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The relationship between fluid intelligence, divergent and convergent thinking in older adults: The moderating effects of demographic and contextual variables

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A B S T R A C T

The nature of the relationship between creativity and intelligence is a matter of ongoing debate. It has been investigated in various ways using a range of methods, participants, and measures, leading to conflicting empirical findings and theoretical models. Research suggests that fluid intelligence, convergent and divergent thinking are fundamental to both creativity and intelligence. To contribute towards the creativity-intelligence debate, we investigated the relationships between these constructs in an under-researched sample of older adults (aged 64 years +). Furthermore, associations between these constructs may be influenced by demographic qualities, such as age, sex, and number of languages spoken, as well as contextual factors, such as socio-economic status (SES) and level of education. Thus, we explored whether fluid intelligence is separately related to convergent and divergent thinking and whether the abovementioned demographic and contextual qualities moderate these relationships. Our findings suggest that both years of education and SES are important in fluid intelligence, divergent and convergent thinking, and, therefore, are likely to be influential in creative thinking. Number of languages spoken had some (negative) association with fluid intelligence but was not significantly related to either convergent or divergent thinking. Further, neither age nor sex were significantly associated with fluid intelligence, divergent thinking, or convergent thinking.

1. Introduction

Creativity, or the ability to generate novel and effective ideas, is a defining aspect of the human experience and is a vital component of progress in multiple spheres (Kaufman, 2016; Runco, 2010). Given its importance, creative thinking and its cognitive bases have received increased research interest. Among the unresolved questions is its relationship with intelligence, particularly fluid intelligence (the ability to apply executive functions to solve novel problems; Frith et al., 2021; Schneider & McGrew, 2018). We aimed to contribute additional information regarding the relationship between fluid intelligence and divergent and convergent thinking components of creativity in a sample of older adults (aged 64 years +). This represents the second part of our original study [removed for review]. The first part used structural equation modeling (SEM) to develop and test a comprehensive, multifactorial model of creative thinking in an elderly sample and explored whether the components of this model differed according to a set of demographic

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variables. Here, we explored whether demographic and contextual factors, including age, multilingualism, socioeconomic status (SES), level of education, and gender, interact with or moderate the relationship between fluid intelligence, divergent thinking, and convergent thinking in the same elderly sample. Research often fails to acknowledge the role of such contextual factors (Glăveanu & Beghetto, 2021), thereby oversimplifying the relationship between creativity and fluid intelligence when investigating creativity. By focusing on the role of these demographic and contextual factors, we hoped to address the oversimplification of these relationships as well as identify variables that may influence these relationships in an under-researched sample (MacKinnon, 2011).

1.1. Creativity and intelligence

Several influential models of intelligence encompass components of creativity, which often regard creativity as a subset of intelligence. For example, imaginativeness in the Berlin Model of Intelligence structure (Jäger et al., 1997) and general retrieval ability in cognitive abilities models encompassing originality aspects of divergent thinking (Carroll, 1993; Schneider & McGrew, 2018), however, recent empirical findings question theoretical models placing originality among factors of retrieval ability (Weiss et al., 2024). An alternative, widely accepted perspective is the Threshold Hypothesis, which maintains that the creativity-intelligence relationship depends on the level of intelligence. Specifically, the strength of this relationship diminishes at higher levels of intelligence, and the relationship between the constructs may be segmented or non-linear (Breit et al., 2023; Jauk et al., 2013). An important implication of the Threshold Hypothesis is that intelligence is a necessary yet insufficient condition for creative achievement (Jauk, 2018). While there is evidence in support of the Threshold Hypothesis (Jauk et al., 2013; Karwowski & Gralewski, 2013; Shi et al., 2017), other studies fail to find compelling evidence for the existence of an intellectual threshold in creative thinking (Holling & Kuhn, 2008; Weiss et al., 2020).

The lack of empirical resolution regarding the Threshold Hypothesis represents inconsistencies in the broader topic of the relationship between creativity and intelligence. A possible explanation for these conflicting findings is that creativity and intelligence are multifaceted constructs with various definitions and methods of psychometric assessment, each containing a variety of sub-dimensional measures (Cho et al., 2010). Despite the various definitions, we conceptualize creativity as creative thinking, which refers to the cognitive process comprising divergent and convergent components (Pinkow, 2022), referred to as divergent thinking and convergent thinking in this paper. Divergent thinking involves generating multiple ideas from a single starting point and operates in a context where selection criteria are relatively vague, and multiple solutions are correct (Runco, 2010). In contrast, convergent thinking refers to the application of established rules and logical reasoning to extract a single correct or best-fit solution to a given problem (Cropley, 2006). In keeping with these definitions, standardized divergent thinking measures, such as the Unusual Uses Test (Guilford, 1967), Torrance (1966) Test of Creative Thinking (TTCT), and the Wallach and Kogan (1965) Creativity Battery require test takers to produce multiple responses to an open-ended problem, while convergent thinking instruments, such as the Remote Associates Test (RAT; Bowden & Jung-Beeman, 2003; Mednick, 1962) involve generating a single, correct solution. The convergent nature of measures such as the Compound Remote Associates Test (CRAT) and the RAT (i.e., only one allowable correct solution per test item) makes these assessments more similar to traditional analytical measures of cognitive ability, such as IQ, than measures of divergent thinking (i.e., multiple possible solutions; Lee et al., 2014). Thus, the relationship between creativity and intelligence may depend on whether convergent or divergent thinking measures were used to tap creativity. In our study, we used measures of both divergent and convergent thinking.

Similar to creative thinking, differentiating intelligence into core components may offer a useful approach for assessing the relationship between these constructs. Given that the current study is based on the CHC theory, intelligence is conceptualized as a hierarchical construct consisting of many correlated cognitive abilities that enable goal-directed behavior (see Schneider & McGrew, 2018 for an overview). Among the most important of these constructs are fluid and crystallized intelligence (Cattell, 1971, 1987). Fluid intelligence represents the ability to apply executive control mechanisms to solve novel problems, whereas crystallized intelligence refers to the experience-based, knowledge aspect of intelligence (Schneider & McGrew, 2018). Both of these capacities have been linked to creativity. While crystallized intelligence may lead to qualitatively less creative output by producing ideas that represent extensions of existing knowledge, it may benefit creative thinking by expanding conceptual network structures, providing the raw materials for creative products (Dane, 2010), and helping identify knowledge gaps and evaluate creative output (Cropley, 2006). Although there appears to be unequivocal evidence for the positive role of crystallized intelligence (see recent meta-analysis; Gerwig et al., 2021, and research; Cho et al., 2010; Kellner & Benedek, 2017), this study focused on the relationship between fluid intelligence and convergent and divergent thinking aspects of creativity.

