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**Age-Related Differences in Working Memory and Creativity:  
Younger and Older Adults in Comparison**

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# Age-Related Differences in Working Memory and Creativity: Younger and Older Adults in Comparison

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**Abstract.** Working memory and creativity are relevant for health and wellbeing in older adults. While age-related decline in working memory has constantly been observed, results for creativity are ambiguous. This study aims to investigate age-related differences in working memory and creativity and potential age-related differences in their relationship. 49 younger adults and 165 older adults performed a digit sorting task (measuring working memory) and the Torrance test of creative thinking (measuring creativity). Younger adults showed higher working memory capacity and were also more creative than older adults. However, no relationship between both measures was observed neither in younger nor in older adults. Results are discussed in line with the common-cause theory as well as other potential reasons for age-related cognitive decline.

High levels of cognitive functioning in old age are related to increased wellbeing, life satisfaction and other health factors. Therefore, it is important to expand our knowledge on age-related decline in cognitive functioning, such as working memory and creativity, in order to further promote high levels of mental health and life satisfaction for older adults, for example by investing interventions and training programs.

Even though some cognitive functions such as crystalized abilities (e.g., verbal knowledge, semantic memory) stay relatively constant across the years (e.g., Christensen, 2001), other fluid abilities such as episodic memory start to decline around the age of 60 years according to longitudinal studies (Rönnlund, Nyberg, Bäckman, & Nilsson, 2005).

High levels of cognitive functioning in old age are related to increased wellbeing, life satisfaction and other health factors. Therefore, it is important to expand our knowledge on age-related decline in cognitive functioning, such as working memory and creativity, in order to further promote high levels of mental health and life satisfaction for older adults, for example by investing interventions and training programs.

The main focus of this study is on working memory and creativity. Working memory is crucial for overall health and life satisfaction, since it is a critical cognitive function for several higher-order cognitive abilities, such as everyday planning, problem solving, reason and language comprehension (Baddeley, 1992). Regarding creativity, a comparative study of 300 Americans observed that individuals, who engage in creative activities, improved their general health, reduced the number of visits to the doctor and reduced the need for medication (i.e., Cohen, 2006). However, the relationship between creativity and working memory in younger and older adults has not sufficiently been investigated so far. Since working memory includes the ability to maintain as well as to

update and flexibly process information, which are characteristics of creative processes as well, there might exist a relationship between these cognitive processes. The relationship between working memory and creativity might differ across the adult lifespan in relation to age-related decrease in fluid abilities (i.e., stronger relationship in older adulthood).

The purpose of this study is to investigate age-related differences in working memory and creativity and their relationship in younger and older adults. In the following sections, I will first briefly define working memory and age-related changes in working-memory functioning across the adult lifespan before I will present current findings on creativity and the potential relationship between both domains.

## **Working memory**

Working memory has been defined as “*the cognitive process used to manipulate or temporarily store information while planning or controlling other mental processes*” (i.e., Campbell & Charness, 1990, p.879). Working-memory functioning has been related to comprehending language, learning, making decisions and solving problems (Baddeley, 1992). Working memory is the information processing part of our cognition. It consists of several systems such as the phonological loop, which deals with spoken and written material (e.g., remembering a phone number), the visuospatial sketchpad, which deals with visual and spatial information (e.g., knowing where we are in relationship to other objects) and the central executive, which govern these systems (Baddeley & Hitch, 1974). Together they encode, maintain and process information presented to us. Working memory capacity refers to the individual differences of the limited capacity of an individual’s working memory (Wilhelm, Hildebrandt, & Oberauer, 2013).

