, especially when divergent thinking was measured through elaboration (Swartwood, Swartwood, & Farrell, 2003).

Working memory and Intelligence.

There are considerable gaps in what is understood about the components that underlie the relationship between working memory and intelligence, although there is evidence to suggest there is a strong relationship between the two (Colom et al., 2008; Chooi, 2012). These gaps in understanding could be due to a lack of comprehensive assessments, some studies only consider parts of working memory like verbal, visuo-spatial or quantitative individually but not as a collective whole (Colom et al., 2008). Colom et al. (2008) found that simple short-term storage is what mediates the relationship between working memory and intelligence. Short-term storage is typically used to remember pieces of information for very brief periods of time; if this information is not rehearsed it will be forgotten (e.g. remembering directions; Alloway, Gathercole, & Pickering, 2006). However, working memory is different, it allows a person to mentally rehearse the directions they were given while following the directions, and are then able to drive to the location they were trying to reach (Alloway & Copello, 2013). If the simple short-term storage component is ever statistically removed then the remaining working memory component is no longer related to intelligence (Colom et al., 2008). The consensus of recent investigators suggests that working memory and intelligence are not identical concepts, even though these constructs are considered highly related to each other (Ackerman et al., 2005; Colom et al., 2003; Kane et al., 2005; Kyllonen & Christal, 1990; Oberauer et al., 2005, as cited in Chooi, 2012, p.46).

Current Study

De Dreu et al. (2012) report that working memory capacity and creativity both have been found to correlate with general intelligence. However, previous research does not clearly answer the question: are working memory and creativity related only through intelligence? Very few researchers have explored the possibility of a direct relationship between working memory and creativity.

In this exploratory study, we are interested in taking a closer look at the relationships between working memory, creativity, and intelligence. We are interested in identifying if working memory is not only related to creativity, but if it can also be considered a predictor of creativity. We are also interested in exploring a relationship between creativity and intelligence, in order to clarify how these constructs relate to each other.

Method

The sample for this study consisted of 166 students enrolled at the University of North Florida. Of the students in our sample 29 were Freshmen, 21 were Sophomores, 65 were Juniors, and 51 were Seniors. A large portion of our sample (42.77%) were between 18 and 20 years old, 30.72% were between 21 and 23 years old, 9.64% were ages 24-26, and 15.66% were 27 or older. The majority, 53.61%, of the participant’s ethnicity was Caucasian, 18.07% were African-American, 13.25% were Hispanic, 7.23% were Asian/Pacific Islander, and 7.83% identified their ethnicity as Other.

Creativity Tests

Two tests were used to measure divergent thinking. One test used was Guilford’s Alternative Uses Task; this task is a well-known measure of creativity in which participants are asked to list as many possible uses as they can for everyday items (Allmaras & Ferraro, 2010). In the present study, participants were presented with common objects, a pen and a brick, and given two minutes per object to write their responses. These responses were then scored on four components: originality, fluency, flexibility, and elaboration. The scoring for originality is based on a comparison within the group's set of responses, not to a standard response; the less often a response occurs the more original it is considered. Fluency is scored based on the number of responses the participant provides (e.g. six responses are worth six points). Flexibility is scored on how many different categories the responses can be divided into (e.g. using a rock as a weapon would be in the same category as using a rock to hit a person). Finally, elaboration is scored based on the amount of detail a person provides in their response, the more detail provided the more points the participant receives (e.g. using a brick as a step to reach a book on a high shelf is worth more points than just saying you can use a brick as a step.) ("Creativity Test," n.d.). Since the four components of scoring for this task are based off the responses from open-ended questions reliability was evaluated through inter-rater reliability, for this study an inter-rater reliability was calculated for elaboration (.53) and for flexibility (.88). We chose to calculate an inter-rater reliability for these two categories because they were the most vulnerable to individual differences in scoring.