1.2. The relationship between fluid intelligence and divergent and convergent components of creative thinking

Theories proposing that creativity emerges as a function of general intelligence hold that fluid intelligence plays a prominent role in this relationship as it is characterized by the ability to adapt to new and unfamiliar circumstances and solve problems using complex reasoning. Moreover, it is conceptualized as relational structure mapping, reflecting the ability to represent, process, and integrate relations between different elements or concepts (Chuderski, 2019, 2022; Jastrzębski et al., 2020). As such, fluid intelligence may facilitate the selection and manipulation of task-relevant concepts elicited during creative thinking tasks (Frith et al., 2021) and identify novel interconnections between concepts (Benedek et al., 2018; Dane, 2010).

The overall trends described by a recent meta-analysis reveal a modest positive relationship between fluid intelligence and creativity (Gerwig et al., 2021), which is supported by empirical findings (Frith et al., 2021; Karwowski et al., 2016; Weiss et al., 2021). Moreover, when investigating whether intelligence and creativity are related using factor analysis, Wechsler et al. (2022) identified three factors, namely fluid intelligence, crystallized intelligence, and creativity, the latter of which comprised the divergent thinking components of fluency (number of responses produced), originality (novelty and uniqueness of responses), and elaboration (the degree to which individual embellish responses with details). These three components were also correlated with general intelligence, supporting the idea that creativity and intelligence are positively related despite being distinct constructs. Further evidence comes from studies showing a relationship between fluid intelligence and fluency (Batey et al., 2010), the production of original responses (Forthmann et al., 2019; Karwowski et al., 2016), and the adoption of creative strategies on measures of divergent thinking (Nusbaum & Silvia, 2011). Additionally, fluid intelligence appears to moderate the relationship between self-rated executive functioning and both nonverbal and verbal measurements of divergent thinking (Taylor & Zaghi, 2021), as well as shares underlying cognitive functions with divergent thinking (i.e., attentional control; Frith et al., 2021). While this association has been attributed to the underlying executive mechanism of working memory, which predicts both divergent thinking and fluid intelligence (Benedek et al., 2014), these constructs seem to share mechanisms beyond working memory (Eymann et al., 2022).

Similar findings exist for the relationship between fluid intelligence and convergent aspects of creativity. For example, using confirmatory factor analysis, fluid intelligence predicted convergent thinking ($\gamma = 0.96$, $p < .001$, Lee & Therriault, 2013), and the scores on the measure of convergent thinking (the Remote Associate Test; RAT) were positively correlated with scores on the measure of fluid intelligence, namely the Raven's Advanced Progressive Matrices (APM; Akbari et al., 2012; Lee et al., 2014). Moreover, there are positive associations between fluid intelligence and alternative measures of convergent thinking, such as metaphor generation tasks (Beaty & Silvia, 2013; Silvia & Beaty, 2012, 2021) and insight problem-solving (Beaty et al., 2014). These measures are considered convergent thinking tests given the need to link remote ideas or words and rework them to pragmatically address the task requirements (Silvia & Beaty, 2021; Weiss et al., 2021).

A possible explanation for the relationship between fluid intelligence and the components of creative thinking is that fluid intelligence helps obtain unusual conceptual combinations by identifying patterns in problem tasks (Gerwig et al., 2021; Miroshnik & Shcherbakova, 2019) and by implementing executive control over attentional resources when exploring semantic networks (Forthmann et al., 2019; Frith et al., 2020, 2021; Nusbaum & Silvia, 2011; Wilken et al., 2020), which can overcome limitations in semantic knowledge (Beaty et al., 2023). Additionally, fluid intelligence appears to alter semantic network structures to facilitate the spread of activation to reach more remote concepts, enabling a broader search process (Kenett et al., 2016; Rastelli et al., 2020). For example, using network science to assess how creativity and fluid intelligence relate to the structure of semantic networks, Kenett et al. (2016) showed that creativity was associated with the flexible properties of the semantic network (exhibited by lower modularity of the network), whereas fluid intelligence was related to the structural properties of the network (higher modularity and longer average shortest path length). Individuals who scored high on creativity and fluid intelligence measures possessed both structural and flexible properties.

While there is general consensus regarding the association between fluid intelligence and the components of creative thinking, research tends to focus on the processes and functions that lead to creative outcomes (Glăveanu & Beghetto, 2021). More encompassing research designs and methodologies that account for the interactions between person, product, process, and context are needed (Glăveanu & Beghetto, 2021; Gustafsson, 2023). The present study, therefore, aims to address the lack of consideration of certain demographic and contextual factors that may influence the relationship between intelligence and creative thinking, given the context-embedded nature of both constructs, in a sample of cognitively intact older adults.

1.3. The role of moderating variables in the relationship between creative thinking and fluid intelligence

The importance of considering the role of demographic and contextual factors arises from the diversity of South Africa (the context of the current study) and its population. In particular, South Africa is characterized by significant disparities in socioeconomic status (SES) that have a major impact on access to and quality of education (Spaull, 2013). Moreover, the population is linguistically heterogeneous, and multilingualism is the norm (Posel & Zeller, 2016). These factors may have significant implications for learning outcomes and cognitive skills (Guerra-Carrillo et al., 2017). Therefore, we considered the roles of age, multilingualism, SES, level of education, and sex in the relationship between creative thinking and fluid intelligence.

1.3.1. Age

Age was considered since our sample comprised an under-research cohort (i.e., older adults), and cognitive decline is well-documented in older populations. This decline is particularly prevalent in higher-order functions, such as fluid intelligence and mental flexibility, due to a decline in the functionality of the prefrontal cortex (Baum & Titone, 2014; Manard et al., 2014; Salthouse, 2012). Older adult's cognitive processing tends to be more rigid than that of their younger counterparts (Manard et al., 2014; Oosterman et al., 2010; Salthouse, 2010). This age-related decline is theorized to function as a double-edged sword for creative thinking, with bottom-up aspects, such as divergent thinking, remaining unaffected by age as it may benefit from reduced cognitive control. In contrast, top-down aspects of creative thinking, such as convergent thinking, may be negatively affected by age as it relies on highly engaged cognitive control compared to divergent thinking (Amer et al., 2016). In accordance with the double-edged sword hypothesis, research has demonstrated maintained verbal divergent thinking (Palmiero, 2015) and partial maintenance of all indexes of divergent thinking in older adults (Palmiero et al., 2017). Similarly, divergent thinking abilities appear unchanged across age and cognitive status, although there is an age-related decrease in performance on the Test of Creative Thinking – Drawing Production (TCT-DP) and the Standard Progressive Matrices (SPM), which rely on higher-order functions that decline with age (Ross et al., 2023). This suggests that creative thinking is preserved in older age but decreases if task demands are too taxing on higher-order thinking. As such, age would possibly play a greater role in the relationship between fluid intelligence and convergent thinking compared to divergent thinking.

