Age-Related Differences in Executive, Social and Creative Cognition in Neurologically Healthy Adults

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Abstract

Despite evidence of aging-related decline in frontal lobe and associated executive cognitive functions, findings in relation to social and creative cognition have been inconclusive. The present study examined executive, social and creative cognition, as well as crystallized and fluid intelligence, in a community sample of 88 neurologically healthy participants (61 females, 27 males) ranging in age from 25 to 85 years, with the goal of detecting aging-related differences in these cognitive domains. Social cognition was operationalized using a Theory of Mind task. Creative cognition was operationalized using verbal and non-verbal idea fluency tasks. Executive cognition was operationalized via the Stroop and Wisconsin Card Sorting tests. Although the indices of executive cognition and fluid intelligence showed expected age-related differences, creative cognition showed no relationship with age, and performance on the social cognition task appeared to be compensated for by age-related increase in crystallized intelligence. Despite the issue of cohort effects, results are consistent with the notion that compensatory processes may help maintain social and creative cognitive functioning in normal aging.

Keywords: cognition, aging, executive function, theory of mind, creativity

Introduction

The process of aging involves facing many challenges such as physical ailments, social losses, psychological stress, increasing dependence on others and an increasing awareness of the transience of life. Despite these challenges many healthy older people remain well-adjusted mentally and emotionally into their later years. Further, the capacity for creativity has been demonstrated well into later life. Giuseppe Verdi wrote his last opera *Falstaff* in his 80s; William Butler Yates wrote a major completion to his life's work, *Under Ben Bulben,* at age 73; Johann Wolfgang von Goethe wrote one of his finest works, the *Marienbad Elegy,* at age 83; Pablo Picasso painted into his early 90s. Such examples may seem surprising given the abundant evidence of cognitive decline in normal aging. The present study examined the hypothesis that although some aspects of cognitive function clearly deteriorate with aging, other aspects are preserved.

Executive Cognition and Normal Aging

A longstanding interpretation of aging-related cognitive decline is the frontal lobe hypothesis of aging, supported by a large body of evidence of aging-related decline in executive cognitive function (cognitive control processes such as planning, organizing, goal setting, inhibition of impulses, cognitive flexibility in problem solving, etc.) and fluid intelligence (the ability to solve new problems independent of acquired knowledge) as well as corresponding pathophysiological age-related changes in prefrontal cortex (PFC) morphology and processing (see reviews by Cabeza & Dennis, 2013; Kievit et al., 2014). Although several regions of the brain demonstrate aging-related changes, the PFC appears to be the first cerebral region to be affected in normal aging (Tisserand & Jolles, 2003), showing pronounced shrinkage (Gunning-Dixon & Raz, 2003). Neuroimaging of structural changes in white matter and grey matter suggest that the healthy adult brain matures into middle age followed by progressive volume loss, with the later maturing cortical regions such as the PFC being most vulnerable to aging-related decline. Neuropsychological evidence indicates that performance on PFC-dependent executive cognition tasks declines with normal aging, starting around the age of 60 (Treitz, Heyder, & Daum, 2007).

Successful performance of executive cognition tasks has long been known to depend on the functional integrity of the PFC. For example, negative correlations have been reported between perseverative errors on the Wisconsin Card Sorting Test (WCST) and PFC volume (Raz, Gunning-Dixon, Head, Dupuis & Acker, 1998) as well as myelination and integrity of prefrontal white matter (Valenzuela et al., 2000). There is an aging-related increase in PFC activation during executive cognition tasks, perhaps reflecting increased effort or other compensatory processes (Spreng, Wojtowicz, & Grady, 2010). The frontal lobes are the seat of conscious, deliberate, attentive, effortful control, outcomes of which include executive cognitive performance and fluid intelligence. This controlled processing has a limited capacity, however, which may become taxed as the frontal lobes decline with age. Automatic processing, by contrast, is not capacity limited; it is unconscious, involuntary, and responsive to environmental stimuli (Norman & Shallice, 2000). Decline in controlled processing with increasing age as the frontal lobes deteriorate may thus be compensated for to some degree by an increased reliance on access to previously stored information. As such, automatic processing recruits knowledge and memories acquired over a lifetime, and thus may support effective social and creative cognition in older adults even as the frontal lobes and their associated executive cognitive processes decline (Hedden & Gabrieli, 2004; Hedden, Lautenschlager & Park, 2005). There is strong support for the stability of implicit memory

with aging (Mitchell & Bruss, 2003), consistent with intact automatic processing. Implicit memory refers to knowledge that is not verbalized but which is nevertheless available as evidenced by changes in behavior, such as in classical conditioning or sensorimotor skill acquisition. Further, although episodic memory (memory for experienced life events) and working memory (holding a limited amount of information in consciousness temporarily to use or manipulate in problem-solving, etc.) show gradual declines with normal aging, semantic memory (abstract knowledge and word meanings) remains relatively stable (Churchill, Stanis, Press, Kushelev, & Greenough, 2003; Hedden & Gabrieli, 2004; Spaniol, Madden, & Voss, 2009; St-Laurent, Abdi, Burianová, & Grady, 2011). Thus in the present study, although performance on tests of executive cognition were expected to show aging-related declines, this was not expected for tasks tapping social and creative cognition due to age-related increase in reliance on automatic processing and acquired knowledge, which were theorized to offset the decline in executive cognition.

Social Cognition and Normal Aging

The varying roles of automatic vs. controlled processing in different tasks may account for some of the differential findings on social cognition (how people acquire, store and use information about others) in relation to normal aging. Satpute and Lieberman (2006) pointed to an automatic component of social cognition, as opposed to the executive control involved in reflective processes. Social cognition tasks, such as Theory of Mind (ToM) tasks where participants must judge the mental states or intentions of others depicted in images (e.g., photos of eyes), activate both executive control and automatic processes (Adolphs, 2009). The conscious control aspects can involve declarative reasoning and reflective thinking; however, judgements are also made about people and their behaviors based on automatic schematic beliefs. Accessing schemas in the stored knowledge base is an example of crystallized intelligence (the general ability to access and use stored knowledge), which appears relatively impervious to decline in normal aging (Horn & Cattell, 1967; Salthouse, 2000; Sullivan & Ruffman, 2004).

