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Creativity in Older Adults: Elucidating the Interactions between Cognitive Functions Underlying Creativity and the Role of Demographic Variables

ABSTRACT

Creativity involves generating novel and valuable ideas. While the importance of creative thinking is widely acknowledged, its cognitive basis is poorly understood, particularly in older adults. This study aimed to develop and test an explanatory model of creative thinking to elucidate its underlying cognitive functions in an elderly sample. The role of demographic variables, including age, multilingualism, socioeconomic status (SES), level of education, and gender in creative thinking was also investigated. One hundred and twenty-five participants aged 65 years and above-completed measures of divergent, convergent and associative thinking, as well as task-switching, inhibition and fluid intelligence. Structural equation modeling (SEM) analyzed the relationships between these cognitive functions, and group differences assessed whether there were significant differences in the cognitive measures based on the demographic variables. Creative thinking appeared to entail the cooperation between divergent and convergent thinking, which both rely on associative thinking, suggesting an associative basis of creative thinking. Creative thinking involved fluid intelligence and task-switching, but not inhibition, recasting it as a higher-order function. This study supports the dual-process account of creative thinking by demonstrating an associative basis and the role of executive functions. Differences among education and SES groups occurred for most cognitive functions analyzed. These findings inform prevailing theoretical frameworks of creative thinking.

Keywords: associative thinking, creative thinking, convergent thinking, divergent thinking, elderly, executive functions.

INTRODUCTION

Creativity is a construct that spans multiple disciplines, has been subjected to several analysis methods and has many definitions (Pinkow, 2022). It is often defined as the process of generating products that are both novel and effective (Runco & Acar, 2012) and encompasses both creative thinking (viewed as the antecedent cognitive process to creativity) and creative cognition (which refers to various cognitive processes that underlie creative thinking; Pinkow, 2022). These definitions highlight creativity as a multifaceted and complex construct (Beaty & Kenett, 2023). Nevertheless, given that creative thinking is the cognitive process that comprises divergent and convergent thinking (Pinkow, 2022) and that we focus on these two processes in this study, we use the term "creative thinking."

Theoretically, creative thinking is conceptualized as either a bottom-up, automatic process (Mednick, 1962) or as a top-down process reliant on executive control (Benedek et al., 2017), with findings in support of each approach (Barr, 2018). The dual-process theory consolidates these two seemingly opposing conceptualizations as it suggests a complementary role between both associative (bottom-up) and executive (top-down) processes (Barr, 2018). Dual-process theories include the Geneplore (Finke, Ward, & Smith, 1992), the blind-variation and selective-retention theory (BVSR; Simonton, 2022) and the dual-process theory of reasoning (Sowden, Pringle, & Gabora, 2015). The Geneplore model maintains that creative ideas result from an interplay between generative and explorative processes. In contrast, the BVSR theory proposes that individuals generate ideas that they adapt differently, select a best-fitting variate, and repeat this procedure until a creative idea is produced (Simonton, 2022). The dual-process theory of reasoning argues that creative output results from the interaction of two sets of thinking processes, including intuitive (type 1) and deliberate (type 2) thinking (Sowden et al., 2015).

Although the dual-process theory has gained popularity in the creativity literature, few studies have considered both associative and executive functions in the same study (Beaty, Zeitlen, Baker, & Kenett, 2021). The current study attempts to address this gap and consolidate conflicting findings by evaluating the relative contribution of associative and executive processes to creative thinking. The specific theoretical contributions of the study include the development of a coherent explanatory model of creative thinking and empirically testing this model using structural equation modeling (SEM). In doing so, we elucidate the cognitive functions implicated in creative thinking and investigate their relationships in an under-researched sample, namely older adults (i.e., 65 years and older). By simultaneously assessing multiple relationship pathways between several variables, SEM affords this study additional methodological significance, as prior research tends to focus on individual factors in creative thinking (Fryer, 2012). Finally, this study addresses a limitation of cognitive approaches to creativity, namely the tendency to neglect demographic and contextual factors. We included the demographic variables of age, number of languages spoken (monolingual, bilingual, or multilingual), socioeconomic status (SES), level of education, and gender.

The first step of SEM is model specification, which involves determining the variables of interest and the relationships between them (Crockett, 2012). In this regard, creative thinking comprises both divergent and convergent thinking (Guilford, 1967), and a combination of cognitive functions underlie these abilities (Kharkhurin, 2012). Divergent thinking is an ideational, bottom-up process that occurs when concepts and associations disperse in varied directions (Runco & Acar, 2012). A common feature of divergent thinking measures is the production of multiple responses to an ambiguous and open-ended problem (Lee & Therriault, 2013). Despite insufficient evidence to suggest that creative thinking is a psychometrically unitary construct (Arden, Chavez, Grazioplene, & Jung, 2010), divergent thinking tests are typically used as sole measures of creative thinking (Benedek, Mühlmann, Jauk, & Neubauer, 2013; Simonton, 2015). Contemporary creativity researchers argue against this oversimplified approach, and there is increasing recognition that creative thinking draws on convergent thinking (Cropley, 2006; Kharkhurin, 2012; Sowden et al., 2015).

Convergent thinking is an analytical, top-down thinking style that extracts a single, best-fit, or correct solution. Creative thinking is proposed to rely on the joint operation of divergent and convergent thinking, with the divergent phase generating multiple responses, which tend to be more spontaneous and bottom-up. These responses are subsequently assessed during the convergent phase, which evaluates the utility of the initial output (Chrysikou, 2019). This conceptualization implies that divergent thinking is a prerequisite for convergent thinking and that one mode of thinking needs to terminate before the other is engaged (Sowden et al., 2015). The distinction between divergent and convergent thinking implies a dichotomy, representing these two processes as opposing or unrelated (Runco, 2014). This is supported by nonsignificant correlations between divergent and convergent thinking subscores on the Creative Reasoning Test (CRT; Jaarsveld, Lachmann, & van Leeuwen, 2012). In this study, the CRT compares divergent and convergent thinking abilities in the same knowledge domain, providing strong support that they are separate functions. However, there are significant relationships between associative processes and both divergent (Beaty, Silvia, Nusbaum, Jauk, & Benedek, 2014; Benedek et al., 2017) and convergent thinking (Benedek, Könen, & Neubauer, 2012; Marko & Riečanský, 2018) aspects of creative thinking, suggesting that divergent and convergent thinking are related through their reliance on associative thinking, rather than being mutually exclusive processes (Lee & Therriault, 2013).

An associative basis to creative thinking fits with Mednick's (1962) theory of creativity, which considers semantic memory as the root of creative thought as it enables loosely related concepts to be combined into novel and useful ideas. Specifically, creative thinking entails conceptual nodes in semantic memory being stimulated, causing residual activation that spreads along associative links, automatically activating other nodes in the network (Foster et al., 2017). Flexible and highly interconnected networks with few large association clusters, characterized by "flat" (widespread associations) rather than "steep" (few, common associations) associative hierarchies, enable the activation of more remote and discrete conceptual nodes, thereby establishing complex connections and, hence, more creative output (Benedek et al., 2017; Mednick, 1962). The associative theory conceptualizes creative thinking as a bottom-up, automatic process, implying that it occurs independently of conscious control (Colzato, Szapora, Pannekoek, & Hommel, 2013). Although automatic processing may result in novel ideas, the criterion of novelty alone is not sufficient for creativity

(Runco & Jaeger, 2012). Individuals prone to automatic processing may experience thought perseveration, leading to more conventional ideas and, hence, produce less creative output (Zabelina & Robinson, 2010).