1.3.2. Multilingualism

While cognitive decline often accompanies the natural aging process, not all individuals experience significant declines in function with age (Lyu & Burr, 2016). A possibility proposed by the cognitive reserve hypothesis is that certain lifetime practices, such as bi- or multilingualism, may contribute to cognitive functioning (Stern, 2009). There is evidence that bilingualism enhances certain cognitive processes, such as executive functions (Bialystok et al., 2012), and may be an additional trigger for individuals' creative potential (Kharkhurin, 2008). Research demonstrates a bilingual advantage for components of divergent thinking, such as originality (Kharkhurin, 2009), fluency (Kostandyan & Ledovaya, 2013), flexibility (Adi-Japha et al., 2010), and elaboration (Kharkhurin, 2008; Lee & Kim, 2011). Beneficial effects of bilingualism on convergent thinking and fluid intelligence (but not divergent thinking) have been observed in children and adolescents (Zheng et al., 2023). Similar effects have also been found for adults (Bak et al., 2014; Hilchey & Klein, 2011; Lehtonen et al., 2018; Zhao et al., 2019). Although these studies show that bilingualism has a specific, positive effect on creative thinking and executive function, other studies have provided opposing results (Booton et al., 2021; Kim & Runco, 2022; Lange et al., 2020; Lehtonen et al., 2018). For example, using a linguistic, figural, and ideational task to assess divergent thinking, Booton et al. (2021) found no performance differences between bilingual and monolingual children. Similarly, Lange et al. (2020)) concluded that bilingualism conferred no advantages to creativity as assessed on the AUT and argued that the mixed results in the literature resulted from false positives or statistical noise.

Available studies tend to adopt a narrow perspective on both creativity and multilingualism by focusing solely on the cognitive functions underlying these constructs (Kharkhurin et al., 2023). Alternative perspectives, such as the Plurilingual Creativity paradigm (Kharkhurin, 2021), emphasize the importance of considering additional factors, such as education and socioeconomic status (SES) when researching these topics. Therefore, to broaden the scope of our study, we investigated the role of the contextual factors of SES and education in the relationship between fluid intelligence and creative thinking.

1.3.3. Socioeconomic status

A variety of approaches to conceptualizing and operationalizing this construct exist (see Antonoplis, 2023 for an overview). We adopted the hierarchy approach, which conceptualizes SES as one's relative standing in society based on access to material and social resources (Miyamoto et al., 2018). As such, we used the extent of urbanization, possession of particular assets, and accessibility to essential services as indicators of SES. In terms of its relationship with creativity, it has been argued that low SES fosters creativity by providing challenging experiences and environments that inevitably require problem-solving, a view that coincides with the asynchronicity approach (Acar, 2020). In contrast to this approach, a recent meta-analysis by Acar et al. (2022) demonstrated a small, positive relationship between SES and creativity ($r = .120$), which was moderated by the measure of creativity used, SES indicators considered, and sample and study characteristics. This meta-analysis indicates a positive relationship between higher levels of SES and better creative performance, which corresponds to other research findings (Castillo-Vergara et al., 2018; Dai et al., 2012; Niu, 2007). The positive effect of high SES has also been identified on other cognitive functions in children between the ages of two and 13 across studies (Farah et al., 2006; Hanscombe et al., 2012; Kishiyama et al., 2009; Noble et al., 2007). In particular, higher SES children have been observed to outperform their lower SES counterparts on measures of working memory (Farah et al., 2006; Kishiyama et al., 2009; Noble et al., 2007), cognitive control (Farah et al., 2006; Noble et al., 2007), language processing (Noble et al., 2007), cognitive flexibility and semantic fluency (Kishiyama et al., 2009) as well as intelligence (Hanscombe et al., 2012). There does not appear to be research into SES and creativity in the elderly, but lower SES is associated with poorer performance on measures of memory, executive function, and processing speed in older adults (Steptoe & Zaninotto, 2020).

1.3.4. Level of education

As with SES, there are varying perspectives regarding the positive effects of high and low levels of education on creative thinking. On the one hand, higher levels of education are proposed to hinder creative thinking by creating a focus on existing knowledge and established ways of thinking and problem-solving (Beghetto & Plucker, 2006). Conversely, it is argued that cognitive abilities are enhanced by enriching environments characteristic of higher education levels or negatively affected by a lack of particular resources (Dai et al., 2012). Despite the varying perspectives, research tends to consistently demonstrate that higher levels of education correspond with better performance on measures of fluid intelligence (Kishiyama et al., 2009) and cognitive control (Noble et al., 2013) and has been found to account for significant individual differences in creativity in older adults (Zhang & Niu, 2013).

1.3.5. Sex

It is important to note that the terms "sex" and "gender" are not mutually exclusive, as sex is considered a biological component, while gender encompasses behavioral, social, environmental, and cultural factors. Given that we describe differences between males and females, we use the term "sex" in this study. While it is generally accepted that there are no sex differences in fluid intelligence (Giofrè et al., 2022; Kishiyama et al., 2009; Lakin & Gambrell, 2014), the findings regarding the role of sex in creative thinking are equivocal (Abraham, 2016; Baer & Kaufman, 2008). For example, greater variability exists for divergent thinking, originality, and unconventionality scores for males, while greater variability appears in adaptiveness scores for females (Abdulla Alabbasi et al., 2022; Karwowski et al., 2016). A suggestion is that sex differences in creativity may be related to the domain (e.g., verbal vs figural creativity) under investigation (Taylor & Barbot, 2021). The role that sex may play in moderating the relationships between fluid intelligence and convergent and divergent thinking is thus unclear. Sex differences in creativity and intelligence are of practical importance since a better understanding of how males and females may differ, or be the same, in their performance in these areas could not only assist with avoiding biases and stereotypes, but also have implications for developing intervention programs to foster creative thinking.

There appear to be conflicting findings regarding the relationship between intelligence and creativity and the role of particular demographic and contextual factors in this relationship. Most commonly, the creativity-intelligence debate focuses on the relationship between fluid intelligence and divergent thinking (Gerwig et al., 2021). Therefore, we aimed to broaden this focus and investigate the potential relationships between fluid intelligence and both divergent and convergent thinking in an understudied population of older adults. We also considered whether certain demographic (i.e., age and sex) and contextual (i.e., multilingualism, level of education, and SES) variables moderate the relationship between these constructs. The reviewed literature demonstrates mixed findings on all of these topics, probably due to differences in the tests used to tap the various constructs, as well as differing sample ages. For this reason, we did not propose a priori hypotheses for our exploratory study.