The Consequences Test was another test used to measure divergent thinking. This task is a popular measure of divergent thinking, and has been for some time. Part of its attractiveness comes from the fact that it does not draw on existing knowledge so it can be used across different populations (Furnham, et al., 2009). Similar to the Alternative Uses Test, it measures the originality of responses and ideational fluency, as well as divergent thinking, and has also been found to be a valid predictor of creativity. Participants were asked to produce a number of possible consequences to the presented scenario or situation (Jones, et al., 2009). Participants were presented with two different scenario questions and given two minutes per scenario to produce as many responses as they could. An example of a scenario is, "What would be the results if none of us needed food anymore in order to live?" (Jones, et al., 2009). The responses from this task were scored in the same way as the responses from the Alternative Uses Test.

The Creative Achievement Questionnaire is a three part self-report checklist that consists of a total of ninety-six items (Carson, et al., 2005). This questionnaire measures creative achievement in 10 domains: drama, humor, music, visual arts, creative writing, invention, scientific discovery, culinary arts, dance, and architecture. This allowed for an achievement score to be calculated for each domain, in addition to, an overall test score. Carson, et al. (2005) tested the internal consistency of the CAQ and found it to have high internal reliability with an $\alpha = 0.96$, in addition the test-retest reliability showed a significant correlation of .81.

Working Memory Tests

Working memory was measured using a standardized memory assessment, the Alloway Working Memory Assessment (AWMA-2, Alloway, 2012). All test trials began with two items (e.g. a letter or Mr. X), and increased by one item in each block, until the participant was unable to recall three correct trials at a particular block. There were four trials in each block and the number of correct trials was scored for each participant. The move forward and discontinue rules, as well as the scoring, were automated by the program.

The Screener version was administered and this comprised of one verbal and one visuo-spatial working memory test. In Processing Letter Recall (verbal working memory), the participant views a letter in red that stays on the computer screen for one second. Another letter in black immediately follows this on the screen. Participants verify whether or not the black letter was the same as the red letter by clicking on a box marked either ‘Yes’ or ‘No’ on the screen. They then click on the red letters they saw in the correct sequence.

Visual working memory was tested using the Mr. X test. Participants are presented with a picture of two Mr. X figures. They identify whether the Mr. X with the blue hat is holding the ball in the same hand as the Mr. X with the yellow hat. The Mr. X with the blue hat may also be rotated and can appear upside down or sideways during the trial. At the end of each trial, participants have to recall the location of each ball in Mr. X’s hand in sequence, by pointing to a picture with eight compass points. Both the Mr. X figures and the compass points stayed on the computer screen until a response is provided. Test-reliability of the AWMA was established in a random selection of the normative sample tested on two separate occasions, four weeks apart. The reliability coefficient for the verbal working memory tests was .86 and for the visuo-spatial working memory test, it was .84 (Alloway, 2007).

Intelligence Test

Nonverbal intelligence was indexed with the matrix test from the Wechsler Abbreviated Scale of Intelligence (WASI, Wechsler, 1999). The participant is shown a set of shapes and has to select the next shape in the sequence from an array. Raw scores were converted into standard scores based on a normative sample (M=100; SD=15).

Procedure

Volunteers were recruited over a three-month period through an advertisment on the university research participation system. The criteria for participation were English as their first language, and at least 18 years of age. Individuals who chose to participate first completed the working memory tasks. They were then prompted to click on a link hosted by a third-party website, Qualtrics. Through Qualtrics, participants were first asked to report their scores from the working memory tasks and also asked to provide demographic information. They then completed the two divergent thinking tests and were given two minutes to complete each of the four questions. After this participants completed the Creative Achievement Questionaire, followed by the nonverbal intelligence task. Participants were given one hour to complete this series of assessments.

Results

Participants were scored on two divergent thinking tasks, each consisting of two questions, and one creative achievement task. Scoring for the divergent thinking tasks consisted of response times and total scores on each question, as well as scores for each of the subcomponents (fluency, flexibility, elaboration, and originality). The score for the creative achievement task consisted of all domain scores combined into one total score (see Table 1). The divergent thinking tasks had an average response time of 97.42 seconds. Participants spent the longest time responding to the *brick* question (102.91 seconds), while the *pencil* question had the shortest response time of 91.94 seconds. The fluency component of the *brick* question had the highest score, with a group mean of 8.17. While the participants scored the lowest on the elaboration component of both the *pencil* and *group* questions, with a group mean of .45 for each question.

