Age-related Changes in Creative Thinking

ABSTRACT

Age-related differences in cognitive processes were used to understand age-related declines in creativity. According to the Geneplore model (Finke, Ward, & Smith, 1992), there are two phases of creativity — generating an idea and exploring the implications of the idea — each with different underlying cognitive processes. These two phases are measured in the Creative Invention Task (CIT; Finke, 1990). Younger adults \((n = 41)\) and older adults \((n = 41)\) completed the CIT, the Torrance Tests of Creative Thinking (TTCT), and a measure of working memory capacity (Paper Folding test). In addition, the CIT was scored by both younger and older raters. There were age-related declines on both phases of the CIT, but not on the TTCT. These declines were noted by both the younger and older raters. After adjusting for working memory capacity, however, age-related differences on the CIT were nonsignificant.

INTRODUCTION

Creativity is difficult to study, and yet we are dependent on it for our livelihood and, more generally, for our society’s progress. Researchers and scholars have addressed many questions about creativity, such as: How does one define creativity? How is it measured? Do all people have the ability to create, or is it limited to a few select individuals? Does it change across one’s life span? In this paper, we have elected to focus our investigation on the extent to which age-related changes in cognitive processes might impact age-related changes in creativity. To do so, we chose a definition of creativity that focuses on processes that everyone possesses, and we investigated those processes in younger and older adults. We also chose a measure of creativity that focused on originality, rather than productivity, because we were interested in the quality of a product rather than the quantity of products one can produce. Furthermore, we chose to focus on creativity that is visual in nature, rather than verbal, partly because we know less about visual information processing compared to verbal processing (Cornoldi &
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Vecchi, 2003; Logie, 1995), and because age-related differences may be more sensitive for visual information than for verbal information (Jenkins, Myerson, Joerding, & Hale, 2000; cf. Park et al., 2002). Finally, in the creativity literature, verbal performance is often used exclusively or is combined with visual performance to form a composite measure without reporting them separately (e.g., Torrance, 1988, 2004; Torrance & Safter, 1989). Thus, our main interest was to use age-related differences in visual cognitive processes to understand better any age-related differences in visual creativity, as measured by originality.

Definitions of creativity, sometimes referred to as divergent thinking, vary widely, but most include Guilford’s (1967) emphasis on fluency, flexibility, and originality. Fluency reflects the number of responses produced, whereas flexibility is the number of different categories that are produced. Originality is a joint product of statistical rarity and appropriate cleverness. Unfortunately, in our opinion, much research on creativity, especially on creativity over the life span, has focused only on fluency or, in other words, productivity (e.g., Cole, 1979; Dennis, 1966; Lyons, 1968; Horner, Rushton, & Vernon, 1986; Zuckerman & Merton, 1972; Zusne, 1976; see Lindauer, 2003, for related argument). This emphasis on fluency probably occurred because it is the simplest outcome to measure and because there is some evidence that it is more reliable than other outcomes such as originality (Plucker & Renzulli, 1999). Further, many investigators studied only the most well-known persons within a field (Lehman, 1953; Over, 1989; Simonton, 1977, 1985, 1989, 1997). In any case, the general finding is that productivity increases until about 20 years into one’s career, where it peaks, and then declines as one ages further. One exception to the emphasis on creativity as productivity is work by Simonton (1985), who investigated both the quantity (fluency) and quality (impact/originality) of works produced by distinguished scholars, in this case psychologists. Simonton found the inverted U shape for overall productivity across the career span. In addition, he found that the percentage of products that were quality products (i.e., published articles that were cited at least once) remained constant throughout the career (see also Simonton, 1977). That is, although the absolute number of one’s quality products follows the inverted U shape, the percentage of one’s products that are of high quality remains constant.

These studies, showing an age-related decline in productivity, do not necessarily imply a decline due solely or even primarily to age-related changes in cognitive processes (Crozier, 1999; Esquivel & Hodes, 2003; Sasser-Coen, 1993; Simonton, 1990). In fact, few studies have focused on the cognitive processes underlying the creativity of young adults or college students—the typical participants in creativity studies; far fewer studies focus on the cognitive processes underlying creativity in the aged.

To be fair, some researchers use the terms fluidity, flexibility, and originality to reflect cognitive processes. For example, Jaquish and Ripple (1980, 1981, 1984) investigated age-related differences in each of these cognitive creative abilities (see also McCrae, Arenberg, & Costa, 1987; Ruth & Birren, 1985). Beginning in preadolescence (ages 9–12), each of these abilities increases until middle
adulthood (ages 40–60). In another study, Jaquish (1984) found age-related declines in flexibility of thinking and in the number of responses (fluency) in divergent thinking tasks, but determined that there was no difference in the quality of responses (originality). Nonetheless, this literature does not tend to overlap much with the literature on age-related differences in cognitive processes (e.g., Salthouse, 2004).

An alternative way to understand creativity is from the creative cognition approach (e.g., Smith, Ward, & Finke, 1995). Finke, Ward, and Smith (1992) introduced a two-stage model of creativity, the Geneplore model, which attempts to connect research on creativity to basic cognitive research. The Geneplore model purports that creativity results from two distinct processes: generation and exploration (see also Grohman, 2006; Roskos-Ewoldsen, 1993). The generation stage involves the formation of pre-inventive structures that are mental representations of potentially original “things” (e.g., ideas, inventions, and works of art). These pre-inventive forms are evaluated during the exploration stage. They may be accepted or sent back to the generation stage for further modification. This cycle continues until a subjectively acceptable product is achieved. According to the Geneplore model, different cognitive processes are applied at the generation and exploration stages of creativity. For example, during the generation phase processes such as retrieval, transformation, and analogical transfer may be used, whereas during the exploration stage processes such as conceptual interpretation, contextual shifting, and hypothesis testing may be used. No processes are always appropriate nor are any processes necessary for the production of original products; rather, task demands determine which processes are used during the two stages of creativity (Finke et al., 1992). With these cognitive processes identified, we can begin to tease apart which aspects of creativity — generation or exploration — may decline with age.