2. 2.Method

Data was collected as part of a larger research project by [omitted for review], which developed and tested a theoretical model of creativity using SEM to elucidate its underlying cognitive processes in an elderly sample. This data was reanalyzed for the purpose of the current study, which was not preregistered. Given that the larger research project and the current study used single measures to tap the constructs, we assessed non-multivariate relationships. A strength of this approach is the simplicity of the research design, an important consideration as the larger study [removed for review] included additional instruments, namely the Design Fluency Test (Conditions 1, 2, and 3), Verbal Fluency Test (Letter and Category Fluency) and the Victoria Stroop, taking 60 to 90 min. A limitation of this approach is whether the study adequately captures and measures the constructs of interest (i.e., construct convergence).

2.1. Participants

The final sample included 126 English-speaking older adults capable of living independently and excluded individuals with cognitive impairments, psychiatric or neurological disorders, substance use or abuse, and/or pharmacological treatment that impaired their capacity to consent or participate. All participants were South African, recruited via convenience and snowball sampling (Panacek & Thompson, 2007), and provided written and verbal consent with opportunities for withdrawal without prejudice. Ethical clearance [protocol number: removed for review] was provided by the Human Research Ethics Committee (Medical) of the [removed for review].

A post hoc power analysis for two-tailed linear multiple regression was conducted using G*Power 3.1 (Faul et al., 2009). Cohen's f^2 values were used to evaluate effect sizes, with the cut-off values equal to or above 0.35 indicating a large effect size and values equal to or larger than 0.15 indicating a moderate effect size (Cohen, 1988). The power analysis revealed that with a medium effect size, three predictors in the model and the alpha value (α) set at 0.05, a sample size of 126 participants achieves a statistical power of 0.99. The demographic characteristics of the sample are summarised in Table 1. Participants' ages ranged from 64 to 89 years ($M = 73.06$, SD = 6.37). Most participants self-identified as female (64.3 %), spoke English as their home language (57.1 %), attended public school (88.9 %), had a high SES (75.4 %), and spoke two or more languages (94.4 %). Their years of education ranged from 3 to 20 years ($M = 12.8$, SD = 3.3). Age, years of education, and socioeconomic status were measured continuously but are presented in category form in

Table 1
Demographic characteristics of the sample ($n = 126$).

Variable	Category	n (%)	Variable	Category	n (%)
Sex	**Male**	45 (35.7)	**Schooling**	**Public**	112 (88.9)
	Female	81 (64.3)		**Private**	14 (11.1)
Age*	**60–64**	1 (0.8)	**Years of education***	**3–7**	6 (4.8)
	65–69	43 (34.1)		**8–12**	58 (46.0)
	70–74	34 (27.0)		**13–15**	30 (23.8)
	75–79	23 (18.3)		**16–20**	32 (25.4)
	80–84	18 (14.3)			
	85–89	7 (5.6)	**Socioeconomic status***	**High**	95 (75.4)
				Medium	30 (23.8)
Home Language	**English**	72 (57.1)		**Low**	1 (0.8)
	Afrikaans	22 (17.5)			
	Setswana	9 (7.1)	**Number of languages spoken**	**1**	7 (5.6)
	isiZulu	7 (5.6)		**2**	60 (47.6)
	Sepedi	3 (2.4)		**3**	24 (19.0)
	Sesotho	3 (2.4)		**4**	14 (11.1)
	isiXhosa	2 (1.6)		**5**	13 (10.3)
	Tshivenda	2 (1.6)		**6**	3 (2.4)
	German	2 (1.6)		**7**	3 (2.4)
	Xitsonga	1 (0.8)		**8**	1 (0.8)
	isiNdebele	1 (0.8)		**9**	1 (0.8)
	French	1 (0.8)			
	Greek	1 (0.8)			

* Assessed using a continuous scale - categorized for sample descriptive purposes only.

Table 1 for description purposes.

2.2. Instruments

All instruments were paper-and-pencil versions and were administered one-to-one with participants under standardized conditions (i.e., in a quiet, sufficiently lit, and well-ventilated area) to minimize potential distractions or interferences and ensure the participants' comfort.

2.2.1. Demographics

A questionnaire obtained relevant demographic information (e.g., age, sex, and years of education). SES was determined by the Living Standards Measure (LSM), which uses the extent of urbanization, possession of particular assets and appliances, and accessibility to essential services such as water and electricity as indicators of SES (Haupt, 2016). Participants were required to respond "True" or "False" on a series of questions related to the above categories. If participants responded "True" on any of the items, they received a weighted score that was unique to each item. The final SES score was determined by summing the weighted score of each item and subtracting a constant from the total score. The LEAP-Q (Marian et al., 2007) obtained information about the multilingual profiles of the participants.

2.2.2. Cognitive screens

The abbreviated Lawton Instrumental Activities of Daily Living (IADL;Roehrig et al., 2007), which assessed capability for independent living (Graf, 2008), and the Montreal Cognitive Assessment (MoCA) Version 7.2 (Chertkow et al., 2011) were screening measures to identify cognitive impairments. Participants who reported difficulties with any of the items in the IADL ('grocery shopping,' 'food preparation,' 'medication administration,' 'laundry,' and 'transportation') or who had insufficient points on the MoCA were excluded. The scores on the MoCA were evaluated against cut-off scores that were demographically corrected for age, education, and sex (Thomann et al., 2018).

2.2.3. Divergent thinking

The Alternate Uses Test (AUT; Guilford et al., 1978) comprises written words of six everyday objects, including (1.) shoe, (2.) button, (3.) key, (4.) wooden pencil (5.) automobile tire, and (6.) eyeglasses. To maintain standardization, we followed the instructions outlined in the AUT manual. Participants had an eight-minute time limit to complete the test and were instructed to provide up to six different or alternative uses for each object or its parts. Responses were scored using a method that is similar yet not equivalent to snapshot scoring, which is recommended for larger sample sizes to provide a single, holistic rating (Silvia et al., 2008, 2009). This method involved two independent raters who discussed participant responses in terms of the scoring criteria of plausibility (utility), originality (novelty and uniqueness), and flexibility (the degree to which responses differed from the item's conventional use; Guilford et al., 1978) and reached a consensus on item scores. Only items that met all the criteria (plausibility, originality, and flexibility) were deemed acceptable and received one point. The inter-item reliability of the obtained results for the complete AUT was good ($\alpha = 0.86$).

2.2.4. Convergent thinking

The Compound Remote Associates Test (CRAT; Lee et al., 2014) was used with items from Bowden and Jung-Beeman's (2003) item bank. There are 30 items, each comprising three words that are remote from each other (e.g., wise, work, tower). Participants had to find a fourth word that related to each word through the formation of a compound word (e.g., clock). The total score included all correct responses provided within the 10-minute time limit. We applied the shorter time limit (determined via piloting) to prevent cognitive fatigue, which was important to consider given the extent of the larger study test battery and the fact that our sample comprised older adults.