Previous studies have mostly found working-memory capacity to decrease with age (e.g., Baddeley, 1986; Gick, Craik, & Morris, 1988; Salthouse, Mitchell, Skovronek, & Babcock, 1989). In a more recent study (Jenkins, Myerson, Hale & Fry, 2000), younger adults ( $Age_{range} = 18-24$  years of age) and older adults ( $Age_{range} = 62-77$  years of age) worked on verbal working-memory tasks. Older adults remembered only 67% of the number of letters remembered by younger adults, indicating that younger adults have better verbal working than older adults. Jenkins and colleagues (2000) also found an even greater difference in the age groups when performing visuo-spatial working-memory tasks, indicating that visuo-spatial working memory declines more in older adulthood than verbal working-memory. Similarly, Chen and colleagues (Chen, Hale & Myerson, 2003) found that age affected working-memory capacity and that increasing memory load resulted in greater age-related decline in working-memory performance. According to the inhibitory deficit hypothesis, age-related decline in working memory (and other cognitive abilities) is proposed to be due to the inability to inhibit interference from task-irrelevant information (e.g., Hasher & Zacks, 1988). However, according to the processing speed hypothesis, others have argued that the age-related difference in working memory is explained by declines in processing speed, indicating that older adults can perform as well as younger adults, given sufficient amount of time (Babcock & Salthouse, 1990).

## Creativity

Another aspect of cognition which is widely accepted as an important indicator of individuals' life satisfaction is the ability to be creative. Creativity is defined in different ways by different researchers. Stein (1953) defined creativity as: "... *that process, which results in a novel work that is accepted as tenable or useful or satisfying by a group at some point in time*" (p.311). Boone & Hollingsworth in 1990 (p.3) said that creativity is "... *any form of action that leads to results that are novel, useful, and predictable.*" According to Mumford (2003, p.110) creativity "... *involves the production of novel, useful products*". Even though these are only few of the many definitions of creativity, most researchers have accepted divergent thinking (Guilford, 1950, 1967) as an appropriate characteristic when measuring individuals' creativity. Divergent thinking is an open-ended mental process, functionally directed to find many novel, convenient and different answers to a particular problem (Guilford, 1950; 1967). When measuring divergent thinking abilities, they are often divided into four distinct subscales: fluency (i.e., number of ideas generated), flexibility (i.e., shifts in responses), originality (i.e., number of statistically rare responses) and elaboration (i.e., amount of detail in responses, see for example Torrance & Ball, 1984; Torrance, 1990). Divergent thinking is often measured with the Torrance Test of Creative Thinking (TTCT, Torrance, 1966). In this study, I use creativity in line with Guilford's definition of divergent thinking, since it is one of the most widely accepted definitions of measuring creative abilities.

Engaging in creativity promotes social interaction, provides cognitive stimulation and enhances individuals' sense of self-worth (Price & Tinker, 2014). As Fisher & Specht (1999) proposed, creativity can be used by older people to better cope with the cognitive and physical negatives of aging, by fostering a sense of competence, purpose and growth. Research has found different results on whether creativity decreases, increases, or stays intact with increasing age. There are two different approaches with regard to age-related changes in creativity: (a) the deficit approach, which states that creativity declines with age in line with other mental processes and (b) the lifetime developmental approach, which argues that older people can be as creative as younger people (Sasser, 1993).

In line with the deficit approach, different researchers have found declines in divergent thinking abilities starting from middle age (e.g., Alpaugh & Birren, 1977; Jaquish & Ripple, 1981; McCrae, Arenberg, & Costa, 1987; Reese, Lee, Cohen, & Puckett, 2001). More recent studies however, have found results aligned with the lifetime developmental approach, which proposes that older adults can think as divergently as younger adults (Foos & Boone, 2008; Roskos-Ewoldsen, Black, & Mccown, 2008). Other studies found a more differentiated picture of findings. Jaquish & Ripple (1984) found age-related decline in divergent thinking abilities in terms of fluency and flexibility but not in originality. When comparing younger adults ( $Mean_{age} = 19.37$ ) and older adults ( $Mean_{age} = 73.05$ ) on the Torrance Test of Creative Thinking—Figural Form B (Torrance, 1966; Torrance & Ball, 1984), Roskos-Ewoldsen et al., (2008) found no difference between younger adults and older adults in terms of fluency, flexibility, originality, or elaboration. Another interesting finding was discovered by Foos and Boone (2008), showing that older adults ( $Mean_{age} = 72.10$ ) performed as well as younger adults ( $Mean_{age} = 20.53$ ) on divergent thinking tasks when time limits were removed, showing that older adults can be as creative as younger

adults but at a slower rate. Given these results, it is still unclear whether creativity declines (deficit approach) or stays intact (life span developmental approach) in older adulthood.