Each aspect of the generation phase of creativity, involving retrieval, transformation, and analogical transfer, is associated with age-related declines. There is strong evidence of age-related declines in retrieval (Salthouse, 2004; for reviews see Burke & Light, 1981; Craik, 1977; Craik & Jennings, 1992; Light, 1992; Poon, 1985). There are age-related changes in transformation whether it is operationally defined as mental rotation or spatial visualization. With transformation operationally defined as mental rotation, researchers have found that older adults tend to be slower and more error-prone than younger adults (e.g., Dollinger, 1995; Hale, Lima, & Myerson, 1991; Hale, Myerson, Faust, & Fristoe, 1995). When transformation is operationally defined as spatial visualization, there still are age-related declines (Salthouse, 2004). With analogical reasoning, most research has focused on verbal analogical reasoning of the form A:B::C:(D1, D2). This research showed that older adults process information more slowly and therefore are slower with their responses than younger adults, but older adults are not necessarily more error prone than younger adults (e.g., Clark & Gardner, 1990; Clark, Gardner, Brown, & Howell, 1990). In the visual analogy realm in which geometric analogies were used, the performance of older adults was impaired more than younger
adults especially when the stimuli were complex (Salthouse, 1987, 2004). Taken together, these results suggest that older adults will have more difficulty generating preinventive forms than younger adults. In addition, they may settle for the easiest preinventive form that comes to mind, given the time constraints of this task. This form is likely to be less creative than other forms.

The cognitive processes underlying the exploration stage, involving conceptual interpretation, contextual shifting, and hypothesis testing, show similar declines with age. Older adults tend to have difficulty interpreting unusual concepts, which often involves hypothesis testing and shifting from one concept to another (for a review see Denney, 1990). Thus, older adults may have more difficulty than younger adults in exploring their preinventive form and interpreting it as an invention. In other words, older adults may be less likely to produce an invention than younger adults, and their invention may be less original for the same reasons that preinventive forms may be less creative — they may settle for the first invention that comes to mind and it will likely be less creative than later inventions. On the other hand, older adults have more experience and their conceptual knowledge is likely more extensive than younger adults. Creative tasks tend to invoke a wider or less defined search for information than non-creative tasks such as retrieving information from memory based on its association with a particular learning episode (Bink & Marsh, 2000). Thus, they may perform as well as or possibly better than younger adults in terms of invention originality, due to their more extensive knowledge base. Nevertheless, to the extent that contextual shifting and hypothesis testing involves a working memory component, then productivity and originality will decline as one ages, just as working memory declines with age (Park et al., 2002).

We are not aware of any research directly investigating the impact of age-related changes in these underlying cognitive processes on age-related changes in creativity. With this dearth of research in mind, we decided to investigate age-related differences in creativity by using the two stages of creativity proposed in the Geneplore model. We based the design of our study on research by R. Finke in which he had participants complete his Creative Invention Task (Finke, 1990; see also Anderson & Helstrup, 1993; Finke & Slayton, 1988). In a typical Creative Invention Task, participants see triplets of shapes (e.g., circle, D, 8) and create (draw) a form, using all the shapes, that has potential as an invention. This form is called a preinventive form. Then they see or hear a category name (e.g., furniture) and think of an invention within the category, using the form they just created. That is, they interpret the preinventive form as an invention within the given category. They give the invention a name and briefly describe how it works. The preinventive form reflects the generation stage of the Geneplore model, whereas the interpretation of the form as an invention reflects the exploration stage. Both the preinventive form and the interpretation of the form are separately judged by independent raters for originality. The typical variables manipulated in these studies include whether the shapes or categories were chosen randomly by the experimenter or selected by the participant (Finke, 1990) and whether the participants thought on paper (i.e., doodled) or in their minds (Anderson &
Helstrup, 1993). Original forms and interpretations are more likely to occur when the shapes and the categories are randomly chosen than when they are not (Finke, 1990). Interestingly, the proportion of inventions that are deemed original is equivalent for doodling and for imagining (Anderson & Helstrup, 1993).

Including the two stages of creativity from the Creative Invention Task enabled us to compare younger and old adults in their ability to generate new forms and to explore possible interpretations of those forms. By inference, we will be investigating how known age-related differences in the cognitive processes underlying these two stages impacts age-related differences in the two stages of creativity. In our study, we randomly chose both the shapes and the categories to maximize originality. We also manipulated the amount of time participants had to produce a form and an invention (1 minute per stage, or 2 min per stage). We thought it likely that we would see age differences at the typical 1 minute time lag because of the age differences that are apparent in the cognitive processes underlying the two stages. We also hypothesized that older participants would be more likely to produce an original preinventive form or invention if they had more time, given the well-known slower processing speed of older adults (Salthouse, 2004; for reviews see Cerella, 1990; Salthouse, 1985).

We included another test of creativity to compare with the two-stage Creative Invention Task. We chose the Torrance Tests of Creative Thinking (Torrance, 1966; Torrance & Ball, 1984), which has both a Verbal and a Figural subtest. We used only the Figural subtest because it corresponded most closely to the Creative Invention Task. In this test, participants see various geometric shapes and draw pictures that tell stories. The subtest produces six subscales. Three of the subscales overlap with Gifford’s definition: fluency, resistance to premature closure (flexibility), and originality as measured by statistical rarity. The other three subscales are: elaboration, abstractness of titles, and a bonus for the use of constructs like humor, imagery, and fantasy. Including this test allowed us to investigate the relations between the generation and exploration stages of the Geneplore model and the subscales of the Torrance Figural Test. Of course, we also tested differences between younger and old adults on each of the Torrance subscales.

Finally, we included a measure of visual working memory capacity. The Creative Invention Task in particular seems to rely on working memory. During the generation stage, participants are mentally playing with different combinations of the shapes. Although we encouraged participants to play on paper (i.e., doodle), there might still be some mental play occurring. Likewise, during the exploration stage, participants are mentally playing with the functioning of different parts within the preinventive form. Again, participants could doodle on paper, but there may be some mental manipulation occurring. The exploration phase, unlike the generation phase, includes a verbal component — participants label their invention and describe briefly how it works. Therefore, verbal working memory may be involved in addition to visual working memory. However, we were interested more in the visual aspects of the tasks than the verbal aspects and so we only included a measure of visual working memory. Because older adults have less visual working memory resources than younger adults (Salthouse, 2004; Salthouse, Mitchell,
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Skovronek, & Babcock, 1989), we predicted that older adults would have more difficulty than younger adults when combining the shapes to generate a preinventive form and visualizing the functioning of the form’s parts to produce an invention. This difficulty would increase the likelihood that older adults would settle for the easiest solution that comes to mind, which will tend to be less original than other possible solutions. Hence, their preinventive forms and their inventions would be rated as less original than younger adults’ preinventive forms and inventions. Including a measure of visual working memory capacity permitted us to investigate how much of the age differences in originality are due to this cognitive resource and how much is due to cognitive processes unique to the generation and exploration stages of creativity.