2.2.5. Fluid intelligence

Fluid intelligence was evaluated with a brief version of Raven's Standard Progressive Matrices (SPM; Raven et al., 1998), which included sets B, C, and D of the original test (36 items in total). Participants viewed a series of black-and-white patterns, each with a missing piece. They had unlimited time to select, among 6–8 response options, the item that correctly completed each pattern. The inter-item reliability for sets B, C and D of the SPM was good ($\alpha = 0.92$)

2.3. Data analysis

Given that our ethics approval does not contemplate the open data options, all data is only available upon request. There was no missing data. Analyses were carried out using IBM SPSS Statistics v.28©. Zero-order correlations established the nature of the relationships between the study variables; for calculations that included sex, point-biserial correlations were used.

Hierarchical moderated multiple regressions were carried out to establish whether the relationships between fluid intelligence and divergent and convergent thinking were moderated by age, years of education, SES, number of languages spoken, and/or sex. For each model, fluid intelligence and the relevant demographic moderator were entered for the first step, and the interaction between these was added for the second step. Model effect sizes were calculated using Cohen's f^2, with values equal to or larger than 0.35 indicating a large effect size and values equal to or larger than 0.15 indicating a moderate effect size (Cohen, 1988). All variables were centered and in instances where the interaction term in the model was significant, simple slopes analysis set one standard deviation above and below

Table 2
Descriptive statistics and zero-order correlations for the study variables ($n = 126$).

Variables	M	SD	Skewness	Kurtosis	Minimum	Maximum	1	2	3	4	5	6	7
1. Fluid intelligence (SPM)	20.29	8.49	−0.375	−0.986	2	35							
2. Divergent thinking (AUT)	10.87	6.91	.478	−0.370	0	29	.638***						
3. Convergent thinking (CRAT)	5.55	5.63	.892	−0.255	0	21	.636***	.532***					
4. Age	73.06	6.37	.542	−0.672	64	89	−0.022	−0.015	−0.069				
5. Years of education	12.79	3.30	−0.477	−0.064	3	20	.613***	.532***	.434***	.143			
6. Socioeconomic status	1.47	0.96	−0.653	−0.375	−1.67	2.83	.556***	.427***	.493***	.052	.562***		
7. Number of languages	2.98	1.52	1.45	2.18	1	9	−0.301***	−0.133	−0.168	−0.341***	−0.212*	−0.302***	
8. Sex^	–	–	–	–	–	–	.060	.075	.088	.083	.002	.008	−0.118

* $p < .05$.
**$p < .01$.
*** $p < .001$; ^ = point-biserial correlations; sex (male = 0; female = 1; reference category male); SPM = Raven's Standard Progressive Matrix; AUT = Alternate Uses Test; CRAT = Compound Remote Associates Test.

the mean was carried out to explore further the nature of the moderation (Aiken & West, 1991). In this analysis, the gradient of the regression equation between fluid intelligence and divergent or convergent thinking was examined at a set value of one standard deviation above and one standard deviation below the mean value of the relevant demographic moderator variable, thereby establishing the pattern of the interaction visually by plotting each line (Aiken & West, 1991). For all regression models, independence, linearity, normality, and homoscedasticity were checked using the Durbin-Watson statistic, scatterplots, and normal probability plots. These assumptions were retained except for homoscedasticity in the models that included convergent thinking as a criterion, where heteroscedasticity was identified as a possible concern but was deemed to have a minimal impact on the regression models (Field, 2017). Multicollinearity was ruled out using the variance inflation factor (VIF) and the condition index; and a lack of outliers was established using Cook's Distance, standardized residuals, and scatterplots (Field, 2017). For all analyses, the level of significance (α) was set at 0.05.

3. Results

Table 2 presents means, standard deviations (SD), skewness, kurtosis, minima and maxima values, and zero-order correlations for all the variables in the study. Fluid intelligence was significantly, moderately, and positively related to both convergent and divergent thinking, and these were also significantly, moderately, and positively correlated with one another. Neither age nor sex were significantly related to fluid intelligence, divergent thinking, or convergent thinking; however, both years of education and SES were significantly, moderately, and positively correlated with all three of these. Number of languages was significantly, weakly, and negatively correlated with fluid intelligence scores but was not significantly related to either convergent or divergent thinking. The standard deviation for the CRAT (SD = 5.63) indicates that the poorest performance on this test was at floor level ($M = 5.55$), and few participants obtained markedly higher scores than the mean. Results from this test should thus be interpreted with caution, although the skewness and kurtosis estimates for the distribution of scores in the sample did not indicate skewing.

Five regression models explored whether the relationship between fluid intelligence and divergent thinking was moderated by age, years of education, SES, number of languages spoken, and sex, respectively (Table 3). For years of education, the full model (Model 2) was significant with a large effect size, and the combination of predictors accounted for 46 % of the variance in divergent thinking ($F_{3;122} = 34.18$, $p < .001$, $r^2 = 0.46$, $f^2 = 0.84$). The interaction term was also significant ($b = 0.04$, $p < .05$), indicating that years of education was a significant moderator of the fluid intelligence-divergent thinking relationship. As shown in Fig. 1, the simple slopes analysis indicated that the positive relationship between fluid intelligence and divergent thinking was enhanced for participants with more years of education. None of the interaction terms in the other models were significant, indicating that age, SES, number of languages spoken, and sex did not act as significant moderators of the fluid intelligence-divergent thinking relationship in the sample.

Five regression models explored whether the relationship between fluid intelligence and convergent thinking was moderated by age, years of education, SES, number of languages spoken, and sex, respectively (Table 4). The full model (Model 2) for years of education was significant with a large effect size, and the predictors accounted for 43 % of the variance in convergent thinking ($F_{3;122} = 30.69$, $p < .001$, $r^2 = 0.43$, $f^2 = 0.75$). The interaction term in this model was significant ($b = 0.04$, $p < .05$), indicating that years of education acted as a significant moderator of the fluid intelligence-convergent thinking relationship in the sample. The simple slopes analysis, represented in Fig. 2, indicated that for those with fewer years of education, convergent thinking scores were relatively similar regardless of the level of fluid intelligence, whereas, for those with a higher level of education, convergent thinking scores were

Table 3
Hierarchical multiple regressions for fluid intelligence and divergent thinking with demographic moderators ($n = 126$).