Research on ToM as an example of social cognition in normal aging has yielded inconsistent findings. Some studies have indicated aging-related decline in ToM (Baena, Allen, Kaut, & Hall, 2010; Charlton, Barrick, Markus, & Morris, 2009; Maylor, Moulson, Muncer, & Taylor, 2002), whereas others found stability (Bottiroli, Cavallini, Ceccato, Vecchi, & Lecce, 2016; MacPherson, Phillips, & Sala, 2002; McKinnon & Moscovitch, 2007; Sullivan & Ruffman, 2004) or even advantage with increased age (Happé, Winner, & Brownell, 1998). Evidence of stability or improvement in performance of ToM or other social cognition tasks with normal aging may reflect increased reliance on compensatory strategies where conscious explicit reasoning is supported by automatic associations from implicit memory relevant to the particular task. For example, as lexical access to stored information does not decline with age (Fisk & Sharp, 2004), older adults may perform ToM tasks efficiently, despite decline in executive cognition, by relying on their greater cumulative experience with lexical processing (e.g., use of emotion words) than younger adults – reflecting older adults' increased reliance on automatic rather than conscious, deliberate control processes (Allen et al., 2002; Lien et al., 2006). Thus, in the present study, increased reliance on stored knowledge, or crystallized intelligence, was predicted to offset the aging-related decline in executive cognition in terms of ToM task performance.

Creative Cognition and Normal Aging

Theoretical perspectives on creativity distinguish between the gifted creativity demonstrated by eminent artists, and everyday creativity where the cognitive processes that produce innovative ideas and responses contribute to everyday adaptation and survival (Richards, 2010). Creative cognition is generally agreed to involve two distinct qualities: novelty or innovation and usefulness (Sternberg & Lubart, 1999). Ward, Smith and Finke (1999) suggested that the creation of novel and useful ideas is achieved through complex interactions between generative processes and exploratory processes. These processes are often unconscious or automatic and triggered by external cues. More recently, the explicit-implicit interaction theory emphasizes incubation and insight, with creativity resulting from a combination of conscious explicit reasoning and the unconscious, automatic associations of implicit memory (Hélie & Sun, 2010). The latter is cued outside conscious awareness by environmental stimuli, involves minimal attentional focus or inhibition, and is involuntary and time efficient (Moors & De Houwer, 2006). Thus at least theoretically, the creation of novel and useful ideas or responses is an outcome of both explicit or controlled and automatic or implicit processing to varying degrees.

The focus of the present study was to explore everyday creativity, where the relevant cognitive processes are linked to gist representations rather than details, and spontaneous heuristic information is accessed to yield inventive and innovative ideas or solutions. Although the PFC and executive cognition are implicated given the role of working memory in creative cognition (Damasio, 2001), research has indicated that a slower processing speed, defocused attention and reduced response inhibition are important as well (Dorfman, Martindale, Gassimova, & Vartanian, 2008; Vartanian, Martindale, & Kwiatkowski, 2007), suggesting that creativity often involves a reduced reliance on executive control compared to other forms of cognition. Processes of creative "flow" (becoming completely absorbed in, or "one with," an experience or activity) activate implicit memory and automatic processing, deactivate explicit reasoning, and utilize wide bilateral brain networks (Limb & Braun, 2008). Given such considerations, creative cognition might be expected to show stability or even improvement with normal aging. At the very least, the increased reliance on automatic processing and other compensatory aging-related changes such as more widespread patterns of brain activation (Cabeza & Dennis, 2013; Lighthall, Huettel & Cabeza, 2014) may help preserve creative cognition despite decline in other cognitive domains. The present study proposed that an aging-related increase in reliance on automatic processing would allow tasks of creative cognition to show stability across a wide age range in adults despite the aging-related decline in executive cognition.

The purpose of this study investigated was to investigate the performance on tests of executive, social and creative cognition in a sample of neurologically healthy adults aged 25 to 85 years. Based on the previous research and theory described earlier, the following research hypotheses were posed:

> H1: Aging-related differences is anticipated on tasks that tap executive cognitive functions of updating, shifting and inhibition (i.e., Wisconsin Card Sort and Stroop tasks) as well as working memory and fluid intelligence.
> H2: Aging-related increase in reliance on stored knowledge, or crystallized intelligence, was predicted to maintain stability of social cognition (ToM), as tested by mediation analysis.

H3: Independence of creative cognition from decline in executive cognition with normal aging is expected to be evident; that is, no age-related differences in creative cognition were anticipated, despite a decline in executive cognition.

Method

Participants

The initial sample consisted of 92 community-based volunteers, which was reduced to 88 after removal of two multivariate outliers and two who did not meet the inclusion criteria. The final sample consisted of 61 women and 27 men ranging in age from 25 to 85 years (M = 62.76 years, SD = 15.36) with a mean education of 12 years (SD = 2.79). Education level was not significantly correlated with age in this sample, nor was there a relationship of age with gender. Participants were recruited as neurologically healthy volunteers from the general community and social clubs through advertisements and announcements. All participants possessed adequate vision and hearing. Individuals with minor physical abnormalities (e.g., diabetes with no serious complications, essential hypertension, mild hearing loss) were included in the study. Exclusion criteria included brain injury; cardiovascular disease; alcohol misuse; clinically significant cognitive impairment, anxiety or depression; or taking medication likely to affect cognitive function. Participants were screened for brain injury, cardiovascular disease and medications by means of yes-no questioning. Screening for alcohol use, cognitive impairment, anxiety and depression was via the Alcohol Use Disorders Identification Test (AUDIT; Saunders, Aasland, Babor, de la Fuente, & Grant, 1993), the Mini Mental Status Examination – Second Edition, Brief Version (MMSE-2:BV; Folstein, Folstein, White, & Messer, 2010), and the Depression Anxiety and Stress Scales (DASS-21; Lovibond & Lovibond, 1995) respectively. Exclusion was based on accepted cut-off scores for the relevant instruments: an AUDIT score higher than 16, a score below 14 on the MMSE-2:BV, or a depression score higher than 11 or anxiety score higher than 8 on the DASS-21.

Exclusion Criteria Measures

The following measures were used to determine whether volunteers met criteria for participation.

Depression Anxiety and Stress Scales (DASS-21; Lovibond & Lovibond, 1995). The DASS-21 measures three psychometrically distinct factors: Depression, Anxiety and Stress. The total scale is made up of 21 statements, with 7 for each factor. Responses are scored on a 4-point Likert scale from 0 = "did not apply to me at all" to 3 = "applied to me most of the time." It has demonstrated satisfactory psychometrics and factor structure that have been substantiated by Lovibond and Lovibond (1995) and subsequent replication in clinical and non-clinical samples (Antony, Bieling, Cox, Enns, & Swinson, 1998; Clara, Cox, & Enns, 2001; Daza, Novy, Stanley, & Averill, 2002; Henry & Crawford, 2005; Sinclair et al., 2012). Reliability analysis in the present study replicated adequate internal consistency on all factors (α =.89, .65, and .81 for Depression, Anxiety, and Stress respectively).