Consequently, creative thinking relies on executive functions that enable the control of thoughts and actions during goal-oriented tasks (Friedman & Miyake, 2017). Through their influence on lower cognitive processes, executive functions benefit creative thinking by improving the efficiency of memory retrieval, strategy implementation, and the manipulation of information (Benedek et al., 2017). While executive functions facilitate creative thinking by enabling a focus on relevant information and the suppression of irrelevant information, they may make the cognitive system inflexible and nonreactive to alternative possibilities. Similarly, while high flexibility enables effective switching between actions and alternative possibilities, it may increase distraction and interference by task-irrelevant information. Therefore, creative thinking will likely emerge from an appropriate balance between increased and diminished cognitive control, that is, cognitive persistence and flexibility, depending on the given task (Zhang, Sjoerds, & Hommel, 2020).

The executive function of task-switching facilitates this balance through efficient shifting along the divergent and convergent thinking continuum. Task-switching involves disengaging from well-established schema and adopting a new, more task-relevant schema, enabling dynamic adaptation to changing task demands (Daucourt, Schatschneider, Connor, Al Otaiba, & Hart, 2018). This can benefit associative aspects of creative thinking by optimizing information retrieval from semantic memory. In particular, structured semantic networks organize information in a modular or locally clustered manner. Although this structuring facilitates rapid transitions between semantically related concepts within a particular subcategory, the network's topology may limit the spread of activation and, thus, constrain the ability to find remote paths between conceptual nodes. Task-switching mitigates the exploration limitations of network topologies by shifting to alternative semantic fields, which allows the spread of activation to reach more remote associations (Troyer, Moscovitch, & Winocur, 1997) and prevents cognitive fixation on ineffective ideas or unproductive problem-solving strategies (Chrysikou & Weisberg, 2005; Kohn & Smith, 2011; Storm & Angello, 2010). As task-switching may facilitate the spread of activation in semantic memory, it is theorized to predict associative thinking and, thus, is considered one of the key sources of individual differences in creative thinking.

Coupled with the requirement of switching between creative strategies or mental sets is the need to inhibit interference from ineffective strategies, prior responses, and unsuitable content from gaining access to working memory for further processing (Gilhooly, Fioratou, Anthony, & Wynn, 2007). This points toward the role of inhibition in creative thinking, which is the deliberate suppression of processing or expression of information that would otherwise disrupt the achievement of a particular task (Diamond, 2013). Creative thinking may rely on both high and low levels of inhibitory control, with the degree to which control is required being contingent upon the creative task (Lin & Lien, 2013). For example, divergent thinking does not include stringent constraints, and so access to a broad range of unfiltered information and, hence reduced inhibition may benefit the generation of multiple original ideas. This is evident in studies reporting a negative relationship between inhibition and divergent thinking (Dorfman, Martindale, Gassimova, & Vartanian, 2008; Kharkhurin, 2011; Lin & Lien, 2013). Conversely, many criteria need to be met for convergent thinking measures, so a higher degree of inhibition is advantageous in preventing task-irrelevant and distracting information from entering working memory in these instances (Cheng, Hu, Jia, & Runco, 2016; Zabelina & Robinson, 2010). Therefore, we theorized that inhibition benefits the more systematic and convergent phases of creative thinking but interferes with divergent thinking, specifically the ability to generate associative links between loosely connected concepts. As such, an associative pathway between inhibition and convergent thinking, but not divergent thinking, was included in our model.

Finally, fluid intelligence is proposed to play a crucial role in creative thinking by facilitating the allocation of executive functions depending on the context or task (van der Meer et al., 2010). Fluid intelligence entails both inductive and deductive reasoning capabilities applied during novel problem-solving and the ability to generate, store and manipulate new information, abilities that are shared with working memory (Zaval, Li, Johnson, & Weber, 2015). While working memory is likely involved in creative thinking, this function is beyond the scope of this study and is an area for future research. Several studies have demonstrated a link between fluid intelligence and divergent thinking (Akhtar & Kartika, 2019; Beaty, Nusbaum, & Silvia, 2014; Benedek, Jauk, Sommer, Arendasy, & Neubauer, 2014; Nusbaum & Silvia, 2011), with evidence suggesting that the top-down control of attention largely drives this relationship (Frith et al., 2021). A recent meta-analytic review provides further evidence of the fluid intelligence-divergent thinking link, demonstrating a small to moderate relationship between the two constructs (Gerwig et al., 2021). In contrast, in Lee and Therriault's (2013) study, fluid intelligence did not predict divergent thinking but emerged as an indirect predictor via associative fluency. A potential explanation is that, in addition to spontaneous memory activation, controlled retrieval is required when searching for novel associations (Beaty & Kenett, 2023). Thus, fluid intelligence possibly influences divergent thinking by optimizing information retrieval and implementing executive control over the search for associative links.

Fluid intelligence has also been found to predict associative thinking and convergent thinking (Lee & Therriault, 2013), the latter of which corresponds with evidence of a significant positive correlation between performance on the Raven's Advanced Progressive Matrices (APM) and a measure of convergent thinking, namely the Remote Associates Test (RAT; Akbari Chermahini, Hickendorff, & Hommel, 2012; Lee, Huggins, & Therriault, 2014). This suggests that the effect of fluid intelligence on convergent thinking is greater than its effect on divergent thinking, possibly because convergent thinking aspects of creative thinking entail systematic and analytic cognitive processing and, thus, rely more heavily on fluid intelligence. In this regard, fluid intelligence may facilitate the implementation of executive control or top-down strategies over the mental resources required to produce creative ideas (Benedek & Jauk, 2019). It is, therefore, theorized that fluid intelligence predicts both of the executive functions focused on in this study, namely inhibition and task-switching. Depending on the nature of the creative task (i.e., divergent or convergent thinking), fluid intelligence may engage either a high or low degree of executive function (Benedek et al., 2014).

Additionally, there is evidence that fluid intelligence benefits creative thinking by structuring the semantic network to facilitate efficient search processes and conceptual combinations (Dane, 2010). For example, fluid intelligence has been found to relate to the structural properties of semantic networks, while creative achievement was found to relate more to the flexible properties of networks (Kenett, Beaty, Silvia, Anaki, & Faust, 2016). The semantic networks of those who scored high on fluid intelligence and creative achievement measures possessed structural and flexible properties. Therefore, while the semantic networks of those scoring high on creative achievement measures encompass a flexible, chaotic nature, these networks need to contain some structure to prevent semantic chaos. The structured semantic networks associated with high fluid intelligence are thought to contribute to the ability to shift between small sub-communities of nodes with greater ease and thereby overcome conventional ideas (Faust & Kenett, 2014; Kenett et al., 2016). Thus, fluid intelligence and task-switching are important components of creative thinking (Nusbaum & Silvia, 2011). Nusbaum and Silvia (2011) found that fluid intelligence predicts divergent thinking and that task-switching mediates this effect, suggesting that task-switching underlies the relationship between fluid intelligence and the production of creative ideas. Similarly, Forthmann et al. (2019) demonstrated an effect of fluid intelligence (assessed via figural analogical reasoning) on divergent thinking scores, while Wilken, Forthmann, and Holling (2020) found a significant relationship between creative performance and reasoning ability, which was moderated by instruction on divergent thinking tests.