### **Link between Working Memory and Creativity**

The question is then what processes or factors influence one's ability to be creative. Two different approaches to what influences creativity are often highlighted. The first approach is the associative theory of creativity (Mednick, 1962), which proposes that creative idea-generation is based on individual differences in associative hierarchies. Thus, people with steep associative hierarchies will produce high-frequency answers (e.g., fork-knife) and quickly exhaust their output. People with flat associative hierarchies however, will fluently retrieve remote associative elements which can be formed into creative ideas (Beaty, Silvia, Nusbaum, Jauk, & Benedek, 2014). Furthermore, a more recent theory has been developed: the controlled attention theory. According to this theory, creative ideas arise from the ability to exert top-down control over attention and cognition (Beaty et al., 2014).

Working-memory functioning includes maintaining novel information in a heightened state of activity as well as to discriminate between task-relevant and task-irrelevant information (Unsworth & Engle, 2007). In line with the controlled attention theory, working-memory functions are essential in creative performance. Recent studies done in this field, have found positive relationships between working-memory capacity and creativity (Dreu, Nijstad, Baas, Wolsink & Roskes 2012; Lee & Theriault, 2013; Oberauer, Süß, Wilhelm, & Wittmann, 2008), indicating that individuals with high working memory capacity were more creative than individuals with low working-memory capacity. Following these research lines, I expect to find a relationship between these abilities. The research aims and specific hypotheses of this study are presented in the following.

### **Research Aims and Hypotheses**

The present study investigates the link between working memory, creativity and age-related changes in the potential link between both. Specifically, the following questions are in focus of this thesis: (a) Do younger adults have better working memory capacity than older adults? (b) Are younger adults more creative than older adults? (c) Are there age-related differences in the relationship between working memory and creativity? In relation to these questions, the following hypotheses will be tested. First of all, I expect that younger adults perform better than older adults on working memory functioning (Hypothesis 1). Second, younger adults will be more creative than older adults (Hypothesis 2). Lastly, I predict age-related differences in the potential relationship between working memory and creativity. As working memory declines in older adulthood, I predict to find a similar trend with creativity. Hence, I expect to find a stronger link between working memory and creativity in older adults than in younger adults (i.e., the relationship between working memory and creativity will be more positive in older adults than in younger adults; Hypothesis 3).

## Methods

### Participants

This experimental study was part of a large-scale training study investigating the neural correlates of memory plasticity across the lifespan (Brehmer, Shing, Heekeren, Lindenberger, & Bäckman, 2016) run at the Max Planck Institute for Human Development in Berlin, Germany. The initial sample consisted of 95 children, 49 younger adults, and 165 older adults. The focus of this study is on age difference between younger and older adults; hence, the subsample of children was disregarded. The final study sample consisted of 49 younger adults ( $M = 23.8$ ,  $range = 21-26$ ) and 165 older adults ( $M = 67$ ,  $range = 63-74$ ). Participants were recruited through newspaper ads in Germany. They were all healthy and acquired high educational level (Younger adults:  $M = 16.0$ , Older adults:  $M = 16.2$ ). Interestingly, the age groups did not differ in years of education,  $p > .05$ . All participants gave their written informed consent to participate in the study and received financial compensation after finalizing the study.

### Instruments

**Working Memory Assessment.** The Digit Sorting Task (Kray & Lindenberger, 2000) was used to measure working-memory abilities, which was operationalized as the ability to hold information while completing a task. In this task, the test leader read out a list of 1 to 2 digital numbers to the participants. The participants' task was to hold the numbers in mind and sort them ascendingly and only after the test leader finished reading out the list of numbers to write them down from lowest to highest number in an ascending order. Individuals were not allowed to change their answers once they were written. The researcher handed out sheets containing 15 items (1 item consisted of a row of numbers), with 3 practice items before the task. The sheet of 15 items was divided into five levels of difficulty, each containing three rows. The first and easiest level had rows consisting of four numbers while the last level had rows consisting of eight digits. Before reading each row, the researcher informed the participants about the amount of numbers to remember. No time limit was given for the participants to write down their answer. In this study, the total amount of correctly remembered rows was used as the dependent variable. The score had a range from zero to fifteen.