Table 1: *The means and standard deviations for each of the creativity tasks.*

Creative Tasks						
	Response Time *(sec)*	Total Score	Fluency	Flexibility	Elaboration	Originality
Brick	102.91 (26.91)	21.88 (10.01)	8.17 (3.42)	5.15 (2.64)	.75 (1.35)	7.81 (4.32)
Pencil	91.94 (34.81)	20.08 (10.96)	7.74 (3.84)	5.16 (2.67)	.45 (.92)	6.71 (4.86)
Food	100.49 (28.93)	13.85 (7.01)	5.23 (2.67)	3.82 (1.94)	1.20 (1.27)	3.60 (3.04)
Group	94.34 (33.91)	14.63 (9.33)	5.08 (3.06)	4.05 (2.41)	.45 (.82)	5.13 (4.32)
Creative Achievement		8.93 (7.51)				

The participants were also assessed on three cognitive tasks. Participants scored an average of 104.05 on the verbal working memory task. The average score for the visual working memory task was 89.76, and the group mean for the nonverbal intelligence task was 103.42 (see Table 2).

Table 2: *The means and standard deviations for each of the cognitive tasks.*

Cognitive Tasks		
	Mean	Std. Deviation
Verbal Working Memory	104.05	17.537
Visual Working Memory	89.76	24.123
Nonverbal Intelligence	103.42	12.45

Correlations

Creativity and Working Memory.

Correlation analysis was used to explore the relationship between creativity, working memory, and intelligence (see Table 3). A significant relationship was found between verbal working memory and the *food* consequences question (r= .17), as well as the *group* consequences question (r= .25). However, verbal working memory was not significantly related to either the alternate uses for a brick or pencil.

A significant relationship was found between the total score on creative achievement and the total scores for the *food* consequences question (r= .31), and the *group* consequences question (r= .31). Significant relationships were also found between creative achievement and total scores for alternate uses of a *brick* (r= .17), and a *pencil* (r= .27). These results indicate a modest positive relationship between creative achievement and divergent thinking.

Due to the positive significant relationship between creative achievement and divergent thinking a partial correlation, with creative achievement as a covariate, was used to further explore the relationship between divergent thinking and working memory. The relationship between verbal working memory and divergent thinking was still significant for the *group* consequences question (r= .23), when creative achievement was a co-variate, but not for the *food* consequences question (see Table 3). This indicates that the relationship between the *group* consequences question and verbal working memory exists above and beyond the effects of creative achievement, but the relationship between the *food* consequences question and verbal working memory is weakened, suggesting creative achievement might be a partial mediator between verbal working memory and creativity when measured by divergent thinking.

The relationship between verbal working memory and creativity was significant for the total score of the *group* consequences question (r= .21) and creative achievement (r= .18) when intelligence was a co-variate, suggesting that verbal working memory has a unique relationship with creativity over and beyond the effects of nonverbal intelligence (see Table 4).

Creativity and Intelligence.

A significant relationship was found between nonverbal intelligence and the total scores for *brick* (r = .17). There was also a significant relationship found between nonverbal intelligence and the total scores of both of The Consequence Task questions, *food* (r= .19), and *group* (r= .16). These results indicate a modest positive correlation between nonverbal intelligence and the total scores for The Consequences Task, and the Alternate Uses for a brick task (see Table 3).

A significant relationship was found between nonverbal intelligence and the fluency score for *food* question (r=. 15). There was also a significant relationship found between nonverbal intelligence and the originality score for the *group* question (r= .16).

The relationship between nonverbal intelligence and creativity was still significant for the *brick* (r= .14) and *food* (r= .17) questions, when creative achievement was a co-variate, but not for the *group* question (see Table 3). This indicates that the relationship between nonverbal intelligence and the *brick* and *food* questions exists over and beyond the effects of creative achievement, but the relationship between the *group* question and nonverbal intelligence is weakened, suggesting that creative achievement could be a partial mediator between nonverbal intelligence and creativity, when measured by divergent thinking.

The relationship between nonverbal intelligence and creativity was significant for the total score of the *food* consequences question ($r = .17$) when working memory was a co-variate. This suggests that nonverbal intelligence has a unique relationship with creativity over and beyond the effects of working memory (see Table 5).