Model	Moderators	Age		Years of education		Socioeconomic status		Number of languages		Sex	
Model 1	**Predictors**	***b***	***t***	***B***	***t***	***B***	***t***	***b***	***t***	***b***	***t***
	Constant	10.87	22.74***	10.87	23.37***	10.87	22.88***	10.87	22.81***	10.53	13.16***
	Fluid intelligence	0.52	9.18***	0.41	5.84***	0.47	6.99***	0.54	9.06***	0.52	9.15***
	Moderator	−0.00	−0.02	0.47	2.64**	0.75	1.25	1.11	0.90	0.53	0.53
	Summary										
	R^2		.407		.439		.414		.411		.408
	F		42.18***		48.05***		43.50***		42.85***		42.41***
Model 2	**Predictors**	***b***	***t***	***B***	***t***	***b***	***t***	***b***	***t***	***b***	***t***
	Constant	10.86	22.72***	10.19	17.87***	10.40	18.13***	10.79	21.70***	10.46	13.10***
	Fluid intelligence	0.51	8.92***	0.42	6.09***	0.47	6.89***	0.54	9.05***	0.41	4.27***
	Moderator	−0.00	−0.02	0.55	3.03**	1.00	1.61	0.77	0.56	0.58	0.59
	Interaction	−0.01	−1.11	0.04	2.01*	0.11	1.47	−0.08	−0.61	0.17	1.46
	Summary										
	R^2		.413		.457		.424		.412		.418
	F		28.58***		34.18***		29.99***		28.54***		29.24***
	ΔR^2		.006		.018		.010		.002		.010
	ΔF		1.23		4.05*		2.15		0.37		2.12
	f^2		.70		.84		.74		.70		.72

* $p < .05$.
** $p < .01$.
*** $p < .001$; sex (male = 0; female = 1); degrees of freedom for Model 1: $F_{(2;\,123)}$; degrees of freedom for Model 2: $F_{(3;122)}$; ΔF refers to the test statistic for the model comparison test.

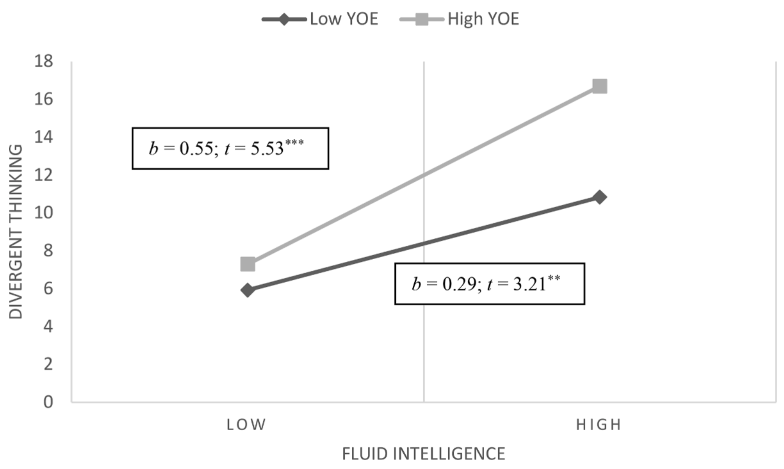

Fig. 1. Simple slopes analysis for fluid intelligence and divergent thinking moderated by years of education (one standard deviation above and below the mean).
**$p < .01$; ***$p < .001$; YOE = years of education.

Table 4
Hierarchical multiple regressions for fluid intelligence and convergent thinking with demographic moderators (n = 126).

Model	Moderators	Age		Years of education		Socioeconomic status		Number of languages		Sex	
Model 1	**Predictors**	***b***	***t***	***b***	***t***	***b***	***t***	***b***	***t***	***b***	***t***
	Constant	5.55	14.25***	5.55	14.25***	5.55	14.56***	5.55	14.22***	5.18	7.93***
	Fluid intelligence	0.42	9.14***	0.39	6.74***	0.35	6.41***	0.43	8.82***	0.42	9.09***
	Moderator	−0.05	−0.79	0.12	0.80	1.19	2.46*	0.36	0.36	0.58	0.71
	Summary										
	R^2		.407		.407		.432		.405		.407
	F		42.23***		42.24***		46.79***		41.81***		42.12***
Model 2	**Predictors**	***b***	***t***	***b***	***t***	***b***	***t***	***b***	***t***	***b***	***t***
	Constant	5.54	14.23***	4.92	10.35***	4.90	10.84***	5.59	13.72***	5.19	7.90***
	Fluid intelligence	0.41	8.88***	0.41	7.04***	0.34	6.33***	0.43	8.72***	0.43	5.52***
	Moderator	−0.05	−0.79	0.19	1.25	1.52	3.12**	0.53	0.48	0.57	0.70
	Interaction	−0.01	−1.03	0.04	2.22*	0.15	2.54*	0.04	0.37	−0.02	−0.19
	Summary										
	R^2		.412		.430		.461		.405		.407
	F		28.52***		30.69***		34.72***		27.72***		27.87***
	ΔR^2		.005		.023		.028		.001		.000
	ΔF		1.06		4.91*		6.43*		0.14		0.04
	f^2		.70		.75		.86		.68		.69

* $p < .05$.
** $p < .01$.
*** $p < .001$; sex (male = 0; female = 1); degrees of freedom for Model 1: $F_{(2;\ 123)}$; degrees of freedom for Model 2: $F_{(3;122)}$; ΔF refers to the test statistic for the model comparison test.

significantly higher for those with a higher level of fluid intelligence as well. For SES, the full model (Model 2) was significant with a large effect size; the combined predictors accounted for 46% of the variance in convergent thinking ($F_{3;122} = 34.72, p < .001, r^2 = 0.46, f^2 = 0.86$). The interaction term was significant (b = 0.15, $p < .05$), indicating that SES significantly moderated the relationship between fluid intelligence and convergent thinking in the sample. The simple slopes analysis (Fig. 3) confirmed that the positive relationship between fluid intelligence and convergent thinking was enhanced for those with a higher SES. The interaction terms in the models for age, number of languages spoken, and sex were not significant, thus, these variables did not act as significant moderators of the fluid intelligence-convergent thinking relationship in the sample.