Alcohol Use Disorders Identification Test (AUDIT; Saunders et al., 1993). The widely used AUDIT contains 10 questions assessing quantity/frequency, dependence, and alcohol-related consequences or harm. Every AUDIT question is scored from 0 to 4, with an overall score ranging from 0–40. The cut-offs for Low Risk, Hazardous and Harmful drinking are 1–7, 8–15 and 16+ respectively. The alpha reliability coefficient was .78 in the present sample.

Mini Mental Status Examination – Second Edition, Brief Version (MMSE-2: BV; Folstein et al., 2010). The MMSE-2 is designed for rapid assessment of global cognitive status and has been shown to be effective for screening purposes. The short form of the original test assesses three cognitive functions of the original MMSE: registration, orientation to time and place, and recall. Of the total 16 points, a score below 14 indicates cognitive impairment. Cross validation with the original MMSE found the short version to be as sensitive a test for screening for cognitive impairment (Schultz-Larsen, Lomholt, & Kreiner, 2007; Schultz-Larsen, Rahmanfard, Kreiner, Avlund, & Holst, 2008). The present study used the MMSE as a screening tool to ensure that only those with scores of 14 or higher were included in the sample.

Primary Measures

Demographic Questionnaire. Participants were asked to complete demographic questions pertaining to age, gender, years of education, smoking and drug use levels, medical conditions (e.g., cardiac health, brain trauma) and medications.

National Adult Reading Test (NART; Nelson, 1982). The NART provides an estimate of crystallized intelligence in the form of accumulated verbal knowledge. The NART is an untimed measure consisting of 50 irregularly pronounced words (irregular grapheme–phoneme or stress patterns) which the subject is required to read aloud. Internal consistency has been found to be high, ranging from $\alpha = .85$ to .94 in repeated investigations (Kiely et al., 2010; Uttl, 2002). The alpha reliability coefficient was .85 in the present sample**.**

Matrices Test from the Kaufman Brief Intelligence Test, Second Edition (KBIT-2; Kaufman & Kaufman, 2004). The KBIT-2 is a brief, individualized format for measuring verbal and nonverbal intelligence in children and adults from age 4 years, 0 months to 90 years, 11 months. The test consists of three subtests, two verbal and one non-verbal, the latter of which is a matrices test of visual processing and fluid intelligence. The matrices test, used for this study, consists of 46 multiple-choice type items based on abstract patterns. For items 10 to 46, the examinee must choose which of six patterns or pictures best completes a 2×2, 3×3 or 3×2 matrix. There is no time limit or motor component in this test. Kaufman and Kaufman reported temporal stability of $r = .80$ over a 2-month interval.

Alternate Uses Task (Wallach & Kogan, 1965). This widely used verbal measure of creative thinking (Cheung, Lau, Chan & Wu, 2004; Plucker & Renzulli, 1999) is an open-ended ideation fluency test that allows numerous responses. Subjects were presented with three common objects (brick, shoe and newspaper) and were asked to generate as many alternate uses as possible for each object, with no time limit imposed. The final scoring of ideation fluency was based on two measures: the number of categories and the rarity of the response.

Figural Task from the Abbreviated Torrance Test for Adults *(*ATTA; Goff & Torrance, 2002). The Figural Task is based on a nonverbal test of ideational fluency from the ATTA but extends the test so that it is composed of two pages of nine triangles rather than one. The subject is requested to use the triangle shapes to generate as many pictures or ideas as possible, with no time limit. Scoring based on total ideation output loads on an innovation/originality factor consistent with creativity and divergent thinking (Kim, Cramond, & Bandalos, 2006).

Reading the Mind in the Eyes Test (RMET; Baron-Cohen, Wheelwright, Hill, Raste, & Plumb, 2001). The RMET is regarded by some as the prototypical task for the assessment of

affective ToM (Kemp, Després, Sellal, & Dufour, 2012; Moran, 2013; Pardini et al., 2013; Poletti, Enrici, & Adenzato, 2012). This task consists of 36 photographs of the ocular region of different human faces. Participants are required to choose between four options for the best descriptor of the individual's mental state. The RMET yields a total score resulting from the sum of correct responses on the 36 items. This score reflects a single factor substantiated through confirmatory factor analysis (Vellante et al., 2012). Temporal stability over one year was adequate at r = .63 (Fernández-Abascal, Cabello, Fernández-Berrocal, & Baron-Cohen, 2013) and excellent over one month at r =.83 (Vellante et al., 2012).

Wisconsin Card Sorting Test (WCST) (Heaton, Chelune, Talley, Kay, & Curtiss, 1993). The WCST assesses planning, cognitive flexibility, set maintenance, goal directed behavior and inhibition of impulsive responding (Chelune & Baer, 1986; Gamboz, Borella, & Brandimonte, 2009). A computerized version of the WCST 64 was administrated in the present study using the Psychological Experiment Building Language (PEBL) test battery version 0.12 (Fox, Mueller, Gray, Raber, & Piper, 2013). On each trial, the participant is presented with four reference cards and a response card and must decide which reference card to match the response card with, based on the stimulus characteristics of color, shape or number. After 10 correct sorts the sorting criterion changes and the participant must discover the new sorting criterion via feedback. Error scores were manually calculated according to the WCST 64 professional manual (Kongs, Thompson, Iverson, & Heaton, 2000). The measures of interest in the present study were total errors and perseverative errors (PE) as both are sensitive to PFC dysfunction (Barcelo & Knight, 2002).

Stroop Test (Stroop, 1935). The Stroop Test is widely used to measure response inhibition (Cothran & Larsen, 2008; Moering, Schinka, Mortimer, & Graves, 2004; Van der Elst, Van Boxtel, Van Breukelen & Jolles, 2006). The procedure tests the ability to inhibit an over-learned verbal response (i.e., the automatic inclination to read printed words) in order to generate a conflicting response of naming dissonant ink colors in which the words are printed. The test consists of three conditions: color naming, word reading and interference/inhibition. The participants are instructed to rapidly read or name colors from three stimulus cards, the first with squares or patches printed in colors, the second with color words printed in black ink on a white background and the third with color words printed in contrasting colors. The cards consist of two practice rows of five columns, followed by the test consisting of 50 elements in five rows and ten columns. The component tasks in this study were considered to be color naming and word reading. The higher-level task was the Inhibition task which asks the subject to ignore the word and name the color of the ink as quickly as possible and therefore demonstrate mental flexibility by inhibiting the natural response. The Stroop interference effect was calculated as the difference in response time (in seconds) for the inhibition task versus the average of the response time for both component tasks, for example: (reading words in black ink + naming colors of color-patch cards)/2.