Beyond these cognitive functions, demographic variables also influence creative thinking. Creativity research tends to focus on samples of either children or young adults (Roskos-Ewoldsen, Black, & Mccown, 2008). By focusing on creative thinking in older adults, this study can extend the generalisability of available results and contribute new knowledge and information regarding creative thinking in an under-represented sample. Moreover, it may yield practical applications for promoting cognitive reserve and active aging. It is unclear how alterations in brain structure and function accompanying typical aging may affect creative thinking (Heilman & Fischler, 2018). Age-related decline in executive functioning may be a double-edged sword since creative thinking relies on the paradoxical interplay between automatic and controlled processes (Hommel, Akbari Chermahini, Wildenberg, & Colzato, 2011). Consequently, analytical aspects of creative thinking (i.e., convergent thinking) may be negatively affected by the decline in executive function (Simon & Bock, 2016), whereas automatic aspects of creative thinking (i.e., divergent thinking) may either benefit or remain unaffected by this decline (Leon, Altmann, Abrams, Gonzalez Rothi, & Heilman, 2014; Madore, Jing, & Schacter, 2016; Palmiero, Di Giacomo, & Passafiume, 2014). While older adults have a richer storage of semantic knowledge that provides the raw materials for creative output (Dane, 2010), there is evidence of diminished flexibility in the semantic networks of older adults (Cosgrove, Kenett, Beaty, & Diaz, 2021). Since creative thinking requires flexibility, without which individuals may lack the spontaneity required to satisfy the novelty criteria of creativity (Kenett et al., 2016), older adults' diminished flexibility in semantic networks may negatively affect the more automatic aspects of creative thinking. Our study hopes to elucidate some of these issues in the creative thinking of older adults.

In addition to being elderly, our sample is also unusual in being bilingual or multilingual. Bilingual advantages have been reported in aspects of creative thinking, such as originality (Kharkhurin, 2009), fluency (Kostandyan & Ledovaya, 2013) and flexibility (Adi-Japha, Berberich-Artzi, & Libnawi, 2010), as well as insightful problems solving (Cushen & Wiley, 2011). Hommel et al. (2011) also demonstrated that high-proficient bilinguals excelled in convergent thinking tasks while low-proficient bilinguals were better at divergent thinking tasks, such as fluency scores. This suggests that the enhanced cognitive control mechanisms of bilinguals possibly benefit more conscious, effortful aspects of creative thinking (i.e., convergent thinking). However, the bilingual advantage hypothesis in the context of creativity has been challenged by Lange et al. (2020), who failed to find this advantage when comparing the creativity of bilinguals assessed in their second language to monolinguals and bilinguals assessed in their first language. Similarly, Kim and Runco (2022) found no significant relationship between bilingualism and creativity, although a mediation effect of bilingualism on creative ideation (i.e., fluency, originality, and flexibility) via cognitive flexibility was reported. The effects of bi- and multilingualism on creative thinking remain unclear, and it is important to note that the influence of contextual factors on cognition, in general, are difficult to ascertain.

The contextual factors that are often associated with creative thinking are socioeconomic status (SES) and level of education (Zhang et al., 2015), especially in the older population as well as in regions that have high levels of social and economic inequality, such as the context of the current study, South Africa (Lucas, 2013). In particular, SES and level of education have a cumulative effect on creative thinking, with better creative performance corresponding with higher levels of education (Zhang & Niu, 2013) and SES (Castillo-Vergara, Barrios Galleguillos, Jofré Cuello, Alvarez-Marin, & Acuña-Opazo, 2018; Dai et al., 2012; Niu, 2007). Correspondingly, recent meta-analytic findings reported a significant positive correlation between creativity and SES and identified several moderators of this relationship. Specifically, the mean effect size was significantly higher when SES was assessed in terms of one's own level of educational and parental occupation or when flexibility was the index of creativity rather than fluency (Acar, Tadik, Uysal, Myers, & Inetas, 2022). A candidate mechanism for these effects is cognitive stimulation and enrichment offered by particular environments (Hackman, Farah, & Meaney, 2010).

The last demographic variable considered in our study is gender. The role of gender in creative thinking is uncertain, as there is evidence for no significant gender differences in creative performance (Charyton, 2005; Cheung, Lau, Chan, & Wu, 2004; Kaufman & Baer, 2004), as well as for both female (Anwar, Shamim-ur-Rasool, & Haq, 2012; Hong, Peng, O'Neil Jr., & Wu, 2013; Kousoulas & Mega, 2009) and male (Furnham, Crump, Batey, & Chamorro-Premuzic, 2009; Stoltzfus, Nibbelink, Vredenburg, & Hyrum, 2011) advantages. These differences may arise from different strategies employed by males and females during tasks (Abraham, 2014), although alternative explanations have been provided, such as the Greater Male Variability Hypothesis (GMVH; Abdulla Alabbasi, Thompson, Runco, Alansari, & Ayoub, 2022; Karwowski et al., 2016).

Based on the reviewed literature, we developed a hypothesized theoretical model (Figure 1)[1] of creative thinking and evaluated it using SEM. The structural relationships between the variables underlying creative thinking were analyzed, namely divergent thinking, convergent thinking, associative thinking, and the executive functions of task-switching, inhibition and fluid intelligence. We also investigated whether selected demographic variables contributed to differences in performance on the cognitive functions included in the model to determine whether these accounted for group differences in creative thinking.

MATERIALS AND METHODS

PARTICIPANTS

Individuals aged 65 and older (see demographics in Table 1), living independently, were recruited via convenience and snowball sampling (Panacek & Thompson, 2007). Participants had to be at least functionally fluent in English, and those with cognitive impairments were excluded based on their scores on the Lawton Instrumental Activities of Daily Living (IADL) and the Montreal Cognitive Assessment (MoCA). After screening, the final sample included 125 participants.

The study was approved by the Human Research Ethics Committee (Medical) of the University of the Witwatersrand and granted ethical clearance (protocol number: M180726). The Helsinki Declaration and the Singapore Statement on Research Integrity were followed (Resnik & Shamoo, 2011). Participants received written information about the study and provided written consent before participation.

[1] H1: Fluid intelligence predicts inhibitionH2: Inhibition predicts convergent thinkingH3: Fluid intelligence predicts task-switchingH4: Task-switching predicts convergent thinkingH5: Task-switching predicts associative thinkingH6: Task-switching predicts divergent thinkingH7: Associative thinking predicts convergent thinkingH8: Associative thinking predicts divergent thinking

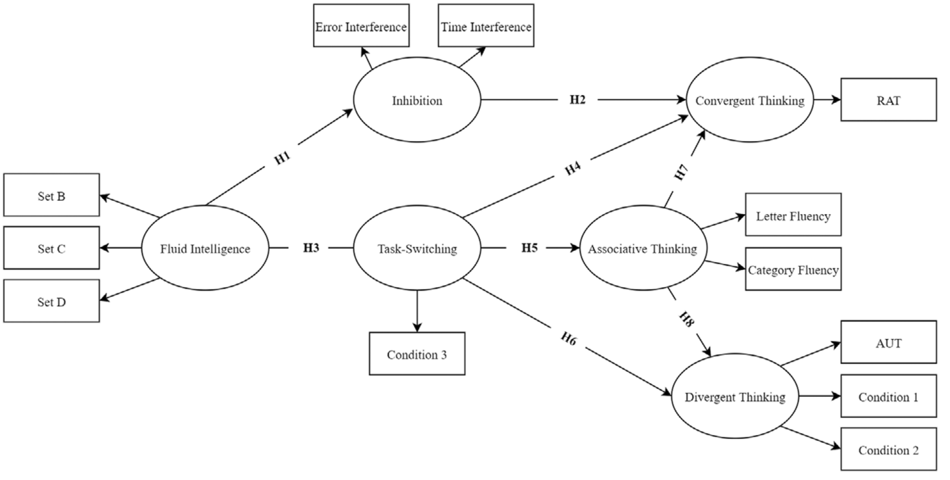

FIGURE 1. Hypothesized theoretical model of creative thinking. *Note*. The letter H is an abbreviation for the eight hypothesized pathways between the cognitive functions.