4. Discussion

Investigations into the association between creativity and fluid intelligence have yielded conflicting results, possibly due to variations in construct conceptualization and measurement (Plucker et al., 2015), and these findings are further muddied by situational and contextual factors, which may moderate this relationship (Corazza & Lubart, 2021). In this study, we investigated the relationship between fluid intelligence, divergent and convergent thinking and assessed whether demographic and contextual factors such as age, sex, level of education, SES, and multilingualism moderate the relationships between these constructs in a sample of South African

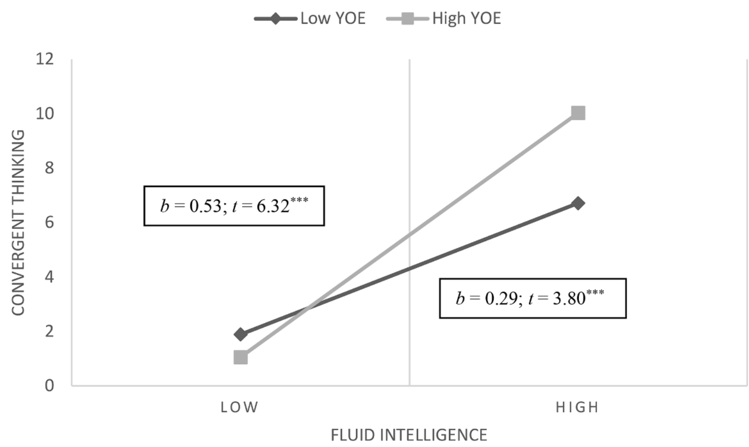

Fig. 2. Simple slopes analysis for fluid intelligence and convergent thinking moderated by years of education (one standard deviation above and below the mean).
$^{***}p<.001$; YOE = years of education.

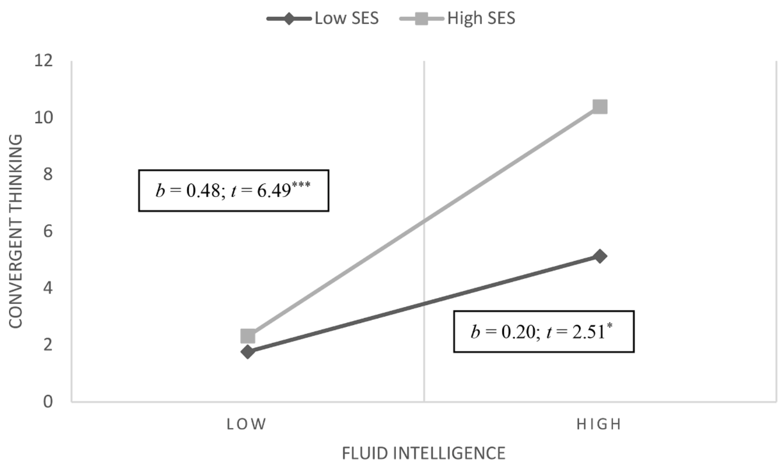

Fig. 3. Simple slopes analysis for fluid intelligence and convergent thinking moderated by socioeconomic status (one standard deviation above and below the mean).
$^{*}p < .05$;$^{**}p < .01$; $^{***}p < .001$; SES = socioeconomic status.

older adults (64 to 89 years).

4.1. The relationship between fluid intelligence and the components of creativity

Evidence suggests that fluid intelligence plays an important role in creativity and its divergent and convergent aspects (Cortes et al., 2019; Cropley, 2006; Miroshnik & Shcherbakova, 2019), that divergent and convergent thinking are correlated (Nusbaum & Silvia, 2011; Salvi et al., 2020), and that these constructs are both present in most measurements of creativity (Cortes et al., 2019). Our findings corroborate this evidence as we found significant, moderate, positive relationships between fluid intelligence, divergent thinking, and convergent thinking in our sample. These results suggest that divergent and convergent thinking components of creative thinking are more similar than initially conceptualized. That is, while divergent thinking is often considered more associative and unconscious, with responses emerging spontaneously without voluntary control, it can also be effortful and intentional. Similarly, responses on convergent thinking assessments can emerge through stepwise analytical search and spontaneous insight (Sowden et al., 2015). Therefore, the processes underlying divergent and convergent thinking may share similarities (Zhang et al., 2020). The following sections discuss the contributions of moderating factors in the relationship between fluid intelligence and divergent and convergent thinking.

4.2. Age, sex, and multilingualism as moderators

We found no significant correlations between age and fluid intelligence, divergent or convergent thinking. Additionally, age was not a significant moderator for the relationships between fluid intelligence and convergent and divergent thinking in the sample. This is inconsistent with findings that convergent and divergent thinking (Simon & Bock, 2016), as well as fluid intelligence (Andrés et al., 2008; Manard et al., 2014; Salthouse, 2009), are negatively affected by age. It is also inconsistent with research suggesting that age confers advantages on creativity's more associative, automatic components, such as divergent thinking (Leon et al., 2014). The failure to find a significant age-related association could be because our sample's age range was fairly constricted, resulting in limited variance in this factor, and we did not have a comparison group of significantly younger individuals. Although we used single measures of divergent thinking, restricting findings to this measure, it may be reasonable to expect similar findings for other divergent thinking measures.

Similarly, sex was not significantly related to, and did not act as a significant moderator of, the relationships between fluid intelligence and convergent and divergent thinking in our sample. These findings contradict those reporting gender differences across different measures of creative thinking, including male advantages in creative abilities (He & Wong, 2011; He et al., 2013; Karwowski et al., 2016), female advantages in domain-specific creative thinking (Hong et al., 2013), better performance on tests of divergent thinking for males (Stoltzfus et al., 2011) and females (Anwar et al., 2012), as well as male advantages (He & Wong, 2021) and female advantages (Hardy & Gibson, 2017) in creative problem-solving abilities. In contrast, our findings correspond to research that compared males and females on measures of divergent thinking (Batey et al., 2010; Said-Metwaly et al., 2021), convergent thinking (Harris, 2004; H. Zhang et al., 2020; Zhu et al., 2019) and fluid intelligence (Kaufman et al., 2009). Therefore, our results align with the gender similarity hypothesis, indicating a divergence from biological and socio-cultural theories regarding sex differences in creative thinking (Abraham, 2016).

Regarding multilingualism, the number of languages spoken did not significantly relate to convergent or divergent thinking and was only weakly and negatively correlated with fluid intelligence. Multilingualism was also not a significant moderator of the relationships between fluid intelligence and divergent and convergent thinking in the sample. The negative relationship between multilingualism and fluid intelligence may suggest that additional languages in older age compete with executive resources. The need to continuously manage, select, and inhibit information between languages increases the cognitive load and taxes executive control processes (Zheng et al., 2023). Most studies in this area sampled children, adolescents, and young adults, and it is possible that this relationship may change later in life or that there is no multilingual advantage in older age, propositions that require further research (Ellajosyula et al., 2020). Our results could also possibly be attributed to the manner in which language was conceptualized and operationalized in the study, that is, by using a self-report measure to enumerate the number of languages participants spoke without considering proficiency and age of acquisition and objective measurements of ability (de Bruin, 2019; Yang et al., 2016; Zhao et al., 2019).