Procedure

After obtaining ethical clearance from the University Human Research Ethics Committee, recruitment of community participants was made possible through flyers posted on shopping center notice boards and at Endeavour College, visits to clubs (National Seniors, Lions clubs, University of the Third Age and RSL club), and word-of-mouth. Each participant was de-identified by assigning a number to their packets of questionnaires and performance tests. To minimize fatigue, questionnaire completion and testing were conducted in two sessions: one for the questionnaires and one for the performance tasks. Testing was conducted at a time and

location convenient to participants, either in the privacy of a psychology clinic or their own homes. Participants were requested to take regular breaks while completing the tasks to reduce fatigue. Time taken to complete testing in total ranged from one to two hours, with older participants generally taking more time. To maintain consistency, all testing was conducted by a single administrator. There was no incentive offered for participation.

Results

Intercorrelations of measures are shown in Table 1. The NART index of crystallized intelligence was significantly positively correlated with age, suggesting accumulation of verbal knowledge across the lifespan, and with the RMET index of social cognition. On the other hand, the K-BIT Matrices index of non-verbal fluid intelligence was significantly negatively correlated with age, and the executive cognition indices of WCST total errors, WCST perseverative errors and Stroop interference were all significantly positively correlated with age, indicating worse performance with increasing age across the sample as expected based on the evidence that these tests are sensitive to PFC function. By contrast, none of the measures of social or creative cognition were significantly correlated with age, though they were intercorrelated with each other.

	Age	RMET	Uses	ATTA	NART	Stroop	WCST	PE
RMET	-.16							
USES	-.04	.26*						
ATTA	-.15	.21*	.51**					
NART	.29**	.34**	.17	.13				
Stroop	.36**	-.20	-.16	-.31**	-.21			
WCST	.45**	-.23*	-.10	-.30**	.01	.13		
PE	.35**	-.27*	-.07	-.13	.14	.08	.78**	
K-BIT	-42**	.27*	.29**	.41**	.13	-.47**	-.45**	-.30**

**p <.01 *p <.05

Table 1: Intercorrelations among Age, Reading the Mind in the Eyes Test (RMET), verbal and non-verbal creativity tasks (Uses and ATTA), crystallized intelligence (NART), inhibition (Stroop), WCST total errors (WCST) and perseverative errors (PE), and nonverbal fluid intelligence as measured by Matrices (K-BIT).

Mediation Analysis

Given the positive correlation of RMET performance – a ToM index of social cognition – with NART scores and of the latter with increasing age, we examined the hypothesis that the apparent preservation of RMET performance across age in the sample might be attributable to increasing age-related reliance on accumulated knowledge, or crystallized intelligence, for this task. Path analysis, using the SPSS bootstrap macro (Preacher & Hayes, 2004), assessed for the indirect effect of crystallized intelligence on the relationship between age and affective ToM as indexed by RMET. This nonparametric resampling method of estimating effect size does not impose the assumption of normality of the sampling distribution. In small to moderate sized samples where the total indirect effect is rarely normal, bootstrapping is recommended (Preacher & Hayes, 2008ab). It uses a random sampling-with-replacement technique generating a number of subsamples from the original sample to provide an empirical sample distribution of indirect effects. At least 1000 bootstrap samples are selected to compute confidence intervals (derived from the indirect effect estimates and their standard

errors); the 95% confidence intervals must exclude zero if a significant indirect effect is to be supported. There was a significant effect of aging on the RMET scores through the NART, *b* = 0.03, BCa CI [0.01, 0.08]. The relationship between affective ToM and aging was explained by the influence of crystallized intelligence (see Figure 1).

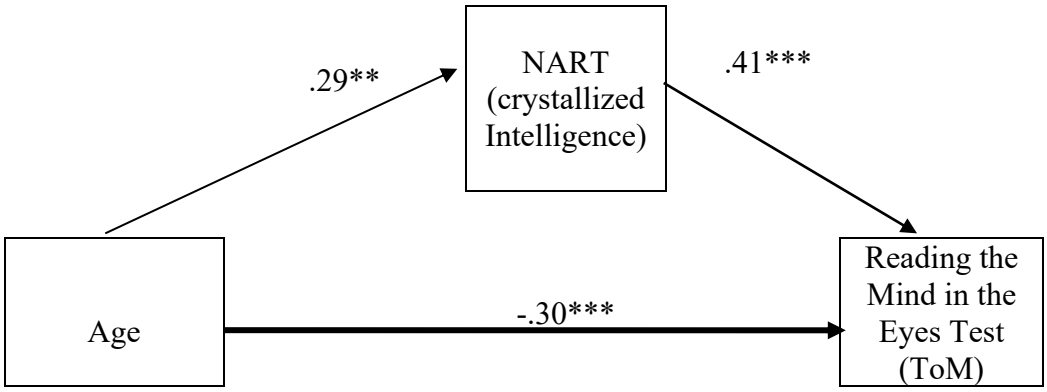

Figure 1: Age as a predictor of affective Theory of Mind (ToM), mediated by crystallized intelligence. The confidence interval for the indirect effect is bootstrapped based on 1000 samples. Standardized betas are shown for all paths.

The direct effect was negative and significant: increasing age was associated with a significant reduction in emotion recognition performance. The effect of age on NART was positive (increasing age, greater word recognition) and the effect of NART on emotion recognition was positive (improved word recognition, improved emotion recognition), resulting in a positive indirect effect. The magnitude of the direct effect (β = -.30, p = .004) was greater than the total effect (β = -.17, p =.09). This indicates suppression rather than mediation (MacKinnon, Krull, & Lockwood, 2000), such that the magnitude of age-related differences in social cognition was reduced by the influence of word recognition from the crystallized knowledge base, as predicted.

Single Dissociation Design

To explore whether creative cognition is largely independent of the apparent age-related decline in executive cognition, a single dissociation design was used. The differences in magnitude of the correlations of age with verbal and non-verbal tasks of creativity compared with the magnitude of correlations of age with executive function indices of inhibition and perseveration were tested for significance using Fisher's r to z transformation. The correlation of age with the Alternative Uses Task for verbal creativity was found to be significantly smaller than the correlation of age with Stroop inhibition (z = -2.50, p = 0.01). The correlation of age with the ATTA for non-verbal creativity was also found to be significantly smaller than the correlation of age with Stroop inhibition (z = -3.24, p = .001). The correlation of age with verbal creativity was found to be significantly smaller than the correlation of age with WCST perseveration (z = -2.63, p = .008). The correlation of age with non-verbal creativity was also found to be significantly smaller than the correlation of age with perseveration (z = -3.37, p = .0008).