MEASURES

Demographic questionnaire

A demographic questionnaire gathered information about age, gender, level of education, and home language. The Living Standards Measure (LSM) assessed SES. It consists of 29 variables that group individuals according to their standard of living (Haupt, 2016). The Language Experience and Proficiency Questionnaire (LEAP-Q; Marian, Blumenfeld, & Kaushanskaya, 2007) established multilingual profiles. This self-report questionnaire obtained information regarding the number of languages spoken and level of proficiency in various domains (speaking, comprehension, and reading) for each language.

Cognitive screening

The abbreviated Lawton Instrumental Activities of Daily Living (IADL; Roehrig, Hoeffken, Pientka, & Wedding, 2007) assessed capability for independent living (Graf, 2008) and was used as a screening measure. It comprises five items related to "grocery shopping," "food preparation," "medication administration," "laundry" and "transportation." Participants answered "true" or "false" when asked if they had difficulty with each activity. Those who answered "true" on any activities were excluded from participation.

The Montreal Cognitive Assessment (MoCA) Version 7.2 (Chertkow, Nasreddine, Johns, Phillips, & McHenry, 2011) was also used as a screen for mild cognitive impairment. The scores obtained for each item provided an overall MoCA score with a maximum possible score of 30. Demographically corrected (age and education) cutoff scores (Thomann et al., 2018) were used.

Divergent thinking

Two measures of divergent thinking were used, including the Alternative Uses Test (AUT) and Conditions 1 and 2 from the Design Fluency test of the Delis-Kaplan Executive Function System (Delis, Kaplan, & Kramer, 2001). The AUT comprises two sections, each with three everyday items. The instructions included asking participants to provide as many as six alternative or different uses for objects or their parts. Participants had 4 min to complete each section. Their responses were scored using the methods outlined in the AUT manual (Guilford, Christensen, Merrifield, & Wilson, 1978) and were similar yet not equivalent to Snapshot scoring methods (Silvia et al., 2008; Silvia, Martin, & Nusbaum, 2009). The scoring method used in this study involved providing a single holistic rating for responses (1 point for acceptable responses). Multiple criteria were considered when evaluating responses, including the plausibility (utility) and originality (novelty and uniqueness) of responses, as well as whether they differed from the item's conventional use (flexibility). Thus, the AUT tapped originality, flexibility and plausibility aspects of creative thinking, and if

TABLE 1. Demographic Characteristics of the Sample

Variable	***n*** **(Total** ***n*** **= 125)**	**%**	**Mean (SD)**
Age			
65–70	53	42.4	73.14 (6.347)
71–75	27	21.6	
76–80	24	19.2	
81–85	16	12.8	
86–90	5	4	
Education			
≤12 years	63	50.4	12.8 (3.309)
≥13 years	62	49.6	
Gender			
Male	44	35.2	
Female	81	64.8	
SES			
Low	3	2.4	
Middle	21	16.8	
Upper	54	43.2	
High	47	37.6	
Home language			
English	72	57.6	
Afrikaans	22	17.6	
IsiZulu	7	5.6	
IsiXhosa	2	1.6	
Southern Sesotho	3	2.4	
Batswana	8	6.4	
Northern Sesotho	1	.8	
Tshivenda	2	1.6	
Xitsonga	1	.8	
IsiNdebele	1	.8	
Other	6	4.8	
Linguistic category			
Monolingual	7	5.6	
Bilingual	60	48	
Multilingual	58	46.4	

responses did not meet all of these criteria, they were deemed unacceptable and scored zero. Two independent raters collaboratively discussed and came to a consensus on item scores. While typical methods of scoring the AUT (originality, flexibility, fluency and elaboration criteria) yield larger effect sizes, this holistic assessment of divergent thinking also perform well and is recommended for larger samples (Silvia et al., 2009).

Conditions 1 and 2 from the DF were used to account for fluency aspects of creative thinking. Participants were given 60 s for each condition to produce as many different designs as possible by connecting an array of dots using straight lines. Condition 1 comprised black dots and required participants to draw designs by connecting the filled dots. Condition 2 comprised black and white dots and required participants to draw designs using only the white dots. The number of correct and unrepeated designs produced within the time limit provided the score for each condition.

While the AUT and the DF tap different modalities of divergent thinking, namely verbal and figural respectively, the results demonstrate that the AUT significantly correlates with the DF Conditions 1, $r = .37$, $p < .01$ and DF Condition 2, $r = .49$, $p < .01$, respectively, and were therefore used as indicators of divergent thinking. Cronbach's Alpha values ($\alpha = .80$) indicate good internal consistency between the measures of divergent thinking.

Convergent thinking

Adaptation of the Remote Associates Test (RAT; Mednick, 1962) by Lee et al. (2014) assessed convergent thinking. Thirty items comprising three seemingly unrelated words (e.g., cake, break, and bean) were presented. Participants produced a fourth word that related to the others via forming a compound word (e.g., coffee; Bowden & Jung-Beeman, 2003). The score was the total number of correct responses within 10 min.

Associative thinking

The Letter and Category Fluency tasks were indicators of associative thinking. The Letter Fluency task (Borkowski, Benton, & Spreen, 1967) requires the oral production of as many words as possible beginning with the letter B in 60 s (Strauss, Sherman, & Spreen, 2006). B is suitable for three predominant South African languages (English, Afrikaans and isiXhosa; Ferrett et al., 2014). The Category Fluency task (Benton & Hamsher, 1983) requires participants to produce examples of animals in 60 s orally. The number of correct responses is the total score for each task.

Fluid intelligence

A shortened version of Raven's Standard Progressive Matrices (SPM; Raven, Raven, & Court, 1998), comprising three sets of 12 items (sets B, C and D; $\alpha = .92$), served as a non-verbal estimate of fluid intelligence. Participants viewed abstract black-and-white designs, each with a missing piece. They were given unlimited time to select the missing items from among 6–8 response options. The number of correct answers represented the total SPM score (Van der Elst et al., 2013).

Task-switching

The switch condition (Condition 3) of the DF test tapped task-switching. It comprises filled and unfilled dots, and participants must draw as many designs as possible in 60 s by alternating between connecting filled and unfilled dots. The task-switching score is the total number of correct designs produced within the time limit (Delis et al., 2001).