4.3. Socioeconomic status and level of education as moderators

We found that the number of years of formal education was significantly, moderately, and positively correlated with fluid intelligence, divergent thinking, and convergent thinking in our sample. Years of formal schooling also significantly moderated the relationships between fluid intelligence and convergent and divergent thinking. In both instances, for those with fewer years of education, divergent and convergent thinking scores were relatively similar regardless of the level of fluid intelligence, whereas, for those with a higher level of education, divergent and convergent thinking scores were significantly higher than those who also had higher fluid intelligence scores. This supports evidence of a significant relationship between fluid intelligence and level of education (Kishiyama et al., 2009). This is an important finding as it suggests that level of education may play a facilitative role in maintaining the relationship between fluid intelligence and creative thinking in older adults, although more research is needed to corroborate this.

Socioeconomic status was also significantly, moderately, and positively correlated with fluid intelligence, divergent thinking, and convergent thinking in the sample. These findings contradict the asynchronicity perspective (Acar, 2020) that the diverse experiences conferred by a high SES may hinder creativity by causing cognitive fixation (Doboli & Umbarkar, 2014) and that lower SES exposes individuals to situations that enhance problem-solving abilities and thus creativity. Instead, our findings suggest that access to resources, such as economic and social capital, and exposure to enriching experiences afforded by a higher SES are associated with greater fluid intelligence, divergent, and convergent abilities (Aartsen et al., 2019; Hackman et al., 2010).

Socioeconomic status encompasses and is highly intercorrelated with educational attainment (Acar et al., 2022; Hackman et al., 2010), yet it only functioned as a significant moderator and facilitator of the fluid intelligence-convergent thinking relationship in the sample. These results may be due to the influence SES has on language abilities in conjunction with the language-heavy measure used to tap convergent thinking. The environment in which language is acquired and the rate of language development varies as a function of SES (for an overview, see Hoff, 2015). In our study, convergent thinking was tapped via the CRAT, which requires good English vocabulary and conceptual knowledge (Behrens & Olteţeanu, 2020). As such, enhanced language skills facilitated by a higher level of SES may have benefitted participants' convergent thinking performance and strengthened the relationship between their fluid intelligence and convergent thinking. In contrast, the relationship between fluid intelligence and divergent thinking was not moderated by SES in the sample. This could possibly be due to confounding resulting from the complex relationship between education and SES, whereby increased education appears to reduce gaps in creativity between lower and higher SES individuals (Acar et al., 2022). Overall, our findings support the positive role of SES in facilitating the relationship between convergent thinking and fluid intelligence while suggesting that the relationship between fluid intelligence and divergent thinking may be more robust to the role of SES.

These findings have several implications. The significant correlation between divergent and convergent thinking contributes to creativity theory as it suggests that creativity is comprised of both processes rather than being only synonymous with divergent thinking (Benedek et al., 2013; Runco, 2008). However, it is important to note that this interpretation is based on the positive association between two particular measures of creative thinking (i.e., the AUT and CRAT) and is therefore limited to these measures. The associations between the components of creativity and fluid intelligence in this study augment existing literature regarding the nature of the relationship between creative thinking and fluid intelligence in older adults, an under-represented population. The moderation of SES and level of education demonstrates not only their importance in cognitive abilities, which is often ignored but also the need to consider the role of these variables in cognitive testing (Weizenbaum et al., 2020).

5. Limitations and future research

The way fluid intelligence, divergent, and convergent thinking were operationalized, namely the use of single measures (SPM, AUT, and CRAT, respectively), allows our data to be considered as only approximations of these constructs, and the correlations are, therefore, limited to these measures. To provide a more comprehensive understanding of the relationship between creative thinking and fluid intelligence, future research should undertake a multivariate or multitrait-multimethod approach (Campbell & Fiske, 1959), whereby multiple traits of fluid intelligence (e.g., abstract reasoning, problem-solving ability, and pattern recognition), divergent thinking (e.g., fluency, flexibility, originality, and elaboration) and convergent thinking (e.g., logical reasoning and problem-solving skills) are operationalized using multiple methods and measures.

Although well-established and psychometrically sound, the AUT and the CRAT have some limitations. Questions have been raised about the suitability of a single-score outcome and the extent to which solutions provided in the AUT derive from a genuinely creative process (Gilhooly et al., 2007). Firstly, how the AUT was scored does not account for the possibility that participants may provide various responses that are scored as original when they are actually based on previously encountered ideas stored in memory. For example, participants may suggest “swing” or “planter” in response to alternative uses for an automobile tire. These would be scored as creative, but they are not necessarily new to most people. Therefore, there is a lack of clarity on whether participants’ AUT scores reflect broad retrieval abilities or are the result of a genuinely creative act (Gilhooly et al., 2007). To ensure that divergent thinking scores are not confounded by general retrieval abilities, future research can benefit from either alternative administration or scoring methods, such as think-aloud techniques (Gilhooly et al., 2007) or old/new scoring methods (Benedek et al., 2014). The latter method involves requesting participants to categorize responses as being either old or new, with research using this approach revealing an association between fluid intelligence and the generation of more original ideas (Miroshnik & Shcherbakova, 2019; Nusbaum & Silvia, 2011). Replication of the current study’s results using these alternative scoring methods will provide strong evidence for the current findings.

The language-dependent nature of the CRAT may have affected performance, which showed some floor effects (Toivainen et al., 2019). This emphasizes the importance of appropriate task specification and considerations of language and cultural bias in test selection for future research (Becker & Cabeza, 2023). Additionally, the time constraints applied to the CRAT possibly restricted participants’ performance on this measure.

The categorical operationalization of multilingualism (monolingual, bilingual, or multilingual) oversimplifies multilingual experiences. Future research should study the role of multilingualism from a more nuanced sociolinguistic framework, which considers social and contextual factors (Lähteenmäki et al., 2011).

Given the smaller sample size and demographic profiles of the participants, as well as the heteroscedasticity in the convergent thinking data, the generalisability of the findings is limited. This emphasizes the need for additional studies with larger samples from diverse contexts (Rosenthal & Rosnow, 2008). Future research exploring non-linear relationships between the constructs is also warranted (Breit et al., 2023).

6. Conclusion

Our findings suggest that both years of education and SES are important variables in fluid intelligence and divergent and convergent thinking in older adults and are likely to be influential in their creative thinking. Number of languages spoken had some (negative) association with fluid intelligence but was not significantly related to either convergent or divergent thinking. Further, neither age nor sex were significantly associated with fluid intelligence, divergent thinking, or convergent thinking, suggesting that their roles are minimal.

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CRediT authorship contribution statement

Stephanie Alcock: Writing – original draft, Methodology, Investigation, Data curation. **Aline Ferreira-Correia:** Writing – review & editing, Writing – original draft, Supervision, Conceptualization. **Nicky Israel:** Writing – review & editing, Writing – original draft, Visualization, Formal analysis, Conceptualization. **Kate Cockcroft:** Writing – review & editing, Writing – original draft, Supervision, Funding acquisition.

Declaration of competing interest

None.

Data availability

Data will be made available on request.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.tsc.2024.101557.

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