Table 3: *Zero-order correlation coefficients shown in lower triangle; correlation coefficients with creative achievement partialed out showed in upper triangle. For coefficients in excess of .16, p<.05; for coefficients greater than .23, p<.01*

Correlations

	Verbal WM	VS_ WM	RavensStnd Score	Brick RT	Brick_ Total	Pencil RT	Pencil_ Total	Food RT	Food_ Total	Groupfeeling RT	Group_ Total	CA_ TOTAL
VerbalWM	1	.42**	.12	-.13	.004	-.10	.02	.05	.14	.09	.23**	
VS_WM	.45**	1	.15	-.16	.00	-.12	-.04	-.04	.01	-.08	.05	
RavensStndScore	.13	.18*	1	.02	.14*	.07	.06	.12	.17*	.14	.08	
BrickRT	-.04	-.07	.01	1	.46**	.82**	.46**	.61**	.23	.56**	.21*	
Brick_Total	.04	.06	.17*	.47**	1	.35**	.60**	.23*	.40**	.14	.31**	
PencilRT	-.04	-.02	.06	.79**	.39**	1	.58**	.74**	.36**	.66**	.31**	
Pencil_Total	.052	.06	.10	.49**	.63**	.62**	1	.44**	.53**	.41**	.40**	
FoodRT	.11	.02	.07	.65**	.27**	.73**	.48**	1	.53**	.82**	.42**	
Food_Total	.17*	.08	.19*	.30**	.45**	.38**	.56**	.54**	1	.44**	.69**	
GroupfeelingRT	.13	-.05	.10	.54**	.18*	.61**	.41**	.79**	.45**	1	.51**	
Group_Total	.25**	.14	.16*	.25**	.37**	.34**	.47**	.43**	.73**	.53**	1	
CA_TOTAL	-.04	.15	.06	.04	.17*	.13	.27**	.12	.31**	.11	.31**	1

**. Correlation is significant at the 0.01 level (2-tailed). *. Correlation is significant at the 0.05 level (2-tailed).

Table 4*: Correlation coefficients with nonverbal intelligence partialed out shown in lower triangle; correlation coefficients with working memory partialed out in upper triangle. For coefficients in excess of .19, p<.05; for coefficients greater than .20, p<.01.*

Correlations								
	Brick_Total	Penicl_Total	Food_Total	Group_Total	CA_Total	RavensStndScore	VerbalWM	VS_WM
Brick_Total	1	.62**	.43**	.36**	.20**	.15	-	-
Pencil_Total	.62**	1	.56**	.47**	.30**	.07	-	-
Food_Total	.04	.57**	1	.72**	.33**	.17	-	-
Group_Total	.34**	.46**	.72**	1	.34**	.07	-	-
CA_Total	.19*	.30**	.31**	.33**	1	.05	-	-
RavensStndScore	-	-	-	-	-	1	-	-
VerbalWM	-.01	.01	.12	.21*	.00	-	1	-
VS_WM	.02	.01	.08	.01	.18*	-	.40**	1
**. Correlation is significant at the 0.01 level (2-tailed). *. Correlation is significant at the 0.05 level (2-tailed).								

Regression

We were also interested in the relationships between divergent thinking, working memory, creative achievement, and nonverbal intelligence. Stepwise regression analyses were conducted for the each of the divergent thinking questions and the response times. Model statistics, as well as standardized beta values and *t*-statistics, are provided in Table 5.

The total score for the food consequences question was the outcome variable and the predictor variables were verbal working memory, creative achievement, and nonverbal intelligence. The overall score on the creative achievement task was found to be a predictor of total score on the *food* consequences question (accounting for 9.6% of the total variance) followed by nonverbal intelligence (accounting for 3.1% of the total variance).

The total response time for the *food* consequences question was the outcome variable and the predictor variables were verbal working memory, creative achievement, and nonverbal intelligence. Overall, there was not a link found between participant's response time and nonverbal intelligence. However, total score on the creative achievement task did account for a significant proportion (3.2%) of the response time to the food consequences question.

The fluency score for the *food* consequences question was the outcome variable and the predictor variable was verbal working memory. This was found to be a predictor for creative fluency on the food consequences question, accounting for 5.8% of the total variance.