Discussion

As predicted based on the frontal lobe hypothesis on aging – which claims that there is a characteristic aging-related decline in executive cognitive function and fluid intelligence due to deterioration of the PFC (Cardenas et al., 2011; Schretlen et al., 2000) – Stroop interference and WCST error scores increased with age in the present sample, and the K-BIT Matrices index of non-verbal fluid intelligence decreased with age. The increase in the Stroop interference effect with age is consistent with an aging-related decline in selective attention, response inhibition and/or processing speed (Davidson, Zacks, & Williams, 2003), whereas the aging-related increase in WCST errors signifies impaired cognitive flexibility and shifting (Miyake et al., 2000). The apparent age-related differences on K-BIT Matrices are consistent with declines in other PFC-related functions such as abstraction and working memory with aging.

The RMET index of ToM, an important aspect of social cognition, was not significantly correlated with age. The path analysis, however, indicated that the association between age and the ability to attribute complex mental states to pictures of eyes was mediated by crystallized intelligence. Age-related differences in performance of this social cognition task appeared to be suppressed by the influence of the crystallized knowledge base, suggesting an aging-related change in strategies used to perform this task. By utilizing the automatic component of social cognition, stability in performance may be maintained despite the decline in executive control processes. Automatic stimulus-induced activation of schemas constructed in stored knowledge – corresponding to crystallized intelligence – appears to remain resistant to decline in normal aging (Horn & Cattell, 1967; Salthouse, 2000; Sullivan & Ruffman, 2004). Furthermore, there was evidence of an apparent increase in crystallized intelligence (as indexed by NART) with increasing age across the sample. The ability to access an increasing store of knowledge derived from lifelong experience may provide a compensatory mechanism underlying the maintenance of stability in performance on those social cognition tasks that require automatic processing to a substantial degree.

Creative cognition tasks did not show variation in performance as a function of age in the present sample. The single dissociation was consistent with the hypothesis that processes involved in creative cognition are largely independent of age-related decline in executive cognition. Although dissociation designs are generally used to infer the existence of separate mental processes, in this research the use of single dissociation does not conclusively indicate that. The single dissociation was however consistent with the hypothesis that creative cognition is selectively preserved in aging and suggests a reduced reliance on controlled processing and an increased reliance on implicit memory and automatic processing with advanced age. The finding that the performance of creative cognition tasks was stable across age may reflect the use by older adults of different strategies and compensatory mechanisms to complete these tasks. An increase in task-related prefrontal activation with advancing age, as well as other compensatory changes, may contribute to the relative stability of creative cognition in older people (Spreng et al., 2010).

Limitations

Limitations of the current study include the non-random sampling where participants were predominantly affiliated with community groups, which restricts generalizability of the findings to the general population; the operationalization of crystallized intelligence with the NART, a word recognition test that only taps one domain of crystallized intelligence; and

most importantly the cross-sectional design, where testing was conducted at a single point in time such that differences associated with aging may have been confounded by cohort effects (inter-generational differences that are not due to aging). The present findings thus can only be interpreted to show age-related differences in task performance rather than age-related decline.

Conclusions and Future Research

Despite the limitations, this study does provide further evidence consistent with aging-related changes in executive cognition and in some aspects of social cognition. In addition, the present research provides evidence consistent with a possible shift in processing strategies to preserve some aspects of cognitive function and compensate for age-related decline. As social cognition and creative cognition rely on both controlled and automatic processing, such compensatory strategies may involve a relative increase in use of automatic processing from stored knowledge and implicit memory. The role of automatic processing in maintaining cognitive performance into old age might be investigated in future research by assessing the contribution of gist reasoning. Furthermore, future research on social or creative cognition should probably utilize a more comprehensive operationalization of crystallized intelligence than that provided by the NART. Finally, although difficult to accomplish, only a longitudinal approach can conclusively demonstrate age-related stability or decline in cognitive functioning across various domains, as such research avoids the vexing issue of potential cohort effects.

References

Adolphs, R. (2009). The social brain: Neural basis of social knowledge. *Annual Review of Psychology, 60*(1), 693–716. https://doi.org/10.1146/annurev.psych.60.110707.163514

Allen, P. A., Mei-Ching, L., Murphy, M. D., Sanders, R. E., Judge, K. S., & McCann, R. S. (2002). Age differences in overlapping-task performance: Evidence for efficient parallel processing in older adults. *Psychology and Aging, 17*(3), 505–519. https://doi.org/10.1037/0882-7974.17.3.505

Antony, M. M., Bieling, P. J., Cox, B. J., Enns, M. W., & Swinson, R. P. (1998). Psychometric properties of the 42-item and 21-item versions of the Depression Anxiety Stress Scales in clinical groups and a community sample. *Psychological Assessment, 10*, 176–181. https://doi.org/10.1037//1040-3590.10.2.176

Baena, E., Allen, P. A., Kaut, K. P., & Hall, R. J. (2010). On age differences in prefrontal function: The importance of emotional/cognitive integration. *Neuropsychologia, 48*(1), 319–333. https://doi.org/10.1016/j.neuropsychologia.2009.09.021

Baron-Cohen, S., O'Riordan, M., Stone, V., Jones, R., & Plaisted, K. (1999). Recognition of faux pas by normally developing children and children with asperger syndrome or high-functioning autism. *Journal of Autism and Developmental Disorders, 29*(5), 407–418. https://doi.org/10.1023/A:1023035012436

Baron-Cohen, S., Wheelwright, S., Hill, J., Raste, Y., & Plumb, I. (2001). The "reading the mind in the eyes" test revised version: A study with normal adults, and adults with asperger syndrome or high-functioning autism. *Journal of Child Psychology and Psychiatry, 42*(2), 241–251. https://doi.org/10.1111/1469-7610.00715

Bechtereva, N. P., Korotkov, A. D., Pakhomov, S. V., Roudas, M. S., Starchenko, M. G., & Medvedev, S. V. (2004). PET study of brain maintenance of verbal creative activity. *International Journal of Psychophysiology, 53*(1), 11–20. https://doi.org/10.1016/j.ijpsycho.2004.01.001

Bottiroli, S., Cavallini, E., Ceccato, I., Vecchi, T., & Lecce, S. (2016). Theory of Mind in aging: Comparing cognitive and affective components in the faux pas test. *Archives of Gerontology and Geriatrics, 62*, 152–162. https://doi.org/10.1016/j.archger.2015.09.009

Cabeza, R., & Dennis, N.A. (2013). Frontal lobes and aging: Deterioration and compensation. In D.T. Stuss & R.T. Knight (Eds.), *Principles of frontal lobe function*. Oxford, UK: Oxford University Press. https://doi.org/10.1093/med/9780199837755.003.0044