Inhibition

The Victoria Stroop (VS) test assessed inhibition. It comprises three parts, each entailing viewing a card containing four rows of six items. Each item is presented in either blue, green, yellow or red. Participants must name the object's color as quickly and accurately as possible. The first condition (D) comprised colored dots, the second condition (W) included neutral words (hard, over, but, when) presented in colored ink, and the last condition (C) comprised color names printed in colored ink incongruent with the written names. Participants were interrupted if they made a mistake in naming, after which they corrected themselves and continued. Spontaneously corrected mistakes did not count as errors (Troyer, Leach, & Strauss, 2006). Both speed (Time Interference) and accuracy (Error Interference) scores were calculated. Time Interference was calculated by subtracting the sum of the time taken to complete condition W and the time taken to complete condition D, divided by two, from the time taken to complete condition C. Error interference was calculated by subtracting the sum of the errors made in condition W and the errors made in condition D, divided by two, from the errors made in condition C (Caffarra, Vezzadini, Dieci, Zonato, & Venneri, 2002).

RESULTS

DESCRIPTIVE STATISTICS

The data was analyzed using IBM SPSS Statistics for Windows Version 24 (IBM Corp, 2016) and IBM SPSS Statistics Amos Version 26 (Arbuckle, 2020). Descriptive statistics and correlations for the respective scores of all cognitive variables are presented in Table 2. The mean and median values are similar for most, indicating approximately symmetrical data distributions (Marshall & Jonker, 2010). There are discrepancies between the means and medians of the RAT, Time Interference and Error Interference, and an instance of floor effects in the RAT. The outliers in the VS scores were checked to ensure they did not distort the SEM results, which they did not, and were thus included in the analyses to avoid reducing the sample size (Kline, 2016).

STRUCTURAL EQUATION MODELING (SEM)

Multivariate structural equation modeling (SEM) investigated relationships between the constructs, with maximum likelihood (ML) estimation. Based on the ratio of the sample-to-observed variables (N:p), the data was adequate in size for SEM. In particular, the participant-to-item ratio was approximately 10:1, where the sample size was 125, and the number of observed variables in the final model was 12 (Nunnally, 1967). The data for this study also met additional assumptions for both SEM, including no multivariate outliers and the absence of multicollinearity, as well as ML estimation, namely multivariate normality.

While the N:p ratio was deemed acceptable, the sample size is relatively small for SEM (Boomsma, 1982, 1985). Therefore, we took an incremental approach whereby we first individually tested smaller components of the full-scale model. This was used to identify and address any issues that become apparent in the smaller models and to demonstrate the contributions or limitations of each component of the full-scale model more effectively. For example, by testing the small-scale models first, we could find and remove nonsignificant relationship pathways and identify pathways that were not initially considered. Moreover, this approach was used to evaluate the adequacy of the sample size for the full-scale model and, thus, assess the overall viability of the full hypothesized model. Figures S1-S3 in the supplementary information document present the smaller models. It is important to acknowledge that the deconstructed models and the complete, larger model comprised single indicator latent variables (i.e., task-switching and convergent thinking), which may prove problematic in model identification. To avoid model identification complications, we fixed the loading of these factors to one, forced their errors to zero, and left their variances free to be estimated, which is sufficient to statistically identify model latents (Hayduk & Littvay, 2012).

Model evaluation was based on regression coefficients (i.e., *p*-value and standard error) and the overall model fit (i.e., model fit indices). The small-scale models and final model were assessed in terms of absolute fit indices, including χ^2 goodness of fit test, and the root mean square error of approximation (RMSEA), as well as comparative fit indices, namely the comparative fit index (CFI) and the Tucker-Lewis index (TLI). The χ^2 test is sensitive to large sample sizes, with a large sample size yielding a significant χ^2. Given that SEM requires a large sample size, it is recommended to consider this together with other model fit indices (Alavi et al., 2020; Kline, 2016). A summary of the model fit indices and cutoff values used in this study is provided in Table 3. Standardized residual covariances were also considered to assess model fit for the final model. For correct models, most standardized residuals should be less than 1.96 (Kline, 2016). The small-scale models and the final, large-scale model were also evaluated in terms of mediation effects using Sobel's (1982) test. Modifications to the small-scale models were made based on the above analysis results. The final theoretical model comprised the accepted and modified smaller models, which were tested using the same criteria.

Theoretical model

The modified models were combined into the full model (Figure 2). Fluid intelligence predicted inhibition, task-switching and associative thinking. Task-switching predicted associative thinking and associative thinking predicted convergent and divergent thinking. Task-switching and associative thinking were identified as mediators.

The model was an adequate fit to the data (χ^2 = 95.926, df = 50, p < .001, RMSEA = .086, 90% CI [.059, .111], TLI = .913, CFI = .944). While the Chi-square values were significant, the other model fit indices were just below the stipulated cutoff points. All standardized residual covariances were below 1.96; thus, none were of concern regarding model fit. The standardized factor loadings for the indicators of each latent variable appear in Figure 2 and loaded sufficiently onto the respective factors. Fluid intelligence significantly predicted inhibition (β = −.52, z = − 4.405, p < .001), task-switching (β = .49, z = 5.691, p < .001) and associative thinking (β = .73, z = 7.035, p < .001). Task-switching predicted associative thinking (β = .23, z = 2.994, p = .003), and associative thinking significantly predicted both divergent thinking (β = .78, z = 5.617, p < .001) and convergent thinking (β = .75, z = 7.754, p < .001). Sobel's (1982) test of mediation revealed a significant, full mediation effect of fluid intelligence on convergent thinking (z = 3.79, p < .001), as well as divergent thinking (z = 3.7, p < .001) through associative thinking. Associative thinking did not mediate the relationship between task-switching and divergent thinking (z = 1.90, p = .057) and convergent thinking (z = 1.91, p = .056), respectively. There was a partial mediation effect (z = 1.98, p = .02) of fluid intelligence on associative thinking through task-switching (16.15%).

TABLE 2. Descriptive Statistics and Correlations between Cognitive Variables

	M	Mdn	SD	Min, Max	Skewness	Kurtosis	1	2
1. AUT	10.94	10	6.89	0, 29	0.47	−0.36	1	
2. RAT	5.59	3	5.63	0, 21	0.88	−0.27	.519**	1
3. Letter Fluency	12.38	12	5.08	3, 24	0.12	−0.84	.472**	.633**
4. Category Fluency	15.42	16	6.05	2, 33	0.25	0.203	.628**	.629**
5. DF Condition 1	7.39	7	3.25	1, 19	0.71	0.83	.379**	.422**
6. DF Condition 2	7.81	8	3.21	2,20	0.68	1.06	.499**	.378**
7. DF Condition 3	5.12	5	2.54	0, 12	−0.05	−0.35	.484**	.406**
8. SPM Set B	7.54	8	2.82	1, 12	−0.39	−0.77	.643**	.589**
9. SPM Set C	6.22	7	2.87	0,12	−0.3	−0.75	.585**	.651**
10. SPM Set D	6.63	7	3.41	0, 12	−0.27	−1.07	.608**	.620**
11. VS Time Interference	16.86	15	9.4	4.5, 56.5	1.62	3.45	−.254**	−.248**
12. VS Error Interference	0.98	0	1.59	−1, 8	1.95	4.49	−.338**	−.202*

Note. AUT = Alternative Uses Test; RAT = Remote Associates Test; DF = design fluency; SPM = Raven's standard progressive matrices; VS = victoria stroop; M = mean; Mdn = median; SD = standard deviation; Min = minimum score; Max = maximum score. *$p < .05$. **$p < .01$.