Summary of Predictions

Generation and Exploration. Ratings of originality will be lower for older adults than for younger adults for both the generation and the exploration phases of the task due to age-related declines in the cognitive processes underlying each phase. However, the age differences may be smaller in the exploration phase because of the more extensive knowledge base that older adults have compared with younger adults.

Time Lag. The difference in originality between older and younger adults in both the generation and exploration phases will be greater when participants have only one minute to generate and one minute to explore, compared with two minutes for each, due to the slower processing speed of older adults.

Visual Working Memory. To the extent generation and exploration involve the cognitive resource of visual working memory, age-related differences in originality will be minimized after controlling for age-related differences in working memory.

METHOD

Participants

There were 82 participants in this project. The 41 younger adults participated for credit towards a course requirement (age range 18-22, M = 19.37; 49% women, 51% men; 73% Caucasian, 22% African-American, 5% Asian). The 41 older adults were recruited from the community through ads in local newspapers and received $10 for their participation (age range 61-86, M = 73.05; 73% women, 27% men; 88% Caucasian, 12% African-American).

Materials

Torrance Tests of Creative Thinking (TTCT). The TTCT Figural Form B (Torrance & Ball, 1984; see also Torrance, 1966) was administered and scored according to the guidelines in the instruction manual and scoring guide (Torrance & Ball, 1978, 1984). The TTCT is divided into three 10-min sections: Picture Construction Activity; Incomplete Figures Activity; and Repeated Figures Activity. In the Picture Construction Activity, labeled Picture Construction on the test, participants think of a picture or an object in which a given shape (e.g., a
jelly bean shape) is an integral part. The instructions encourage participants to think of something that no one else will think of, thereby eliciting original responses. They also encourage elaboration; participants keep adding new ideas that will make the picture tell as interesting and as exciting a story as possible. The product is scored for its originality (statistical rarity or uncommonness) and its elaboration (amount of detail added). For the Incomplete Figures Activity, labeled Picture Completion on the test, participants see 10 incomplete pictures and add lines to sketch an interesting object or picture for each incomplete picture. As with the Picture Construction Activity, participants try to think of something that no one else will think of, and try to make it as complete and as interesting a story as they can. To produce an original response a participant usually has to resist completing the figure in the simplest and easiest way. Each figure is scored for flexibility (resistance to premature closure), originality, and elaboration. In the Repeated Figures Activity, labeled Circles on the test, participants see 36 circles spread across two pages. They make as many different objects or pictures as they can and put as many ideas as they can in each one, with the circles being the main part of whatever they make. As with the other activities, participants try to think of things that no one else will think of, and try to make them tell as complete and as interesting a story as they can. The figures are scored for fluency (number of pictures drawn), flexibility (number of different categories of pictures drawn), originality, and elaboration. In all three activities, participants provide a name title for each object or picture. The instructions encourage participants to make the title as clever and unusual as possible, and to use it to help tell their stories. The titles are evaluated for abstractness.

Interrater reliability on the TTCT is high; it ranges from .86 (originality) to .98 (fluency and flexibility) (Torrance, 1974). One-week test-retest reliability also is relatively high, ranging from .71 (fluency) to .85 (originality) (Torrance, 1974).

Creative Invention Task (CIT). Each trial in the CIT (Finke, 1990) has two phases. During the first phase, the generation phase, participants combine three common shapes (e.g., cube, sphere, and cross) into a potentially useful object (i.e., a preinventive form). There are a total of 15 possible shapes from which three are randomly selected for each trial (see Finke, 1990, p. 41). The instructions encourage participants to doodle as they generate their object. During the second phase, the exploration phase, participants hear a category name (e.g., transportation, toys & games) that has been randomly selected from a list of eight (see Finke, 1990, p. 42). They then try to think of their object as an invention within the category. They write the name of the invention and describe briefly how it functions. The originality of both the preinventive form and the invention are evaluated.

In our study, for each trial, the names of the shapes appeared in the upper left-hand corner of a paper. Participants had drawings of all 15 possible shapes available on a separate paper. At the lower left-hand corner of each trial there was a large box into which the participants drew their final form. To the right of the box was a place for participants to write the category name (when it was announced).
and a place for the title and description of their invention. All eight categories along with token examples were available on a separate paper.

There were eight trials in all. For three of the trials, participants had 1 min to generate a preinventive form and 1 min to interpret it as an invention. For three other trials, participants had 2 min to generate and 2 min to interpret. Two trials were practice trials — one at the 1 min interval and the other at the 2 min interval. The time interval was manipulated within subjects, and the order (1 min–2 min vs. 2 min–1 min) was counterbalanced across participants.

Although we randomly selected the three shapes and the category for each of the eight trials, all participants received the same eight combinations. Two of these combinations were chosen for the practice trials. The remaining six were assigned randomly to one of two sets (Set A, Set B). In addition, although the ordering within each set was randomly determined, all participants received the same ordering within each set. The order of the sets (A–B, B–A) was counterbalanced across participants. This counterbalancing was independent of the counterbalancing for the time interval.

After completing the CIT, participants chose from a checklist of strategies which strategy they used most often to combine the parts into objects. The strategies were, “Combined the parts by trial and error until a pattern emerged from the drawing,” “Thought of a pattern then tried to make the parts fit by manipulating them on paper,” “Combined the parts in my mind and then drew the final object,” and “Some other strategy.” If they chose the last strategy, they briefly described their strategy.

**Paper Folding test (PF).** The PF test (Educational Testing Service, 1962; Ekstrom, French, Harman, & Derman, 1976) is considered a measure of visual working memory (Salthouse, et al., 1989). In the PF test, participants see a 2-dimensional representation of a paper being folded and a hole being punched in the folded paper. Participants then visualize what the pattern of holes would look like if the paper were unfolded, and choose the answer among five alternatives. The PF test has 20 trials that are divided into two parts of 10 trials each, and one practice trial. Participants have 3 min to complete each of the two parts, for a total of 6 min. The reliability of the PF test ranges from .75 to .84 (Ekstrom et al., 1976).