**Creativity Assessment.** This study used the Torrance Test of Creative Thinking (TTCT; Torrance 1966) to measure individuals' creativity. The TTCT has been applied worldwide to be a valid and reliable instrument in testing creativity (Kyung Hee, 2006). Creativity was defined as divergent thinking operationalized with the four subcategories: fluency, flexibility, originality and elaboration. The original TTCT consists of two parts, TTCT-verbal and the TTCT-figural, each of them consisting of two parallel forms: A and B. In this study, the TTCT-figural form A was assessed. The test leader instructed the participant that this was a test of their creativity using pen and paper. The form was handed out to the participants revealing 45 identical parallel, vertical lines, and they were told that they had 10 minutes to create as many different

objects/pictures of these lines. The two vertical lines would have to be the main part of the object/picture. The lines could be above, below, next to and around the lines. Participants were encouraged to create as many different and unique ideas as possible and to try and think of things nobody else would think of and that less emphasize was put on drawing abilities. Lastly, participants were instructed to give each image a name below it and were asked if they had any questions.

Participants' performance was scored on four subscales; fluency (i.e., the number of interpretable, meaningful and different responses), flexibility (i.e., the number of shifts in categories for scored responses), originality (i.e., the number of statistically unique scored responses), and elaboration (i.e., the amount of detail in the scored responses). The scales were scored separately and independently from the participants other responses, except for fluency which all of the responses were based on (e.g., a response that was not scored on fluency could not be scored on originality). Scores for both the subscales of creativity and the combined scoring (mean of the standardized raw score of fluency, rate score of flexibility, rate score of originality, and rate score of flexibility) were used as dependent variables in the analysis. The scoring of the individual subscales was done in line with previous work (Lindenberger, Brehmer, Kliegel, & Baltes, 2008; Lindenberger, Kliegel & Baltes 1992).

## **Procedure**

As mentioned above, the working memory and creativity tests used in this study were assessed in the framework of a large-scale training study (Brehmer et al., 2016). The two tests took place in two consecutive sessions. While working memory was assessed together with a large battery of other psychometric tests in age-homogeneous groups of 3-5 individuals, the creativity test was assessed individually in another test sessions taking place the same week.

## **Statistical Analysis**

First, to investigate age-related differences in working-memory capacity a univariate analysis of variances (ANOVA), with age as independent variable (2 levels: younger adults, older adults) and working memory as dependent variable was conducted. Separate univariate ANOVAs were also used to check for age-related differences in fluency, flexibility, elaboration and originality as well as the combined creativity score with age as the independent variable (2 levels: younger adults, older adults) and the respective creativity sub-score/combined score as dependent variable. Finally, to look for age-related differences in the relationship between working memory and creativity, a comparison of correlation coefficients was planned. Depending on the analysis, a few participants were excluded due to extreme values in some scales (i.e., more than 3 standard deviations above the group mean). Six participants (i.e., 2 younger adults and 4 older adults) were excluded from the creativity analysis with the composite score. Furthermore, within the analysis of the subscales, one older adult was excluded from the analysis of originality, one younger adult from the analysis of flexibility, and three participants (2 older adults and 1 younger adults) were excluded from the analysis

of elaboration. Finally, 6 older adults were excluded from the analysis of working memory.

A combined score of creativity was created by adding the different subscales of creativity (i.e., fluency, flexibility, originality, elaboration) as has been used in previous literature (Lindenberger et al., 1992). The combined score for creativity was operationalized averaging the t-standardized raw scores for fluency and t-standardized rate scores for flexibility, originality, and elaboration (all based on fluency). The T-standardization of the individual scores ( $M = 50$ ,  $SD = 10$ ) for the subscales of creativity was conducted in order to give them all the same weight when conducting the combined creativity score. This was done separately for younger adults and older adults for the group-specific analyses of the relationship between working memory and creativity, as well as across both age groups for the analysis of age-related differences in the relationship between working memory and creativity.

## Results

**Working-Memory Assessment.** The univariate ANOVA for age group x working memory showed a significant main effect  $F(1,202) = 15.62$ ,  $p = .001$ ,  $\eta^2_p = .07$ , indicating that younger adults performed better on the working-memory task than older adults (see Fig. 1).