Cardenas, V. A., Chao, L. L., Studholme, C., Yaffe, K., Miller, B. L., Madison, C., . . . Weiner, M. W. (2011). Brain atrophy associated with baseline and longitudinal measures of cognition. *Neurobiology of aging, 32*(4), 572–580. https://doi.org/10.1016/j.neurobiolaging.2009.04.011

Charlton, R. A., Barrick, T. R., Markus, H. S., & Morris, R. G. (2009). Theory of mind associations with other cognitive functions and brain imaging in normal aging. *Psychology and Aging, 24*(2), 338–348. https://doi.org/10.1037/a0015225

Chelune, G. J., & Baer, R. A. (1986). Developmental norms for the wisconsin card sorting test. *Journal of Clinical and Experimental Neuropsychology, 8*(3), 219–228. https://doi.org/10.1080/01688638608401314

Cheung, P. C., Lau, S., Chan, D. W., & Wu, W. Y. H. (2004). Creative potential of school children in Hong Kong: norms of the Wallach-Kogan creativity tests and their implications. *Creativity Research Journal, 16*(1), 69–78. https://doi.org/10.1207/s15326934crj1601_7

Churchill, J. D., Stanis, J. J., Press, C., Kushelev, M., & Greenough, W. T. (2003). Is procedural memory relatively spared from age effects? *Neurobiology of aging, 24*(6), 883–892. https://doi.org/10.1016/s0197-4580(02)00194-x

Clara, I. P., Cox, B. J., & Enns, M. W. (2001). Confirmatory Factor Analysis of the Depression–Anxiety–Stress Scales in Depressed and Anxious Patients. *Journal of Psychopathology and Behavioral Assessment, 23*(1), 61–67. https://doi.org/10.1023/A:1011095624717

Cothran, D. L., & Larsen, R. (2008). Comparison of inhibition in two timed reaction tasks: The color and emotion stroop tasks. *The Journal of Psychology, 142*(4), 373–385. https://doi.org/10.3200/JRLP.142.4.373-385

Damasio, A. R. (2001). Some notes on brain, imagination and creativity. In K. H. Pfenninger & V. R. Shubik (Eds.), *The origins of creativity* (pp. 59–68). Oxford: Oxford University Press.

Davidson, D. J., Zacks, R. T., & Williams, C. C. (2003). Stroop interference, practice, and aging. *Aging, Neuropsychology, and Cognition, 10*(2), 85–98. https://doi.org/10.1076/anec.10.2.85.14463

Daza, P., Novy, D., Stanley, M., & Averill, P. (2002). The depression anxiety stress scale-21: Spanish translation and validation with a Hispanic sample. *Journal of Psychopathology and Behavioral Assessment, 24*(3), 195–205. https://doi.org/10.1023/A:1016014818163

Dorfman, L., Martindale, C., Gassimova, V., & Vartanian, O. (2008). Creativity and speed of information processing: A double dissociation involving elementary versus inhibitory cognitive tasks. *Personality and Individual Differences, 44*(6), 1382–1390. https://doi.org/10.1016/j.paid.2007.12.006

Fernández-Abascal, E. G., Cabello, R., Fernández-Berrocal, P., & Baron-Cohen, S. (2013). Test-retest reliability of the "Reading the Mind in the Eyes" test: A one-year follow-up study. *Molecular Autism, 4*(1), 1–6. https://doi.org/10.1186/2040-2392-4-33

Fisk, J. E., & Sharp, C. A. (2004). Age-related impairment in Executive Functioning: Updating, inhibition, shifting, and access. *Journal of Clinical & Experimental Neuropsychology, 26*(7), 874–890. https://doi.org/10.1080/13803390490510680

Folstein, M. F., Folstein, S. E., White, T., & Messer, M. A. (2010). *MMSE-2: Mini-mental state examination* (2nd ed.). Lutz, FL: Psychological Assessment Resources, Inc.

Fox, C. J., Mueller, S. T., Gray, H. M., Raber, J., & Piper, B. J. (2013). Evaluation of a short-form of the berg card sorting test. *Plos ONE, 8*(5), 1–4. https://doi.org/10.1371/journal.pone.0063885

Gamboz, N., Borella, E., & Brandimonte, M. A. (2009). The role of switching, inhibition and working memory in older adults' performance in the Wisconsin Card Sorting Test. *Aging, Neuropsychology, and Cognition, 16*(3), 260–284. https://doi.org/10.1080/13825580802573045

Goff, K., & Torrance, E. P. (2002). *Abbreviated Torrance test for adults manual*. Illinois: Scholastic Testing Service, Inc.

Gunning-Dixon, F. M., & Raz, N. (2003). Neuroanatomical correlates of selected executive functions in middle-aged and older adults: A prospective MRI study. *Neuropsychologia, 41*(14), 1929–1941. https://doi.org/10.1016/s0028-3932(03)00129-5

Happé, F. G. E., Winner, E., & Brownell, H. (1998). The getting of wisdom: Theory of mind in old age. *Developmental Psychology, 34*(2), 358–362. https://doi.org/0.1037/0012-1649.34.2.358

Heaton, R. K., Chelune, G. J., Talley, J. L., Kay, G., & Curtiss, G. (1993). *Wisconsin Card Sorting Test manual: revised and expanded*. Odessa, FL: Psychological Assessment Resources.

Hedden, T., & Gabrieli, J. D. E. (2004). Insights into the ageing mind: A view from cognitive neuroscience. *Nature Reviews Neuroscience, 5*(2), 87–96. https://doi.org/10.1038/nrn1323

Hedden, T., Lautenschlager, G., & Park, D. (2005). Contributions of processing ability and knowledge to verbal memory tasks across the adult life-span. *Quarterly Journal of Experimental Psychology: Section A, 58*(1), 169–190. https://doi.org/10.1080/02724980443000179

Hélie, S., & Sun, R. (2010). Incubation, insight, and creative problem solving: A unified theory and a connectionist model. *Psychological Review, 117*(3), 994–1024. https://doi.org/10.1037/a0019532

Henry, J. D., & Crawford, J. R. (2005). The short-form version of the Depression Anxiety Stress Scales (DASS-21): Construct validity and normative data in a large non-clinical sample. *British Journal of Clinical Psychology, 44*(2), 227–239. https://doi.org/10.1348/014466505X29657

Horn, J. L., & Cattell, R. B. (1967). Age differences in fluid and crystallized intelligence. *Acta Psychologica, 26*(0), 107–129. https://doi.org/10.1016/0001-6918(67)90011-x

Kemp, J., Després, O., Sellal, F., & Dufour, A. (2012). Theory of Mind in normal ageing and neurodegenerative pathologies. *Ageing Research Reviews, 11*(2), 199–219. https://doi.org/10.1016/j.arr.2011.12.001