**Procedure**

Participants were tested in small groups of 2–6. Younger and older adults were tested separately. The PF test was always administered first. The order of the TTCT and CIT tests was counterbalanced across groups. General instructions introduced participants to the study, “This study investigates the ability to be creative in everyday situations. The task involves combining common objects into creative forms. No special skills are required, and there are no ‘right’ answers. The experiment will last approximately 2 hours.” After signing the consent form, participants heard instructions specific to each test, and had short breaks between tests. For the Paper Folding test and the TTCT, the instructions from their respective manuals were used.
For the CIT, we used the following instructions. “On each trial, the names of three of the parts drawn on the following page will be presented. The names of the parts are Sphere, Half Sphere, Cube, Cone, Cylinder, Wire, Tube, Flat Square, Bracket, Rectangular Block, Hook, Wheels, Cross, Ring, and Handle. You are to use all three of the parts to make an interesting, potentially useful object. You are not to make a specific object like a chair or an appliance or a toy, but rather you should try to come up with an interesting shape that might be useful in some general way. You must use all three of the parts. If the same part is presented twice, or even 3 times, you must use that same part the designated number of times. You may vary the size, position, or orientation of any part but you may not bend or otherwise alter the shape of the parts, with the exception of the tube and the wire, which are bendable. The parts can vary in their solidity; that is, they can be solid or hollow, open or closed. They can be attached in any way; one part can even be put inside of another. In addition, the parts can vary in their composition; for example, they could be made of wood, metal, rubber, glass, or any combination of materials. On some trials, after you are presented with the names of the parts, you will be given 1 minute to produce an object. On other trials you will be given 2 minutes. In either case, you are encouraged to try out different ways of putting the parts together by doodling on the sheet provided. After 1 or 2 minutes depending on the trial, I will tell you to draw the object. You are to draw the object in the box provided, if you were able to come up with one. It is o.k. to draw the shape before the time period is up. Once the object is drawn, however, you may not change anything about it. After you’ve drawn the object, I will name a category. Write down the category on the sheet, next to the word ‘category.’ Then, you should inspect the object you just drew, and try to interpret it as some kind of original but practical invention or device belonging to that category. On each trial, one of the categories listed on the following page will be presented. The categories are: Furniture, Personal Items, Transportation, Scientific Instruments, Appliances, Tools and Utensils, Weapons, and Toys and Games. On some trials you will be given 1 minute to interpret the object as an invention that belongs to the named category. On other trials you will be given 2 minutes. In any case, when the time limit is up, I will tell you to write down the name of your invention. You are to write the name next to the box with the drawing, and then briefly describe your invention or device, explaining its function and what its parts do. It’s o.k. if you start writing the name and description before the time limit is up.”

After the tests were completed, participants were debriefed and thanked. The entire session lasted approximately 2 hours.

RESULTS

Scoring Procedures

Paper Folding test. The PF test score was obtained by taking the total correct out of 20 items and subtracting one-fourth the number incorrect, as suggested in its manual (Ekstrom, et al., 1976). If the resulting number was negative, it was set to 0 for the analyses.
Torrance Test of Creative Thinking. The TTCT was scored according to the guidelines in the Streamlined Scoring Guide (Torrance & Ball, 1978). Scoring of the TTCT results in an overall creativity index and six component measures, including fluency, originality, abstractness of titles, elaboration, resistance to premature closure, and a bonus score for extensive use of the other sub-measures plus the use of constructs such as humor, imagery, and fantasy. Two undergraduate research assistants received training by the third author. They and the third author each scored 1/3 of the tests. We chose to evaluate the tests in this way because of the high interrater reliability shown in previous research (Torrance, 1974). Younger and older participants’ tests were intermixed, and scorers were unaware of the age group to which each test belonged. Except for the bonus measure, these scores were then translated into normalized scores, with a mean of 100 and a standard deviation of 20 (Torrance & Ball, 1984). To obtain an overall creativity index, the five normalized measures are averaged and then the bonus is added. The overall creativity index has a mean of 100 and a standard deviation of 15 (Torrance & Ball, 1984).

Creative Invention Task. Scoring of the CIT was modeled after procedures outlined by Finke (1990). Two undergraduate research assistants and two older adults recruited from the community rated every trial for originality of the preinventive form and originality of the invention. The older adults were both female and over 65 years of age. They were paid for their efforts. Originality was rated on a scale ranging from 1 (not at all original) to 5 (very original). Raters were given no further definition of originality. Trials from the 1-min and 2-min conditions and from the younger and older participants were intermixed, and the raters were unaware of the condition or age of participant to which a trial belonged. However, preinventive forms were rated independently of inventions, and raters were able to view all trials of one kind (i.e., preinventive form) before assigning originality scores to each one.

Before continuing with the analyses, we assessed the raters for intra-rater and inter-rater reliability. For intra-rater reliability, we averaged each rater’s originality ratings across participants’ ages and time lag, resulting in an averaged rating for each trial and for each rater. Then, for each rater we calculated Cronbach’s alpha (across participants) for the six trials, treating the trials as items in the analysis. We did this separately for preinvention and invention originality. We chose an alpha = .40 or higher for inclusion of their ratings in the main analyses. This level is analogous to an acceptable factor loading in a factor analysis. For preinvention originality, the alphas for younger raters (Raters 1 and 2) and older raters (Raters 3 and 4) were .55, .50, .43, and .46, respectively. For invention originality, the alphas for the younger and older raters were .52, .30, –.01, and .42, respectively. For the creativity index the alphas were .67, .53, .21, and .63. We decided to drop the originality ratings from Raters 2 and 3 because at least one of their alphas was lower than our criterion. Analyses with and without these two raters were nearly identical.

Dropping the two raters left us with one younger and one older rater. To assess the inter-rater reliability of these two raters, we averaged each rater’s originality
ratings across the six trials and then calculated Cronbach’s alpha (across participants) for both preinvention and invention originality, and the creativity index, using the two raters as items. Alphas for preinvention and invention originality were .75 and .71, respectively. For the creativity index, alpha was .80. Correlations between the two raters for preinvention originality, invention originality, and the creativity index were .63, .55, and .68, respectively (ps < .001; see Table 1 for means.) These were considered sufficient for the purposes of the main analyses.