INVESTIGATING THE ROLE OF DEMOGRAPHIC VARIABLES IN CREATIVE THINKING

Since variances were not homogenous, Welch's *t*-test and Welch's ANOVA were used to assess whether there were significant differences in task performance across age, multilingualism (conceptualized as the categories: monolingual, bilingual, or multilingual), SES, level of education and/or gender groups. A significance level of $\alpha = .05$ was applied, and *t*-tests were two-tailed. Where ANOVAs yielded significant group differences, Games-Howell post hoc tests were employed due to a lack of homogeneity of variance (see Tables 4 and 5). Effect sizes were calculated using Cohen's *d* for *t*-tests and Eta squared (η^2) for ANOVAs. Cohen's (1988) guidelines were used to interpret η^2 values ($\eta^2 < .01$: negligible; $.01 \le \eta^2 < .06$: small; $.06 \le \eta^2 < .14$: medium; $\eta^2 \ge .14$: large) and empirically derived guidelines for Cohen's *d* values were used for effect size interpretation (values of .15, .36, and .65 being interpreted as small, medium, and large effects, respectively; Lovakov & Agadullina, 2021).

Most demographic comparisons (age, multilingualism and gender) were not significant. However, the younger age group (71–75 years) significantly outperformed older participants (76–85) on task-switching (Condition 3; $p = .041$, $\eta^2 = .099$). Additionally, monolinguals and bilinguals significantly outperformed multilinguals on associative thinking (Category Fluency, $p = .012$, $\eta^2 = .096$). The eta-squared values from these analyses demonstrate a medium effect size, suggesting meaningful group differences. Regarding SES, there were significant group differences on all the cognitive tests except for the indicators of inhibition (Error Interference and Time Interference). For significant results, individuals with higher levels of SES outperformed those from lower SES groups on divergent thinking, convergent thinking, associative thinking, task-switching, and fluid intelligence. Most eta-squared values for significant results for SES indicated large effect sizes, with the AUT ($\eta^2 = .128$), DF Condition 1 ($\eta^2 = .094$) and VS Time Interference ($\eta^2 = .094$) indicating a medium effect size and VS Error Interference ($\eta^2 = .054$) indicating a small effect size. In terms of level of education, there were significant group differences on all variables, with participants who have 13 or more years of education performing significantly better compared to those with fewer years of education. Large effect sizes were found for all significant results except for Letter Fluency ($d = .59$), DF Condition 3 ($d = .52$), and Error Interference ($d = .51$), which all revealed medium effect sizes. Finally, Time Interference ($d = .46$) showed a small effect size.

DISCUSSION

This study set out to develop and test a coherent theoretical model of creative thinking in older adults to elucidate the cognitive functions underlying creative thinking. It also investigated the roles of demographic variables on the cognitive functions included in the model. Two main findings include the

3	4	5	6	7	8	9	10	11	12
1									
.610**	1								
.414**	.472**	1							
.495**	.508**	.712**	1						
.413**	.437**	.418**	.446**	1					
.537**	.640**	.411**	.558**	.401**	1				
.466**	.610**	.409**	.542**	.425**	.790**	1			
.541**	.620**	.420**	.475**	.431**	.721**	.809**	1		
−.209*	−.299**	−0.097	−.237**	−.231*	−.298**	−.272**	−.301**	1	
−.218*	−.283**	−.184*	−.275**	−.372**	−.336**	−.321**	−.342**	.504**	1

following: 1) creative thinking appears to be based on associative processing, and 2) executive functions operate as a second layer of information processing in this sample. The finding that associative thinking predicts both divergent and convergent thinking corroborates the evidence of significant relationships between these variables (Beaty, Silvia, et al., 2014; Benedek et al., 2012; Lee & Therriault, 2013; Marko & Riečanský, 2018) and suggests an associative basis for creative thinking. This supports Mednick's (1962) associative theory of creativity, which maintains that creative thinking relies on the establishment, activation and fluent retrieval of associations between weakly related, remote concepts that are combined into novel yet feasible ideas. These findings suggest that individual differences in both divergent and convergent thinking may be attributed to differences in semantic memory structure, but this would warrant further investigation (Benedek et al., 2017). Our model demonstrates that divergent and convergent thinking are significant role players in older adults' creative thinking, with divergent thinking generating multiple

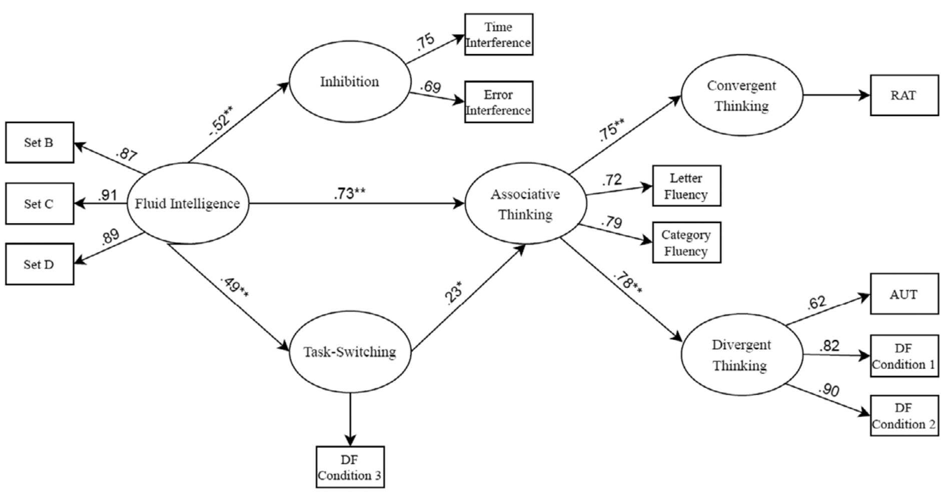

FIGURE 2. Full model of the relationship between fluid intelligence, inhibition, task-switching, associative thinking, divergent thinking and convergent thinking. *$p < .05$, **$p < .01$.

TABLE 3. Summary of the Model Fit Indices and Cutoff Values

Index	Cutoff criteria	References
χ^2	Non-significant statistic	(Barrett, 2007)
RMSEA	≤.05; close fit ≤ .10; adequate	(MacCallum, Browne, & Sugawara, 1996)
TLI	≥.95; excellent .90 ≤ TLI < .95; adequate	(Hooper, Coughlan, & Mullen, 2008)
CFI	≥.95; excellent .90 ≤ CFI < .95; adequate	(Hu & Bentler, 1999)
		(Schumacker & Lomax, 2010)

Note. CFI = comparative fit index; RMSEA = root mean square error of approximation; TLI = Tucker-Lewis index.

potential solutions to a problem and convergent thinking subsequently evaluating these candidate solutions (Kharkhurin, 2012).

The second key finding was that executive functions (fluid intelligence and task-switching) influence and direct the bottom-up processes implicated in creative thinking, such as associative thinking. Together, the findings that fluid intelligence predicted all components of creative thinking (i.e., divergent, convergent and associative thinking) and that associative thinking functions as a mediator between fluid intelligence and both divergent and convergent thinking support earlier findings (Lee & Therriault, 2013), and suggest that semantic network structures form the basis of creative thinking upon which higher-order cognitive functions operate (Kenett, 2018). Our results corroborate evidence of the overarching role of associative processes in both divergent thinking and measures of intelligence (Benedek et al., 2012) and extend these findings by demonstrating that, as for divergent thinking, associative processes are central to convergent thinking.