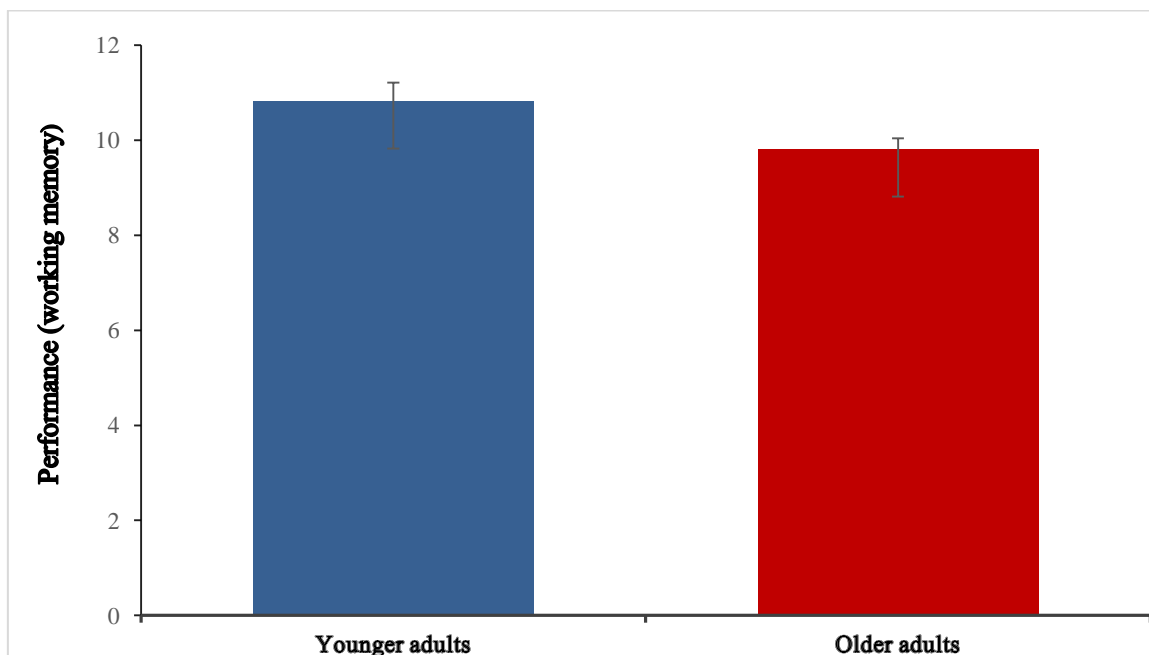


Figure 1. Mean number of correctly remembered rows in the digit sorting task (measuring working memory) separately for younger and older adults. Standard bars represent standard errors around the mean.

**Creativity Assessment.** Results from the univariate ANOVA on age group x creativity for the combined creativity score showed a significant main effect,  $F(1,20) = 74.36$ ,  $p <$



.001,  $n^2_p = .26$ , indicating that younger adults scored higher on the creativity task than older adults (see Fig. 2). The separate univariate ANOVAs for age group with flexibility, originality, and elaboration showed significant main effects indicating that younger adults were more flexible, more original and more elaborative in their responses in relation to older adults ( $ps < .01$ ). However, for fluency, no significant effect between the age groups was observed,  $F(1,20) = .71, p = .79$ , indicating that the age groups did not differ in the number of generated images.