For the main analyses, the two raters’ originality ratings were averaged for each trial, and the three trials at each time period were averaged for each participant. Thus, there were four measures for each participant: originality of the preinventive form and originality of the invention at each of the two time intervals. In addition, an overall creativity index was calculated for each participant at each time interval by averaging preinvention originality and invention originality.

Data Exclusion

Data were incomplete because not all participants took all tests due to time constraints. As a result, for the TTCT there were 78 participants (40 younger, 38 older) and for the CIT there were 74 participants (40 younger, 34 older). All 82 participants completed the PF test. There were 70 participants (39 younger, 31 older) who completed all measures. The data analyses reported below used only the restricted sample (N = 70). However, the results for the fuller samples were nearly identical.

Data Analyses

Descriptive statistics. Table 1 shows the means and standard deviations for each measure. Table 2 shows the correlations among the measures (see Appendix for correlations by age). For the CIT the 1 min and 2 min conditions were collapsed because the analyses revealed no significant differences in creativity as a function of the time intervals (see below). In addition, the younger and older raters’ ratings were collapsed because the age of the rater did not interact with any of the other variables (see below). Not surprisingly, many of the TTCT component measures correlated with each other. Likewise, the CIT measures were correlated. More noteworthy are the correlations between the component measures of each creativity test and visual working memory capacity (i.e., PF). As one can see from Table 2, for the most part, the TTCT did not rely on visual working memory. Exceptions are the subscales of abstractness of titles (r = .36) and bonus (r = .26): as visual working memory increased, the titles became more abstract and therefore more original, and the products included more humor, imagery, fantasy, and so on, leading to a higher bonus score. It would take some working memory capacity to search long term memory quickly for a title that described their product in a clever way, or to think of a way to represent abstract concepts such as humor. For the CIT, all measures were related to visual working memory (preinvention originality, r = .44; invention originality, r = .28; creativity index, r = .41): as visual working memory increased, so did the originality of both the preinvention and the invention. Another important finding was that the TTCT and CIT were uncorrelated overall (r = .09, TTCT composite score and CIT cre-
An exception was that TTCT bonus subscale was correlated with CIT invention originality ($r = .24$) and creativity index ($r = .25$): those who had higher bonus scores also had higher originality scores on the CIT.

**Visual working memory capacity.** Visual working memory capacity (PF test) was much higher for the younger participants than for the older participants, $F(1, 68) = 66.88, p < .001, R^2 = .50$ (Table 1).

**Torrance Tests of Creative Thinking.** Scores on each of five component measures were submitted to a multivariate analysis of variance, with age as a grouping (i.e., between subjects) factor. The bonus and composite index were analyzed separately because the bonus score is scaled differently than the other component measures and because the composite index comprises the component

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<th>Test/Subtest</th>
<th>Younger Participants</th>
<th>Older Participants</th>
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<td>with PF as covariate a**</td>
<td>86.03 (31.06)</td>
<td>107.78 (32.24)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Elaborateness</td>
<td>91.00 (22.62)</td>
<td>84.61 (18.58)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Resistance to PC</td>
<td>83.95 (20.71)</td>
<td>81.13 (26.79)</td>
<td></td>
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</tr>
<tr>
<td>Bonus a †</td>
<td>9.74 (3.64)</td>
<td>8.10 (3.35)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>with PF as covariate</td>
<td>9.29 (4.20)</td>
<td>8.67 (4.36)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Composite</td>
<td>103.21 (16.81)</td>
<td>99.44 (16.11)</td>
<td></td>
<td></td>
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<tr>
<td><strong>CIT</strong></td>
<td></td>
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<tr>
<td>Preinvention Originality a ***</td>
<td>2.80 (.62)</td>
<td>2.21 (.62)</td>
<td>2.60</td>
<td>2.48</td>
</tr>
<tr>
<td>with PF as covariate</td>
<td>2.70 (.73)</td>
<td>2.38 (.76)</td>
<td>.65</td>
<td>.86</td>
</tr>
<tr>
<td>Invention Originality a * b</td>
<td>2.73 (.62)</td>
<td>2.44 (.59)</td>
<td>2.48</td>
<td>2.73</td>
</tr>
<tr>
<td>with PF as covariate</td>
<td>2.60 (.72)</td>
<td>2.54 (.75)</td>
<td>.66</td>
<td>.75</td>
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<tr>
<td>Creativity Index a **</td>
<td>2.77 (.55)</td>
<td>2.32 (.54)</td>
<td>2.54</td>
<td>2.60</td>
</tr>
<tr>
<td>with PF as covariate</td>
<td>2.67 (.61)</td>
<td>2.48 (.63)</td>
<td>.57</td>
<td>.70</td>
</tr>
</tbody>
</table>

* Reliable difference between younger and older participants.

b Reliable difference between younger and older raters, $p = .01$.

† $p < .06$; *$p < .05$; **$p < .01$; ***$p < .001$
### TABLE 2. Correlations among the Creativity Measures and Working Memory Capacity ($N = 70$).

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<tr>
<td>1. Paper Folding</td>
<td>-.06</td>
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<td>.36**</td>
<td>.03</td>
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<td>.26*</td>
<td>.23</td>
<td>.44**</td>
<td>.28*</td>
<td>.41**</td>
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<td>2. Fluency</td>
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<td>.04</td>
<td>.25*</td>
<td>.34**</td>
<td>.22</td>
<td>.47**</td>
<td>-.22†</td>
<td>-.15</td>
<td>-.03</td>
<td>-.08</td>
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<td>3. Originality</td>
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<td>.29*</td>
<td>.34**</td>
<td>.51**</td>
<td>-.11</td>
<td>-.03</td>
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<td>.43**</td>
<td>.61**</td>
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<td>.18</td>
<td>.17</td>
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<td>5. Elaborateness</td>
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<td>.64**</td>
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<td>.04</td>
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<td>6. Resist to PC</td>
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<td>.74**</td>
<td>.04</td>
<td>-.001</td>
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<td>7. Bonus</td>
<td>.81**</td>
<td>.21†</td>
<td>.24*</td>
<td>.25*</td>
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<td>8. Composite</td>
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<td>9. Preinvention Orig</td>
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<td></td>
<td></td>
<td></td>
<td>.61**</td>
<td>.91**</td>
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<td>10. Invention Orig</td>
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<td></td>
<td></td>
<td></td>
<td>.89**</td>
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<td>11. Creativity Index</td>
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†$p < .09$; *$p < .05$; **$p < .01$
FIGURE 1. Subscales of the Torrance Tests of Creative Thinking, Figural: fluency, originality, abstractness of title, elaborateness, and resistance to premature closure (A), and bonus (B) for younger and older participants. Abstractness of Title and Bonus are shown with and without paperfolding as a covariate. The range of scales reflects the 95% confidence intervals.
measures and therefore should not be included in a multivariate analysis alongside them. Instead, the bonus and composite index were analyzed separately using a single factor (age) between-subjects analysis of variance.