The total score for the *group* consequences question was the outcome variable and the predictor variables were verbal working memory, creative achievement, and nonverbal intelligence. Overall score on the creative achievement task best predicted their total score on the group consequences question (accounting for 11.8% of the total variance) followed by verbal working memory (accounting for 5.2% of the total variance).

The fluency score for the *group* consequences question was the outcome variable and the predictor variable was verbal working memory. This was found to be the best predictor for creative fluency on the group consequences question (accounting for 6.9 % of the total variance) followed by visual working memory (accounting for 3.2% of the total variance).

The originality score for the *group* consequences question was the outcome variable and the predictor variable was verbal working memory. This was found to be a predictor for creative originality on the group consequences question, accounting for 6.8% of the total variance.

The total score for the *brick* question was the outcome variable and the predictor variables were creative achievement and nonverbal intelligence. Overall score on the creative achievement task best predicted their total score on the brick question (accounting for 3.8% of the total variance).

Table 5: *Stepwise regression analyses predicting divergent thinking, as a function of verbal working memory, nonverbal intelligence, and creative achievement.*

	R^2 change	F	β	t
Food Consequences Total				
Creative Achievement	.096	15.66*	.310	3.96*
Nonverbal Intelligence	.031	5.22*	.177	2.29*
Food Consequences Response Time				
Creative Achievement	.032	4.84*	.178	2.20*
Food Consequences Fluency				
Verbal Working Memory	.058	9.87*	.24	3.14*
Group Feeling Total				
Creative Achievement	.118	19.88*	.344	4.46*
Verbal Working Memory	.052	9.17*	.228	3.03*

Group Feeling Fluency				
Verbal Working Memory	.069	11.92*	.26	3.45*
Visual Working Memory	.032	5.32*	.18	2.31*
Group Feeling Originality				
Verbal Working Memory	.068	11.81*	.26	3.44*
Brick Total				
Creative Achievement	.038	5.48*	.195	2.34*

* *p* < .05.

Discussion

The main findings of this study are that working memory is related to creativity as measured by divergent thinking and creative achievement, and nonverbal intelligence is related to divergent thinking, but not creative achievement. These two cognitive factors each have a unique relationship with divergent thinking.

Working Memory and Creativity

Verbal working memory is uniquely related to divergent thinking through the Consequences task (Group question), but not through the Alternative Uses task (Brick and Pencil). This could be due to the nature of the task; the Consequences task may utilize similar skills as the verbal working memory task in order to have the forethought and planning needed to propose possible outcomes to the given scenarios. The Consequences task would require the participant to hold multiple pieces of information present in the mind in order to determine how this information could interact and influence possible outcomes. In contrast, the Alternative Uses task requires the participant to form more immediate uses of an object, most likely drawn from past experiences, which would not require as much use of verbal working memory.

Visual working memory is uniquely related to creative achievement. Currently, it is unclear exactly why creative achievement is related to visual working memory and not verbal working memory. One speculation is that the recall process involved in remembering previous accomplishments leads to mental visualizations of events similar to those involved in the visual working memory task (Mr. X). Another speculation is that since our sample consisted of undergraduate students, high scores on the Creative Achievement Questionnaire were rare or absent. So it is also possible that if a relationship between creative achievement and working memory was explored using a sample consisting of older individuals the findings could be different.

Intelligence and Creativity

Nonverbal intelligence is also related to creativity. However, this relationship was dependent on how we measured creativity. We measured creativity in two ways; the first was through divergent thinking (Consequences task and Alternative Uses task) and the second was through creative achievement (Creative Achievement Questionnaire).

When creativity was measured through creative achievement, it was not related to nonverbal intelligence. This could be due to the type of nonverbal intelligence test we used; as this assessment focused on measuring the participant's problem solving abilities. It may be that the creative achievements attained by this sample do not rely on similar problem solving skills. The Creative Achievement Questionnaire consists of domains such as visual arts, humor, inventions, and architectural design. Given that our sample was comprised of undergraduate students, their creative achievements were primarily restricted to domains such as visual arts and humor that do not involve problem solving. In contrast, creative achievements, such as inventions and scientific discovery, that do involve problem solving skills, were rare or absent in the sample.