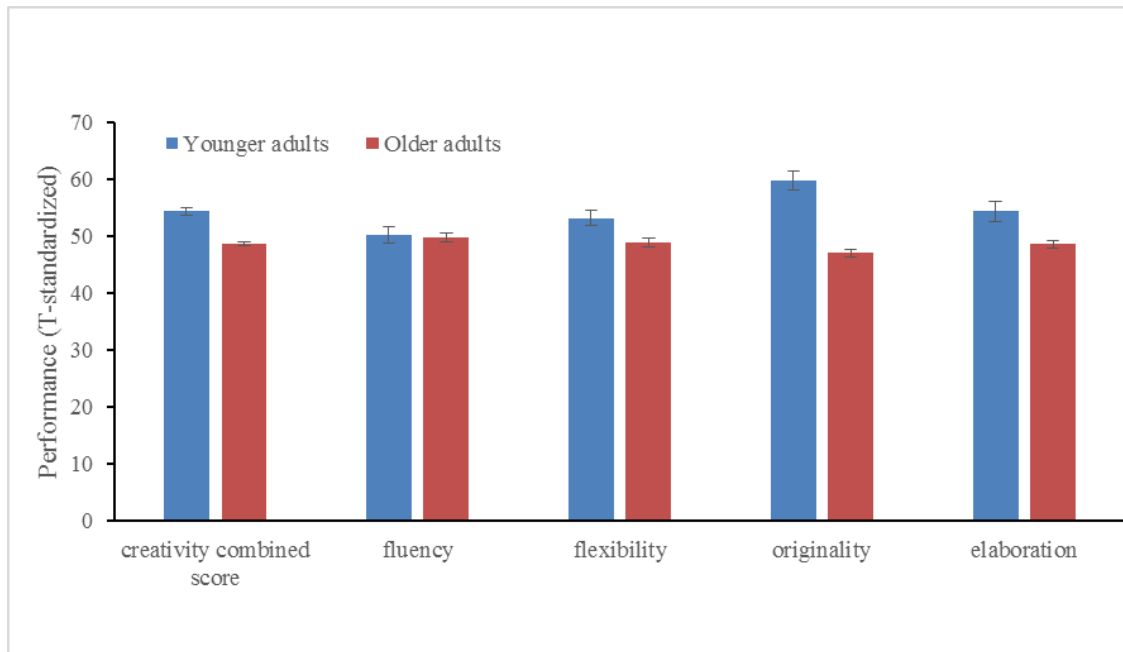


Figure 2. Mean t-standardized creativity scores for the overall combined and the subscales (fluency, flexibility, elaboration, originality) of creativity, separately for younger and older adults. Standard bars represent standard errors around the mean.

### Relationship between working memory and creativity

The results from Pearson's correlation analysis to examine the relationship between working memory and creativity in younger and older adults separately, showed no significant results, neither on the combined creativity score nor on the 4 subscales (i.e., fluency, flexibility, originality and elaboration) of creativity, all  $ps > .05$  (see Table 1). These results indicate that I was not able to find a significant relationship between working memory and creativity in this study, neither in younger adults nor in older adults. Hence, the final analysis of comparing the correlation coefficients between the age groups was not conducted.

Table 1.

*Correlations between working memory and creativity combined score and sub scores*

Creativity test	Younger adults (N=48)	Older adults (N=162)
Creativity combined score	.15 ( $p = .31$ )	.11 ( $p = .13$ )
Fluency	.06 ( $p = .68$ )	.10 ( $p = .11$ )
Flexibility	.00 ( $p = .98$ )	.00 ( $p = .95$ )
Originality	.07 ( $p = .64$ )	.10 ( $p = .18$ )
Elaboration	.11 ( $p = .45$ )	.00 ( $p = .97$ )

## Discussion

The purpose of this study was the investigation of age-related differences in working memory and creativity, as well as to examine potential age-related differences in the relationship between them.

Three primary hypotheses were formulated in order to answer my research questions. First of all, and in line with hypothesis 1, I found that younger adults showed higher working-memory functioning than older adults. This finding supports previous research showing working memory decline in older adulthood (e.g., Baddeley, 1986; Gick, Craik & Morris 1988; Salthouse, Mitchell, Skrovronek & Babcock 1989). Interestingly, this finding contradicts the processing speed hypothesis, stating that older adults would perform similarly to younger adults on working-memory tasks without time pressure (Foos & Boone, 2008), since the digit sorting task in the present study, did not have any time limit. Even though the participants could take as long time as they wanted to finish the test, they still did not perform as well as younger adults.