For the five component measures, overall, younger adults did not differ from older adults (Figure 1A), $F(5, 64) = 0.42, p = .83, R^2 = .03$. For the bonus measure, younger participants tended to have higher scores than older participants (Figure 1B) but the effect size was small, $F(1, 68) = 3.79, p = .06, R^2 = .05$. For the composite index, there were no differences between younger and older adults (Table 1), $F(1, 68) = 0.90, p = .35, R^2 = .01$, reflecting the weight of the five component measures.

Because some of the component measures of the TTCT were correlated with visual working memory capacity (i.e., abstractness of titles and bonus), we conducted a second set of analyses using age as the grouping variable and PF score as the covariate. First, we checked the assumptions for an analysis of covariance (i.e., homogeneity of error variances and homogeneity of slopes) (Stevens, 1992; Green, Salkind, & Akey, 2000). They were met. Then we separately analyzed abstractness of titles and bonus. For the abstractness of titles subscale, after adjusting for visual working memory differences between the age groups, age differences appeared, whereas there were no age differences before the adjustment (Figure 1A). After adjustment, older adults had higher abstractness scores ($M = 107.78$) than younger adults ($M = 86.03$), $F(1, 67) = 6.13, p = .02, R^2 = .08$. This is likely due to older adults’ advantage over younger adults in their vocabulary (Salthouse, 2004) and world knowledge. A check on the other four subscales found no such differences after adjusting for visual working memory. For the bonus subscale, age did not contribute reliably after adjusting for visual working memory capacity (Figure 1B), $F(1, 67) = 0.28, p = .60, R^2 < .01$, suggesting that visual working memory capacity mediates any age differences in this component measure of creativity.

Creative Invention Task. Occasionally, participants did not produce a preinventive form. This occurred on 21 out of 234 trials (9%) for younger participants and 25 out of 186 trials (13%) for older participants; they were spread evenly across the 1-min and 2-min trials. The difference between younger and older adults in absent preinventive forms was not reliable, $\chi^2(1) = 2.12, p > .05$, phi coefficient = .07. When participants were unable to create a preinventive form on a trial, their originality scores were averaged across the remaining trials. All participants were able to create an invention once a preinventive form was produced.

An analysis of variance was conducted separately for preinvention originality and invention originality because, unlike the TTCT which measures different aspects of creativity, the CIT measures the originality of two different types of products — a preinventive form and an invention. The creativity index was analyzed separately. For all measures, the data were submitted to a 2 (time) x 2 (age of rater) x 2 (age of participant) analysis of variance, with time and age of rater as repeated measures and age of participant as a between subjects measure. Age of rater is considered a repeated measure because the raters rate the same forms (i.e., each form received repeated ratings).
For preinvention originality (Figure 2), age had a significant effect, with younger adults producing preinventive forms that were near 3 on the 1-5 originality scale, compared to older adults, whose average originality ratings were around 2 (Table 1), $F(1, 68) = 14.83, p < .001, R^2 = .18$. No other main effects or interactions were reliable. For invention originality (Figure 2), the statistical effect was small, $F(1, 68) = 3.68, p = .06, R^2 = .05$. Younger adults tended to produce inventions that were slightly above the midpoint of the originality scale (midpoint = 2.5) whereas older adults produced inventions that were slightly below the midpoint (Table 1). There also was a main effect of rater age, with the younger rater rating invention originality as near the midpoint of the scale, compared to the older rater whose overall originality rating was slightly above the midpoint (Table 1), $F(1, 68) = 6.55, p = .01, R^2 = .09$. This rater effect does not change the main outcome because neither rater age nor age of participant interacted with any other variable, and none of the other main effects nor interactions were reliable. The difference in ratings of originality due to the age of the rater stands in contrast to Knight and Parr (1999), who found that younger adults tended to have higher ratings of originality than older adults. However, they were rating behaviors described in vignettes whereas our raters rated products. Finally, for the creativity index there was an

![FIGURE 2. Creative Invention Task. Originality of preinventions and inventions on a 1 (low) to 5 (high) scale for younger and older participants, with and without paperfolding as a covariate. The range of scales reflects the 95% confidence intervals.](image-url)
effect of age, as expected, with originality scores for younger adults close to 3 compared to the older adults’ rating which was near 2 (Table 1), $F(1, 68) = 11.40$, $p = .001$, $R^2 = .14$, and no other main effects or interactions.

Corroborating the analysis of variance results are the results from an analysis of how many participants produced at least one highly original preinvention and invention. A preinvention or invention was considered highly original when both raters assigned it a 4 or 5. Comparing younger and older adults on preinventive forms, younger adults were more likely ($n = 19$, or 49%) than older adults ($n = 6$, or 19%) to have at least one highly originally preinvention, $\chi^2(1) = 6.49$, $p = .01$, phi coefficient = -.30. For inventions, the number of younger adults with at least one highly original invention ($n = 16$, or 41%) was nearly identical to the number of older adults with at least one highly original invention ($n = 13$, or 42%), $\chi^2(1) = .006$, $p = .94$, phi coefficient = .009. This difference between preinventions and inventions is probably because attention is narrower and intensified during the exploration, or invention stage of the task, compared with the generation, or preinvention stage of the task, for which attention is broader (Grohman, 2004; see also Nečka, Grohman, & Slabosz, 2006). Perhaps older adults were able to focus better on the task and as a result use more world knowledge in the exploration stage, compared with the generation stage. Conversely, the generation stage may have been too ill-defined for the older group and they were not able to draw as much upon their knowledge as in the exploration stage.