Kiely, K. M., Luszcz, M. A., Piguet, O., Christensen, H., Bennett, H., & Anstey, K. J. (2010). Functional equivalence of the National Adult Reading Test (NART) and Schonell reading tests and NART norms in the Dynamic Analyses to Optimise Ageing (DYNOPTA) project. *Journal of Clinical and Experimental Neuropsychology, 33*(4), 410–421. https://doi.org/10.1080/13803395.2010.527321

Kievit, R.A., Davis, S.W., Mitchell, D.J., Taylor, J.R., Duncan, J., Cam-CAN Research team & Henson, R.N.A. (2014). Distinct aspects of frontal lobe structure mediate age-related differences in fluid intelligence and multitasking. *Nature Communications, 5 (5658)*. https://doi.org/10.1038/ncomms6658

Kim, K. H., Cramond, B., & Bandalos, D. L. (2006). The latent structure and measurement invariance of scores on the Torrance tests of creative thinking–figural. *Educational and Psychological Measurement, 66*(3), 459–477. https://doi.org/10.1177/0013164405282456

Kongs, S. K., Thompson, L. L., Iverson, G. L., & Heaton, R. K. (2000). *Wisconsin Card Sorting Test – 64 Card Version – Professional Manual*. Lutz, FL: PAR.

Lien, M.-C., Allen, P. A., Ruthruff, E., Grabbe, J., McCann, R. S., & Remington, R. W. (2006). Visual word recognition without central attention: Evidence for greater automaticity with advancing age. *Psychology and Aging, 21*(3), 431–447. https://doi.org/10.1037/0882-7974.21.3.431

Lighthall, N.R., Huettel, S.A., & Cabeza, R. (2014). Functional compensation in the ventromedial prefrontal cortex improves memory-dependent decisions in older adults. *Journal of Neuroscience, 34*(47), 15648–15657. https://10.1523/JNEUROSCI.2888-14.2014

Limb, C. J., & Braun, A. R. (2008). Neural substrates of spontaneous musical performance: An fMRI study of jazz improvisation. *Plos ONE, 3*(2), 2–9. https://10.1371/journal.pone.0001679

Lovibond, P. F., & Lovibond, S. H. (1995). The structure of negative emotional states: comparison of the Depression Anxiety Stress Scales (DASS) with the Beck Depression and Anxiety Inventories. *Behavior Research and Therapy, 33*, 335–343. https://doi.org/10.1016/0005-7967(94)00075-u

MacKinnon, D. P., Krull, J. L., & Lockwood, C. M. (2000). Equivalence of the mediation, confounding and suppression effect. *Prevention Science, 1*(4), 173–181. https://10.1023/a:1026595011371

MacPherson, S. E., Phillips, L. H., & Sala, S. D. (2002). Age, executive function, and social decision making: A dorsolateral prefrontal theory of cognitive aging. *Psychology and Aging, 17*(4), 598–609. https://510.1037/0882-7974.1017.1034.1598

Maylor, E. A., Moulson, J. M., Muncer, A.-M., & Taylor, L. A. (2002). Does performance on theory of mind tasks decline in old age? *British Journal of Psychology, 93*(4), 465. https://10.1348/000712602761381358

McKinnon, M. C., & Moscovitch, M. (2007). Domain-general contributions to social reasoning: Theory of mind and deontic reasoning re-explored. *Cognition, 102*(2), 179–218. https://10.1016/j.cognition.2005.12.011

Mitchell, D. B., & Bruss, P. J. (2003). Age differences in implicit memory: Conceptual, perceptual, or methodological? *Psychology and Aging, 18*(4), 807–822. https://10.1037/0882-7974.18.4.807

Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, A. H., Howerter, A., & Wager, T. D. (2000). The unity and diversity of executive functions and their contributions to complex "Frontal Lobe" tasks: A latent variable analysis. *Cognitive Psychology, 41*(1), 49–100. https://110.1006/cogp.1999.0734.

Moering, R. G., Schinka, J. A., Mortimer, J. A., & Graves, A. B. (2004). Normative data for elderly african americans for the stroop color and word test. *Archives of Clinical Neuropsychology, 19*(1), 61–71. https://10.1016/S0887-6177(02)00219-6

Moors, A., & De Houwer, J. (2006). Automaticity: A theoretical and conceptual analysis. *Psychological Bulletin, 132*(2), 297–326. https://10.1037/0033-2909.132.2.297

Moran, J. M. (2013). Lifespan development: The effects of typical aging on theory of mind. *Behavioural Brain Research, 237*(0), 32–40. https://10.1016/j.bbr.2012.09.020

Nelson, H. E. (1982). *National adult reading test (NART): For the assessment of premorbid intelligence in patients with dementia: Test Manual*. Windsor, UK: NFER-Nelson.

Pal, H. R., Jena, R., & Yadav, D. (2004). Validation of the Alcohol Use Disorders Identification Test (AUDIT) in urban community outreach and de-addiction center samples in North India. *Journal of Studies on Alcohol, 65*, 794–797. https://doi.org/10.15288/jsa.2004.65.794

Pardini, M., Emberti Gialloreti, L., Mascolo, M., Benassi, F., Abate, L., Guida, S., . . . Cocito, L. (2013). Isolated theory of mind deficits and risk for frontotemporal dementia: A longitudinal pilot study. *Journal of Neurology, Neurosurgery & Psychiatry, 84*(7), 818–821. https://doi.org/10.1136/jnnp-2012-303684

Plucker, J. A., & Renzulli, J. S. (Eds.). (1999). *Psychometric approaches to the study of human creativity*. New York: Cambridge University Press.

Poletti, M., Enrici, I., & Adenzato, M. (2012). Cognitive and affective theory of mind in neurodegenerative diseases: Neuropsychological, neuroanatomical and neurochemical levels. *Neuroscience & Biobehavioral Reviews, 36*(9), 2147–2164. https://doi.org/10.1016/j.neubiorev.2012.07.004

Preacher, K. J., & Hayes, A. F. (2004). SPSS and SAS procedures for estimating indirect effects in simple mediation models. *Behavior Research Methods, Instruments, & Computers, 36*(4), 717–731. https://doi.org/10.3758/bf03206553

Preacher, K. J., & Hayes, A. F. (2008a). Asymptotic and resampling strategies for assessing and comparing indirect effects in multiple mediator models. *Behavior Research Methods, 40*(3), 879–891. https://doi.org/10.3758/brm.40.3.879

Preacher, K. J., & Hayes, A. F. (Eds.). (2008b). *Contemporary approaches to assessing mediation in communication research*. Thousand Oaks, CA: Sage Publications, Inc.