My second prediction was that younger adults would be more creative than older adults (Hypothesis 2). This hypothesis was confirmed by our finding on overall creativity, indicating that younger adults showed greater overall creativity than older adults. This finding is in line with the deficit approach of creativity, which states that creativity declines with age (e.g., Alpaugh & Birren 1977; Guilford, 1967; Jaquish & Ripple, 1981; McCrae, Arenberg & Costa 1987; Reese, Lee, Cohen & Pucket, 2001). Potential age-related differences were also investigated in the different subscales of creativity (i.e., fluency, flexibility, originality and elaboration). Here, I found that younger adults were more flexible than older adults, produced more unique images, and were more elaborate in their responses. However, the two groups did not differ in the number of images generated (i.e., fluency). These findings indicate that flexibility, originality and elaboration declines in older adulthood, but that younger and older adults do not differ in the number of produced pictures/images. These findings were particularly interesting, since they contradict previous research that found age-related differences in fluency and flexibility, but not in originality and elaboration (Jaquish & Ripple, 1984). However, in that study, age groups were operationalized differently in comparison to our study. The age range for the younger adults in that study ranged from 26 to 39 years of age, while they called a group of adults aged 40 to 60 years of age as older adults. In line with current literature and current longitudinal studies indicating that age-related changes in fluid abilities start around 60 years of age, we operationalize our older adult's age group with an age range from 62-74. This might be one reason explaining the difference between the study of Jaquish & Ripple and this study. The

result of the present study also contradicts the finding of Roskos-Ewoldsen et al., (2008), who did not find age-related differences in any of the subscales of creativity. However, in their analysis they controlled for age-related differences in working memory, and thus, indirectly for age differences per se. Before this adjustment, they found younger adults to be more creativity than older adults, which means their result confirm my results that creativity declines in older adulthood.

Also, we do not know if we would have had the same results if time limits were removed from the creativity task. In the present study, participants were given ten minutes each to finish the creativity task. As previous research has proposed that age-related decline in complex cognitive tasks are due to declining processing speed (Foos & Boone 2008, Babcock & Salthouse 1990), we do not know if older adults in this study would have generated more images if given more time. However, this is not very likely, since both groups generated the same number of images, but older adults instead were less flexible, original and elaborative in their responses. One possible reason for our findings on fluency contradicting previous research is due to our sample of older adults (i.e., exceptionally healthy, as they were eligible to participate in an MRI study and highly educated), which could explain their high scores on fluency. However, younger adults in the sample were also healthy and highly educated, which would equalize this confounding variable.

Finally, I also predicted to find a stronger link in relationship between working memory and creativity in older adults than in younger adults (Hypothesis 3). I predicted that as working memory declines in older adults, so would their creative ability. As previous research has found a positive relationship between working memory and creativity in younger adults (Oberauer et al., 2008; De Dreu et al., 2012; Lee & Therriault, 2013), I predicted the relationship to be even stronger in older adults. Before analyzing potential age-related differences in the relationship between working memory and creativity, the correlation between these two abilities was investigated separately for each age group. However, contradicting our hypothesis, no significant relationship between working memory and creativity (combined score as well as any of the four subscales) was observed. This indicates that no relationship between working-memory functioning and creativity could be found in this study, neither in younger adults nor in older adults, and therefore an age comparison between correlation coefficients was abandoned. These findings contradict the findings of recent studies done in this field, which have found positive relationships between working memory capacity and creativity – however in younger adults only (De Dreu et al., 2012; Lee & Therriault, 2013; Oberauer et al., 2008).

A potential reason for not finding a relationship between working memory and creativity in this present study could be how both measures were operationalized. The present study only used a Digit sorting task to measure working memory, whilst other working-memory tests might had resulted in different findings. The same implication applies for the measurement of creativity. Roskos-Ewoldsen et al. (2008), found that working memory measured through a paper folding test (visual working memory) was positively correlated to creativity measured through a creative invention task (CIT; Finke 1990) but not to creativity measured with the TTCT. The creative invention task consisted of two phases; the generation phase (participants combined three common shapes into a potentially useful object), and the explorations phase (participants heard a category name that has been randomly selected from a list and then needed to name their object in light of the given category). The CIT's two phases were individually

scored for originality. Interestingly, they found no relationship between the TTCT and the CIT (Roskos-Ewoldsen et al., 2008). Roskos-Ewoldsen and colleagues hypothesize that the CIT uses working memory and the TTCT does not, which explains their non-relationship.