Components of the CIT were correlated with visual working memory capacity, as measured by the paper folding test. For this reason, we repeated the three analyses used to examine the CIT but using scores on the paper folding test as a covariate (Table 1), after verifying that the assumptions for an analysis of covariance were met. For preinvention originality, after adjusting for visual working memory capacity, the age difference in originality was no longer reliable, $F(1, 67) = 2.40$, $p = .13$, $R^2 = .04$: preinvention originality was statistically equivalent for younger ($M = 2.70$) and older ($M = 2.38$) participants. No other main effects or interactions were reliable. For invention originality, as with preinvention originality, after adjusting for visual working memory capacity, age no longer contributed reliably to invention originality, $F(1, 67) = 0.09$, $p = .77$, $R^2 < .01$: invention originality of younger participants ($M = 2.60$) was essentially identical to that of older participants ($M = 2.54$). In addition, rater age no longer contributed to invention originality, $F(1, 67) = .85$, $p = .36$, $R^2 = .01$. No other main effects or interactions were reliable. Finally, for the creativity index the results were the same — there was no longer an age difference in originality (Younger: $M = 2.67$; Older: $M = 2.48$), $F(1, 67) = 1.18$, $p = .28$, $R^2 = .02$. There also were no other main effects or interactions.

Table 3 presents self-report indications of which strategies the participants used while completing the CIT. The data were analyzed using a 2 (age of participant) x 4 (strategy) chi-square test. The results suggest that any age differences in the approach used to complete the CIT were small, $\chi^2(3) = 5.81$, $p = .12$, phi coefficient = .29.
TABLE 3. Number of Participants Endorsing Strategies Used During the CIT.

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Younger (n = 39)</th>
<th>Older (n = 31)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Combined the parts by trial and error</td>
<td>9</td>
<td>10</td>
</tr>
<tr>
<td>Thought of a pattern then tried to make the parts fit</td>
<td>9</td>
<td>6</td>
</tr>
<tr>
<td>Combined the parts in my mind then drew the object</td>
<td>20</td>
<td>10</td>
</tr>
<tr>
<td>Some other strategy</td>
<td>1</td>
<td>5</td>
</tr>
</tbody>
</table>

Note. There were no reliable differences between younger and older participants.

DISCUSSION

Our primary goal for this study was to investigate how age-related differences in the cognitive processes might impact age-related changes in creative thinking as measured by originality. We did this by investigating age-related differences in the stages of originality; namely, in the generation of a preinventive form and in the exploration of that form as an invention. Prior research finding age-related declines in many of the cognitive processes underlying each creativity stage led us to expect age-related declines in both the generation and exploration stages. We found such age differences in both phases of the Creative Invention Task, favoring younger adults. However, these differences disappeared completely when originality scores were adjusted for age-related differences in visual working memory capacity. Furthermore, with one exception, there were no age-related differences in the subscales of the Torrance standardized test of creativity after adjusting for visual working memory capacity, and the exception was in the opposite direction one would predict: older participants generated titles that were more abstract (i.e., more original) than younger participants. Thus, we found age differences, especially on the CIT, but the age differences were almost solely due to differences in working memory capacity.

There are two views of cognitive aging that may help explain how age-related differences in working memory capacity may impact age-related differences in creativity. One is the processing speed theory (Salthouse, 1996). According to this theory, performance declines on complex cognitive tasks as one ages because older adults are slow to perform early steps in the task and, as a result, may never reach later stages within an allocated period of time because the products of earlier operations are not available. The other view involves inhibition (Hasher & Zacks, 1988). According to this view, age-related declines in working memory capacity are due primarily to an age-related decline in the ability to inhibit irrelevant information. In other words, older adults are less efficient at inhibiting irrelevant information and, as a result, have fewer resources available to allocate toward the task. Both theories predict age-related differences in the number of
responses and in the originality of the response. For example, when combining the shapes during the generation stage, older adults may manipulate the shapes at a slower rate than younger adults and therefore are less likely to produce an original preinventive form. Or, as the older adults manipulate the shapes, other shapes may enter their mind, preventing them from focusing on the relevant shapes, and decreasing their likelihood of producing an original form. Likewise, when interpreting the form as an invention, older adults may be either slower at testing different ways the form could function as an invention, or more likely to think of irrelevant details about the form or the category. In either case, older adults would be less likely to produce an original invention than younger adults.

However, other research investigating attention, inhibition, and the creativity process shows that inhibition works differently for the generation and exploration stages of creativity (Fiore, Schooler, Linville, & Hasher, 2001; Grohman, 2004; Nećka, et al., 2006). In particular, broader attention (weaker inhibition) aids originality in the generation process whereas narrower attention (stronger inhibition) aids in the exploration stage. In our study, originality for older adults was lower in the generation stage than in the exploration stage. Logically, this implies that older adults were more successful at narrowing their attention and inhibiting extraneous information during the exploration stage, and not as successful broadening their attention during the generation stage. This does not fit the inhibition predictions based on Hasher and Zacks (1988). It may be that the study by Grohman (2004) needs to be replicated in older adults. Or, it may be, as argued in the results section, that the generation stage may have been too ill-defined for older adults and their originality suffered whereas they were able to focus their attention more narrowly during the exploration stage to their benefit. Another explanation may be that the exploration stage may require less working memory than the generation stage and, as more working memory is involved, efficiency in completing the task may decline (Verhaeghen, Cerella, & Basak, 2006). Perhaps older adults spontaneously activate personalistic information during exploration but because of age-related slowing have a more difficult time combining abstract pieces of information during generation.