Raz, N., Gunning-Dixon, F. M., Head, D., Dupuis, J. H., & Acker, J. D. (1998). Neuroanatomical correlates of cognitive aging: Evidence from structural magnetic resonance imaging. *Neuropsychology, 12*(1), 95–114. https://doi.org/10.1037/0894-4105.12.1.95

Richards, R. (2010). Everyday creativity: Process and way of life – four key issues. In J. C. Kaufman & R. J. Sternberg (Eds.), *The Cambridge handbook of creativity* (pp. 189–215). New York: Cambridge University Press. https://doi.org/10.1017/cbo9780511763205.013

Salthouse, T. A. (2000). Steps towards the explanation of adult age differences in cognition. In T. J. Perfect & E. A. Maylor (Eds.), *Models of Cognitive Aging* (pp. 19–49). Oxford: Oxford University Press.

Satpute, A. B., & Lieberman, M. D. (2006). Integrating automatic and controlled processes into neurocognitive models of social cognition. *Brain Research, 1079*(1), 86–97. https://doi.org/10.1016/j.brainres.2006.01.005

Saunders, J. B., Aasland, O. G., Babor, T. F., de la Fuente, J. R., & Grant, M. (1993). Development of the Alcohol Use Disorders Screening Test (AUDIT). WHO collaborative project on early detection of persons with harmful alcohol consumption. *Addiction, 88*, 791–804. https://doi.org/10.1111/j.1360-0443.1993.tb02093.x

Schretlen, D., Pearlson, G. D., Anthony, J. C., Aylward, E. H., Augustine, A. M., Davi, s. A., & Barta, P. (2000). Elucidating the contributions of processing speed, executive

ability, and frontal lobe volume to normal age-related differences in fluid intelligence. *Journal of International Neuropsychological Society, 6*(1), 52–61. https://doi.org/10.1017/S1355617700611062

Schultz-Larsen, K., Lomholt, R. K., & Kreiner, S. (2007). Mini-Mental Status Examination: A short form of MMSE was as accurate as the original MMSE in predicting dementia. *Journal of Clinical Epidemiology, 60*(3), 260–267. https://doi.org/10.1016/j.jclinepi.2006.06.008

Schultz-Larsen, K., Rahmanfard, N., Kreiner, S., Avlund, K., & Holst, C. (2008). Cognitive impairment as assessed by a short form of MMSE was predictive of mortality. *Journal of Clinical Epidemiology, 61*(12), 1227–1233. https://10.1016/j.jclinepi.2007.12.007

Sinclair, S. J., Siefert, C. J., Slavin-Mulford, J. M., Stein, M. B., Renna, M., & Blais, M. A. (2012). Psychometric Evaluation and Normative Data for the Depression, Anxiety, and Stress Scales-21 (DASS-21) in a Nonclinical Sample of U.S. Adults. *Evaluation & the Health Professions, 35*(3), 259–279. https://10.1177/0163278711424282

Spaniol, J., Madden, D. J., & Voss, A. (2009). A diffusion model analysis of adult age differences in episodic and semantic long-term memory retrieval. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 32*(1), 101–117. https://10.1037/0278-7393.32.1.101

Spreng, R. N., Wojtowicz, M., & Grady, C. L. (2010). Reliable differences in brain activity between young and old adults: A quantitative meta-analysis across multiple cognitive domains. *Neuroscience & Biobehavioral Reviews, 34(8),* 1178–1194. https://10.1016/j.neubiorev.2010.01.009

St-Laurent, M., Abdi, H., Burianová, H., & Grady, C. L. (2011). Influence of aging on the neural correlates of autobiographical, episodic, and semantic memory retrieval. *Journal of Cognitive Neuroscience, 23*(12), 4150–4163. https://10.1162/jocn_a_00079

Sternberg, R. J., & Lubart, T. I. (1999). The concept of creativity: Prospects and paradigms. In R. J. Sternberg (Ed.), *Handbook of creativity* (pp. 3–15). Cambridge: Cambridge University Press. https://doi.org/10.1017/cbo9780511807916.003

Stroop, J. R. (1935). Studies of interference in serial verbal reactions. *Journal of Experimental Psychology, 18*(6), 643–662. https://doi.org/10.1037/h0054651

Sullivan, S., & Ruffman, T. (2004). Social understanding: How does it fare with advancing years? *British Journal of Psychology, 95*(1), 1–18. https://doi.org/10.1348/000712604322779424

Tisserand, D. J., & Jolles, J. (2003). On the involvement of prefrontal networks in cognitive ageing. *Cortex, 39*(4-5), 1107–1128. https://doi.org/10.1016/S0010-9452(08)70880-3

Treitz, F. H., Heyder, K., & Daum, I. (2007). Differential course of executive control changes during normal aging. *Aging, Neuropsychology and Cognition, 14*(4), 370–393. https://doi.org/10.1080/13825580600678442

Uttl, B. (2002). North American Adult Reading Test: Age norms, reliability, and validity. *Journal of Clinical and Experimental Neuropsychology, 24*(8), 1123–1137. https://doi.org/10.1076/jcen.24.8.1123.8375

Valenzuela, M. J., Sachdev, P. S., Wen, W., Shnier, R., Brodaty, H., & Gillies, D. (2000). Dual voxel proton magnetic resonance spectroscopy in the healthy elderly:

Subcortical-frontal axonal n-acetylaspartate levels are correlated with fluid cognitive abilities independent of structural brain changes. *NeuroImage, 12*(6), 747–756. https://doi.org/10.1006/nimg.2000.0629

Van der Elst, W., Van Boxtel, M. P. J., Van Breukelen, G. J. P., & Jolles, J. (2006). The stroop color-word test: Influence of age, sex, and education; and normative data for a large sample across the adult age range. *Assessment, 13*(1), 62–79. https://doi.org/10.1177/1073191105283427

Vartanian, O., Martindale, C., & Kwiatkowski, J. (2007). Creative potential, attention, and speed of information processing. *Personality and Individual Differences, 43*(6), 1470–1480. https://doi.org/10.1016/j.paid.2007.04.027

Vellante, M., Baron-Cohen, S., Melis, M., Marrone, M., Petretto, D. R., Masala, C., & Preti, A. (2012). The "Reading the Mind in the Eyes" test: Systematic review of psychometric properties and a validation study in Italy. *Cognitive Neuropsychiatry, 18*(4), 326–354. https://doi.org/10.1080/13546805.2012.721728

Wallach, M. A., & Kogan, N. (1965). *Modes of thinking in young children: A study of the creativity-intelligence distinction*. Oxford, England: Holt, Rinehart & Winston.

Ward, T. B., Smith, S. M., & Finke, R. A. (1999). Creative cognition. In R. J. Sternberg (Ed.), *Handbook of creativity*. Cambridge: Cambridge University Press.

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