Nonverbal intelligence was related to creativity when measured through divergent thinking (Brick, Group, and Food questions). However, when creative achievement was statistically controlled, nonverbal intelligence was only related to divergent thinking through the Brick and Food questions. Also, when we controlled for working memory, nonverbal intelligence was only related to divergent thinking through the Food question.

These changes in how nonverbal intelligence relates to divergent thinking could be item specific. For example, we found a relationship between nonverbal intelligence and the fluency component on the food question ("What would be the results if none of us needed food anymore in order to live?"), but not with originality. Since this question relates to a basic need for survival that drives many aspects of our life, it may be that participants believe they need to focus more on creating as many responses as possible rather than original responses. There are evolutionary psychologists that believe our brains have evolved to have specific processing units that are used to assist in solving problems that have been issues for our ancestors (Tooby & Cosmides, 2005, 1992, as cited in Nairne, Thompson, & Pandeirada, 2007, p. 263). In this type of situation, the ability to produce multiple solutions to a problem, especially one that is tied to so many aspects of our lives and the domino effect that would have on our lifestyles (e.g. jobs, overpopulation, etc.), would be an adaptive feature that would increase the odds of finding a solution that worked.

In contrast, we found a relationship between nonverbal intelligence and the originality component of the Group question ("What would be the results if humans lost their group feeling to the extent that they preferred to live alone?), but not with fluency. Again, this might be due to the type of need underlying the question. The Group question relates to a survival need that our current culture has already provided alternative routes to fulfilling. Technological advances seem to support this, a poll conducted by the Pew Research Internet Project (2013) shows that 73% of adults on the Internet are involved in some kind of social networking. A poll in 2010 examining how Americans used social networking revealed that being involved in some form of social networking leaves online adults half as likely as the average American to consider themselves socially isolated ("Social Networking," 2014). In light of increasing online social opportunities people may not feel the need to create as many solutions because there are alternate forms of social interaction already present to allow them to live alone without feeling lonely; instead they are able to respond with more original solutions.

Working Memory, Intelligence, and Creativity

Working memory and nonverbal intelligence each have unique roles in the creative process. Working memory was related to creativity through divergent thinking and creative achievement, while nonverbal intelligence was only related to creativity through divergent thinking. An example of these individual relationships is the Consequences task; the cognitive processing involved in a working memory task is similar to that used in the Group question of the consequences task. However, the Food question of the consequences task utilizes problem solving abilities similar to what is used in the nonverbal intelligence task. The existence of these unique relationships is further supported through the ability of each of these constructs to maintain their relationship to creativity over and beyond the effects of the other construct.

Limitations and Future Directions

Since there are many different ways to define creativity, it is possible that a different approach to measuring creativity would have led to different results. We used divergent thinking as one of our ways to define and measure creativity because it is one of the most common methodologies in the literature (Furnham & Bachtiar, 2008). Creative achievement was used in this study to not only provide a second definition of creativity, but also to provide a creativity test that was performance based and used a more standard method of scoring. However, the Creative Achievement Questionnaire did not seem to be an appropriate measure given the age of our sample. It may be that using a different measurement of creativity, such as an age appropriate performance measure, would provide more concrete evidence for creativity and result in a clearer understanding of how working memory and intelligence are involved in the creative process.

While the Alternative Uses task and the Consequences task are both frequently used in measuring creativity, they may be better suited for use in combination with a standardized creativity test, like a performance based measure. The guidelines for scoring both of these tasks are vague, which results in the scoring process being somewhat subjective and time consuming. The questions used in the Consequences task might have been tapping into how we approach our survival and social needs more so than creativity. Using questions that are more general might help clarify the type of relationship between these constructs. The use of the Creative Achievement Questionnaire was beneficial to this study since it did have a clear scoring system. However, given the age group of our sample it might not have been appropriate to measure creativity through lifetime achievements, such as patents and publications.

Conclusion

The major findings of the present study were as follows: verbal working memory is related to creativity over and beyond nonverbal intelligence; and is related to divergent thinking over and beyond creative achievement (G*roup* question); nonverbal intelligence is related to divergent thinking over and beyond working memory (*Food* question). Based on our model, creative achievement is the best predictor of total scores on divergent thinking tasks (*Food, Group, Brick* questions).

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Publications:

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Presentations:

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