Despite the age differences on the CIT, we find it affirming that, after adjusting for working memory capacity, the younger and older participants were equally original, statistically speaking. Further, they were equally original on two very different measures of creativity, the TTCT and the CIT. The TTCT measures different aspects of creativity (e.g., elaborateness, resistance to premature closure), whereas the CIT measures the originality of two different types of products (i.e., a preinventive form and an invention). Thus, we are confident that this equivalence in originality, after adjusting for working memory, is robust. Others have found similar results for a problem solving task: after factoring out differences in visuospatial reasoning, age differences in performance were eliminated (Zook, Welsh, & Ewing, 2006). Further, increasing one’s working memory load while performing a visual task delays the employment of visuospatial attention for older adults, but not overall performance (Thornton & Raz, 2006).
Our general finding of equivalence in originality for younger and older adults differs from previous cognitive studies of creativity, which typically found age-related declines in creativity (Alpaugh & Birren, 1977; Alpaugh, Parham, Cole, & Birren, 1982; Guilford, 1967; Jaquish & Ripple, 1981; McCrae, Arenberg, & Costa, 1987; Ruth & Birren, 1985; for a review, see Denney, 1990). We believe that the differences stem from two sources. First, these studies did not control for working memory capacity. It is possible that the age-related declines in creativity noted in the earlier studies would attenuate or disappear after adjusting for working memory capacity. Second, our tests of creativity differed from those used in the previous studies. In most research finding age-related declines, a measure of divergent thinking, with its emphasis on fluency, flexibility, and originality subscales, was used. The use of divergent thinking as a measure of creativity has been heavily criticized because it is considered to capture only surface aspects of creativity (see, e.g., Sternberg, 1985). Our data support the contention that these aspects of creativity, especially fluency and flexibility, may not be the most important aspects of creativity. In our study, these two subscales have the lowest correlations with other subscales of the TTCT, and generally are negatively correlated with preinvention and invention originality.

A secondary goal was to assess whether the amount of time older adults had to generate a form and to explore the form might influence their originality. We had predicted that older adults would be less original than younger adults on the CIT when they had a relatively short time to produce a response, but that additional time would attenuate these differences. This prediction was based on the processing speed theory (Salthouse, 1996; see also Salthouse, 1993; Salthouse, Letz, & Hooisma, 1994). According to this theory, age-related declines in cognitive processes are caused by the slowing of neurological processes that result in quantitative rather than qualitative age differences. The theory also suggests that factors that aid the performance of younger adults (e.g., more time) will aid the performance of older adults to a greater degree. Our data do not strongly address the processing speed theory, in that we found no interaction of age with time interval for either preinvention or invention originality. However, we also found no age-related differences in originality at all, after adjusting for working memory capacity. Obviously, 1 min was enough time for both younger and older participants to produce a form or an invention. We had based our time intervals on previous research that had found 1 minute to be of sufficient difficulty for college students, especially for the invention stage (Finke, 1990). We reasoned that older adults may have even more difficulty at this shorter time period, based on the processing speed theory. However, it is quite possible that time had little impact on originality because participants (both younger and old) did not utilize the entire time allotted to perform the task. The experimenters’ observations corroborate this possibility. They reported that some younger and older adults did not use all of the time allotted for each trial, particularly in the 2-min condition. We think a better test of the general slowing theory would involve having the participants create as many forms or inventions as they can within the time interval (see
Anderson & Helstrup, 1993). Given our overall finding of no age-related differences in originality (after equating for visual working memory capacity), we suspect that there may still be no age-related differences in the originality of the products even though there may be differences in the number produced.

It was interesting to us that the TTCT did not correlate with visual working memory capacity, unlike the CIT. Apparently, the TTCT does not place heavy demands on working memory. The TTCT was designed to be completed by a wide range of individuals, including children. Though the task is timed (divided into three 10-min sections), the allotted time has been shown to be adequate for all age groups. Furthermore, high scores on the TTCT come from completing pictures that tell interesting stories, particularly those involving abstract concepts, not necessarily from being able to play mentally with different combinations of shapes or different ways a form could function. The one exception to our general finding is abstractness of titles, which is positively correlated with working memory capacity. Like the invention phase of the CIT, producing a title that is abstract involves playing with different ideas. Working memory capacity likely plays a role in how many ideas one can play with or in how elaborate (or abstract) the ideas are.

Our findings are consistent with the two approaches to the study of creativity and aging identified by Sasser-Coen (1993): the deficit approach and the life-span developmental approach. The deficit approach suggests that creativity declines with age along with other cognitive processes (also see McCrae, 1987 & McCrae, Arenberg, & Costa, 1987). This misery view of aging implies that older adults are not capable of making significant contributions to society. To the extent that measures of creativity rely on working memory capacity, for example, older adults will produce less original responses. The life-span developmental approach argues that both younger and older adults are capable of creativity; however, what defines creativity is different for the two age groups (see also Nakamura & Csikszentmihalyi, 2003). Our findings suggest that younger and older adults are equally original when adjusting for working memory capacity.

Finding that younger and older adults can be equally original is potentially very important for three reasons. First, the coming change in the age-related strata of our society necessitates that older adults continue to contribute to society. Finding that ordinary older adults are capable of being creative, given the right conditions, will help debunk the misery perspective of aging and increase the opportunity for older adults to make contributions to society. Second, knowing that older adults can be as creative as younger adults has the potential to enhance the quality of life for older adults. However, self-perceptions tied to the misery perspective may lower attempts to be creative, resulting in the loss of a chance to improve the overall quality of life. For example, many older adults have to find creative solutions to manage money on a limited income, to have an active social life despite limited mobility, and to readjust after the death of a loved one. Older adults who view themselves as creative problem solvers may be more apt to find creative ways to maintain a high quality of life (see Carlsen, 1991). Finally, we
attempted to understand the relation between age-related differences in cognitive processes (i.e., visual working memory) and age-related differences in creativity. Understanding this relation helps foster an understanding of the cognitive processes underlying creativity in general. This is an important contribution to the development of better theories of creativity.

REFERENCES


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Steven McCown: E-mail: ikata@yahoo.com
**APPENDIX.** Correlations among the Creativity Measures and Working Memory Capacity Separated by Age of Participant.

Younger Participants ($N = 39$).

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<tr>
<td><strong>Visual Working Memory</strong></td>
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<tr>
<td>1. Paper Folding</td>
<td>.06</td>
<td>-.06</td>
<td>.30</td>
<td>-.08</td>
<td>.22</td>
<td>.07</td>
<td>.17</td>
<td>.07</td>
<td>.11</td>
<td>.10</td>
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<td>2. Fluency</td>
<td>.26</td>
<td>.15</td>
<td>.37</td>
<td>.53</td>
<td>.33</td>
<td>.60</td>
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### APPENDIX. Correlations among the Creativity Measures and Working Memory Capacity Separated by Age of Participant.

**Older Participants** (N = 31)

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'p < .08; *p < .05; **p < .01
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