De Dreu et al., (2012) also found a positive relationship between working memory and creativity. In their study, they used the remote associates test (RAT; Mednick, 1962) which is a task measuring creative insight. Creative insight problem tasks were developed in order to assess the spontaneous “aha” feeling that occurs when an individual is working on a solution to a problem (Beaty et al., 2014). In the RAT task, individuals are asked to identify associations among words that are usually not connected. Another study that found working memory to predict insight problem solving abilities used verbal and visuo-spatial working-memory tasks when measuring working memory (Gilhooly & Fioratou, 2009). Recently however, insight tasks have been criticized as a measurement of creativity since insight problem task involves unconscious associative processes (Bowden et al., 2005). These tasks are related to the older creative thinking theory; the associative theory of creativity (Mednick 1962), while divergent thinking involves controlled strategic processes (Gilhooly et al., 2009), which is associated with more recent creativity theory; the controlled attention theory of creativity. Beaty and colleagues (2014) performed two studies, which did not find a relationship between insight problem solving and self-reported creativity. Hence, previous research has found working memory to be positively related to other measures of creativity, rather than divergent thinking, which was used in the present study. Following these research lines, there is some evidence that working memory is involved with the decline of some creative abilities (insight problem solving) and not in other creative abilities (divergent thinking).

According to the common-cause theory (Lindenberger & Baltes 1994) there could be a common cause for age-related decline in cognitive functions. One potential cause for the decline of working memory and creativity could be declining fluid intelligence or attentional ability. Since both working memory capacity and creativity seem to require the use of attention (e.g., inhibiting interference from external unrelated stimuli, inhibiting task irrelevant information), it could be that attention might be an underlying mechanism for age-related decline in cognitive functioning such as working memory and creativity. Researchers have found that attention declines in older adulthood (McAvinue *et al.*, 2012). Hence, in line with the common cause theory, attentional decline could account for the decline of working memory and creativity. Kane and colleagues (2001) found a positive correlation between working-memory capacity and controlled attention ability. Brehmer, Westerberg & Bäckman (2012), found that training working memory in older adults not only increased working-memory performance, but also non-trained tasks such as attention. Hence, the reason for age-related decline in working-memory capacity and creativity could be a consequence of declining attentional capacity. Unfortunately, this is out of the scope of this study, since measurements of sustained or divided attention were not assessed in this study. However, this line of thinking should be conducted in future studies.

A few limitations of this research should be acknowledged: First of all, the sample of this study included only healthy and highly selected participants since they needed to be eligible for MR scanning. This means that they did not suffer from any physical or mental illnesses that would not have allowed them to be scanned. Also, participants were all highly educated. Hence, this sample does not have high ecological

validity since it does not represent the general population. However, the main purpose of this study was to strengthen the age-comparison and to investigate age-related differences in working memory and creativity. Hence, the cost of ecological validity comes with the benefit of comparing younger and older adults with reducing the potential influence of confounding variables such as education level, cognitive and physical health from the direct age-comparison.

Furthermore, this study shows that younger adults perform better than older adults on the specific creativity task applied (i.e., TTCT). This task investigates divergent thinking, but it is only one way of measuring divergent thinking and creativity. It is based on visual divergent thinking only. Results might have looked different for verbal divergent thinking tasks (see Palmiero, Giacomo & Passafiume 2014). Future studies would benefit from investigating a broader range of divergent thinking tasks including verbal and visual-spatial domains. Even though I was not able to assess a direct link between working memory and creativity, neither in younger adults nor in older adults, this line of research is important to conduct as findings show that creativity is crucial for older adults' life satisfaction, as research has shown creative activities to be crucial for the elderly population in order to maintain their health and life satisfaction after retirement. Therefore, finding a link between creativity and other cognitive functions such as working memory or maybe attention will be beneficial for training programs enhancing creativity in older adults.

In conclusion, this present study has confirmed that both working memory and creativity declines in older adulthood but did not show a relationship between them. Importance of enhancing working memory and creative capacity in older adulthood has been recognized; hence further research should focus on finding a relationship between other cognitive abilities and working memory and creativity in order to increase these abilities in older adults in order to enhance their life, resist declining general health and reduce costs for the individual as for society.

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