Fluid intelligence and, to a degree, task-switching predicted aspects of creative thinking in our model. These relationships are accounted for in the two-component model of semantic exploration (Troyer et al., 1997). The model identifies two factors that optimize information retrieval from semantic memory: the network's structural properties and task-switching. The highly structured semantic networks characteristic of individuals with high levels of fluid intelligence facilitate efficient and rapid information retrieval by organizing concepts in a modular or locally clustered manner (Faust & Kenett, 2014; Kenett et al., 2016). Task-switching mitigates exploration limitations by enabling flexible shifting to alternative semantic fields, which extends the exploration of the network and allows the spread of activation to reach more remote associations.

Unexpectedly, inhibition did not directly predict convergent thinking (RAT) aspects of creative thinking. This suggests that the RAT reflects the ability to coherently activate, retrieve and combine remote concepts in semantic networks without much executive control. This implies that convergent thinking relies on more automatic and associative processes than initially thought. As such, the absence of inhibitory control may improve the spread of activation in semantic memory and, consequently, enable more distantly related information to enter working memory for further processing (Marko, Michalko, & Riečanský, 2019). These findings provide further evidence to suggest that divergent and convergent thinking aspects of creative thinking are considerably integrated (Sowden et al., 2015). Specifically, while tasks that engage more convergent modes of processing may benefit from step-wise, analytical processes, solutions to these tasks may also emerge through unconscious, automatic and associative processes. In this sense, convergent thinking may have more in common with generative, Type-1 processing and shares similarities with divergent thinking. Likewise, solutions on measures of divergent thinking may emerge not only through unconscious, associative processes but can also occur through effortful, explicit and controlled thinking. However, this study did not consider the degree to which divergent thinking engages these higher-order executive functions, namely inhibitory control. An alternative explanation is that inhibition is a general characteristic of executive function rather than a specific, distinct component (Hommel, 2015). For example, if multiple conflicting response tendencies are present, the inhibitory system must identify which response to inhibit. Such a system would, therefore, require access to a representation of the stimulus–response rules and the ability to apply these rules to identify the correct response tendency and subsequently employ that information to inhibit inappropriate responses. In other words, this inhibitory system presumably entails some form of intelligence to identify those response tendencies to inhibit. So, perhaps inhibition is an emergent property of other executive processes, such as fluid intelligence or task-switching, rather than an entirely separate

TABLE 4. Summary of Welch's Test of Equality of Mean, Sum of Squares and Mean Square values for Age Multilingualism and Socioeconomic Status (SES)

Variable	Test	SS		MS		Statistic[a] ($df1$, $df2$)	p	η^2
		Between group	Within group	Between group	Within group			
Age	AUT	208.716	5687.892	52.179	47.399	1.036 (4, 25)	.409	.035
	RAT	187.605	3742.587	46.901	31.188	2.240 (4, 25)	.093	.048
	Letter Fluency	60.077	3141.491	15.019	26.179	.465 (4, 25)	.761	.019
	Category Fluency	100.817	4429.711	25.204	36.914	.768 (4, 25)	.557	.022
	DF Condition 1	35.954	1269.838	8.989	10.582	.773 (4, 24)	.554	.028
	DF Condition 2	37.409	1237.983	9.352	10.317	.839 (4, 28)	.512	.029
	DF Condition 3	78.739	718.461	19.685	5.987	2.948 (4, 23)	.041*	.099
	SPM Set B	49.335	933.673	12.334	7.781	1.735 (4, 25)	.173	.050
	SPM Set C	31.604	989.564	7.901	8.246	1.606 (4, 31)	.198	.031
	SPM Set D	25.622	1413.450	6.406	11.779	.535 (4, 25)	.712	.018
	VS Time Interference	158.799	10806.609	39.700	90.055	.435 (4, 23)	.782	.014
	VS Error Interference	14.694	297.234	3.673	2.477	1.269 (4, 23)	.311	.047
Multilingualism	AUT	13.895	5882.713	6.948	48.219	.103 (2, 16)	.902	.002
	RAT	24.998	3905.194	12.499	32.010	.39 (2, 17)	.683	.006
	Letter Fluency	167.492	3034.076	83.746	24.869	3.367 (2, 17)	.059	.052
	Category Fluency	432.820	4097.708	216.410	33.588	5.784 (2, 17)	.012*	.096
	DF Condition 1	42.659	1263.133	21.329	10.354	1.997 (2, 20)	.162	.033
	DF Condition 2	41.400	1233.992	20.700	10.115	1.971 (2, 17)	.17	.032
	DF Condition 3	26.672	770.528	13.336	6.316	2.056 (2, 17)	.158	.033
	SPM Set B	28.278	1410.794	14.139	11.564	1.259 (2, 16)	.31	.021
	SPM Set C	26.207	994.961	13.103	8.155	1.541 (2, 17)	.243	.026
	SPM Set D	21.045	961.963	10.523	7.885	1.204 (2, 16)	.326	.020
	VS Time Interference	44.724	10920.684	22.362	89.514	.19 (2, 16)	.829	.004
	VS Error Interference	5.045	306.883	2.522	2.515	.824 (2, 17)	.456	.004

TABLE 4. (Continued)

Variable	Test	SS		MS		Statistic[a] ($df1$, $df2$)	p	η^2
		Between group	Within group	Between group	Within group			
Socioeconomic Status (SES)	AUT	752.509	5144.099	250.836	42.513	7.267 (3, 10)	.006*	.128
	RAT	727.993	3202.199	242.664	26.464	12.244 (3, 13)	<.001**	.185
	Letter Fluency	490.141	2711.427	163.380	22.408	8.701 (3, 10)	.004*	.153
	Category Fluency	747.774	3782.754	249.258	31.262	22.199 (3, 40.9)	<.001**	.165
	DF Condition 1	123.139	1182.653	41.046	9.774	4.083 (3, 10)	.04*	.094
	DF Condition 2	209.136	1066.256	69.712	8.812	7.593 (3, 10)	.007*	.164
	DF Condition 3	122.322	674.878	40.774	5.578	7.309 (3, 10)	.007*	.153
	SPM Set B	178.202	858.980	59.401	7.099	9.362 (3, 10)	.003*	.181
	SPM Set C	162.188	804.806	54.063	6.651	30.890 (3, 18)	<.001**	.159
	SPM Set D	266.407	1172.665	88.802	9.691	42.229 (3, 21)	<.001**	.185
	VS Time Interference	1030.674	9934.734	343.558	82.105	1.457 (3, 9)	.290	.094
	VS Error Interference	16.978	294.950	5.659	2.438	2.771 (3, 9)	.101	.054

Note. AUT = Alternative Uses Test; df = degrees of freedom; DF = design fluency; MS = means squares; RAT = Remote Associates Test; SPM = Raven's Standard Progressive Matrices; SS = sum of squares; VS = Victoria Stroop; η^2 = Eta-squared. [a]Asymptotically F distributed. $^{*}p < .05$. $^{**}p < .01$.

TABLE 5. Summary of Group Statistics and Welch's *t*-test for Gender and Level of Education

Variable	Test	*t*	*df*	*p*	MD	Std. Error Difference	*d*
Gender	AUT	−.74	106	.461	−.896	1.21	−.13
	RAT	−.862	87	.391	−.914	1.06	−.162
	Letter Fluency	−.72	98	.474	−.663	.921	−.13
	Category Fluency	−.592	96	.555	−.654	1.104	−.108
	DF Condition 1	−1.351	101	.18	−.78	.578	−.241
	DF Condition 2	−1.594	115	.114	−.861	.54	−.27
	DF Condition 3	.407	80	.685	.201	.493	.079
	Set B	.475	92	.636	.248	.522	.088
	Set C	−.615	87	.54	−.333	.542	−.116
	Set D	−1.092	89	.278	−.695	.636	−.204
	Time Interference	.725	93	.47	1.2569	1.733	.133
	Error Interference	−.662	120	.509	−.1734	.262	−.109
Level of education	AUT	−6.076	119	<.001**	−6.608	1.087	1.09
	RAT	−4.831	107	<.001**	−4.490	.929	.86
	Letter Fluency	−3.301	123	.001*	−2.886	.874	.59
	Category Fluency	−4.145	123	<.001**	−4.215	1.017	.74
	DF Condition 1	−5.191	121	<.001**	−2.742	.528	.93
	DF Condition 2	−5.987	121	<.001**	−3.037	.507	1.07
	DF Condition 3	−2.873	123	.005*	−1.266	.441	.52
	Set B	−6.775	120	<.001**	−2.921	.431	1.21
	Set C	−6.539	118	<.001**	−2.900	.443	1.17
	Set D	−6.318	117	<.001**	−3.354	.531	1.13
	Time Interference	2.581	90	.011*	4.2266	1.6374	.46
	Error Interference	2.855	95	.005*	.7844	.2747	.51

Note. AUT = Alternative Uses Test; *d* = Cohen's *d*; *df* = degrees of freedom; DF = design fluency; MD = mean difference (Mmales – Mfemales for gender variable); RAT = Remote Associates Test; SPM = Raven's Standard Progressive Matrices; VS = Victoria Stroop. $*p < .05$. $**p < .01$.

function. There is evidence for this since inhibition correlates with a common factor shared by other executive functions, namely updating and shifting (Miyake & Friedman, 2012), suggesting that the influence of other executive functions may obscure the role of inhibition in creative thinking.

Our findings have some theoretical implications. By demonstrating that creative thinking involves both associative and higher-order cognitive functions, this study provides supportive evidence for the dual-process theory of creativity. In this theory, creative thinking relies on associative processes during the generative stage to formulate novel output and higher-order processes during the analytic, evaluative stage, which are required to refine initial output into a useful and valuable form (Sowden et al., 2015). Hence, both associative processes and higher-order cognitive functions are required to produce output that meets both the novelty and usefulness criteria of creativity. Additionally, the observation that the effect pathways proceeding from fluid intelligence, and possibly task-switching, to divergent and convergent thinking, which pass through associative thinking, suggests that associative thinking functions as a hub for, or is central to, creative thinking, which supports a recent review highlighting the central role of associative thinking in the creative thinking (Beaty & Kenett, 2023). Moreover, our results suggest that, in addition to associative processes, fluid intelligence is common to several components of creative thinking, namely associative thinking, divergent thinking and convergent thinking.

The second part of our study explored whether there were differences in the measures of cognitive functions in our model of creative thinking across demographic groups. Age, multilingualism and gender had little influence, with age only influencing task-switching, and multilingualism only affecting semantic fluency aspects of associative thinking. In contrast, level of education affected all of the cognitive processes except Time Interference, which had a small effect size, and SES affected most of the functions except for the two inhibition measures. Higher levels of both education and SES corresponded with better task performance. These findings corroborate consistent reports of a positive association between creative performance and both levels of education and SES in younger participants (Acar et al., 2022; Castillo-Vergara et al., 2018; Dai et al., 2012; Niu, 2007; W. Zhang & Niu, 2013). Education and higher SES provide exposure to information, knowledge and general experiences, thereby increasing learning and cognitive flexibility and providing a better context for problem-solving and reasoning (Hackman et al., 2010).

Finally, it is important to acknowledge some of the study's limitations. Methodologically, a sample size of less than 200 is considered relatively small for SEM (Kline, 2016), and such a specified sample limits the findings to older adults who are predominantly bi- or multilingual. There are also limitations regarding the measure used in this study. Firstly, the scoring method used for the AUT equates scores with verbal fluency and, therefore, may overlook other aspects of divergent thinking, namely flexibility and originality. Future research could use multiple criteria, namely originality, flexibility, fluency and elaboration, to evaluate divergent thinking. Additionally, given the time limitations, the be-fluent instructions and the fluency method involved in Conditions 1 and 2 of the DF test may be characteristic of general retrieval ability rather than measures of divergent thinking. Future research could use alternative measures of divergent thinking than the DF test conditions. There are also possible limitations in using the RAT due to its high English demand. Thus, native speakers have an advantage compared to those with English as an additional language (Toivainen, Olteteanu, Repeykova, Likhanov, & Kovas, 2019). Future research can address these limitations by diversifying the sample and using the Visual RAT (vRAT) to minimize language bias (Toivainen et al., 2019).

CONCLUSION

Creativity is a multifaceted construct (Dietrich, 2019) and its underlying cognitive processes are not well specified (Reiter-Palmon, 2014). This study contributes to a clearer understanding of the processes implicated in creative thinking in an under-researched sample, namely older adults. We found that creative thinking involves the joint roles of divergent and convergent thinking, which have an associative basis, and higher-order cognitive functions, such as fluid intelligence, which influence divergent and convergent thinking via associative thinking and task-switching. Therefore, semantic memory may be directly related to both components of creative thinking through its structural properties (bottom-up, associative account) or indirectly by functioning as the basis upon which executive functions operate (top-down, executive account). Our model supports dual-process models of creativity. These cognitive processes were influenced by level of SES and education.

CONFLICT OF INTEREST

The authors declare they have no conflict of interest.

ETHICS APPROVAL

The study was approved by the Human Research Ethics Committee (Medical) of the University of the Witwatersrand and granted ethical clearance (protocol number: M180726).

AUTHOR CONTRIBUTIONS

Stephanie Alcock: Study conceptualisation and design, data collection, assessment of participants (administration and scoring), data capturing, statistical analysis, and writing of the manuscript. Aline Ferreira-Correia: Study conceptualisation and design, study supervision, and critical revision of the manuscript for important intellectual content. Kate Cockcroft: Study supervision, and critical revision of the manuscript for important intellectual content.

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DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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SUPPORTING INFORMATION

Additional Supporting Information may be found in the online version of this article at the publisher's web-site:

Data S1. Fluid intelligence, inhibition and convergent thinking.
Figure S2. Relationship between fluid intelligence, inhibition and convergent thinking. *p < .05, **p < .01.
Data S2. Fluid intelligence, task-switching, associative thinking and convergent thinking.
Figure S2. Relationship between fluid intelligence, task-switching, associative thinking and convergent thinking. *p < .05, **p < .01.
Data S3. Fluid intelligence, task-switching, associative thinking and divergent thinking
Figure S3. Relationship between fluid intelligence, task-switching, associative thinking and divergent thinking. *p < .05, **p < .01.