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Wisdom and fluid intelligence are dissociable in healthy older adults

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ABSTRACT

Objectives: The relationship between wisdom and fluid intelligence (Gf) is poorly understood, particularly in older adults. We empirically tested the magnitude of the correlation between wisdom and Gf to help determine the extent of overlap between these two constructs.

Design: Cross-sectional study with preregistered hypotheses and well-powered analytic plan (<https://osf.io/h3pjax>).

Setting: Memory and Aging Center at the University of California San Francisco, located in the USA.

Participants: 141 healthy older adults (mean age = 76 years; 56% female).

Measurements: Wisdom was quantified using a well-validated self-report-based scale (San Diego Wisdom Scale or SD-WISE). Gf was assessed via composite measures of processing speed (Gf-PS) and executive functioning (Gf-EF). The relationships of SD-WISE scores to Gf-PS and Gf-EF were tested in bivariate correlational analyses and multiple regression models adjusted for demographics (age, sex, and education). Exploratory analyses evaluated the relationships between SD-WISE and age, episodic memory performance, and dorso-lateral and ventromedial prefrontal cortical volumes on magnetic resonance imaging.

Results: Wisdom showed a small, positive association with Gf-EF ($r = 0.181$ [95% CI 0.016, 0.336], $p = .031$), which was reduced to nonsignificance upon controlling for demographics, and no association with Gf-PS ($r = 0.019$ [95% CI -0.179 , 0.216], $p = .854$). Wisdom demonstrated a small, negative correlation with age ($r = -0.197$ [95% CI -0.351 , -0.033], $p = .019$), but was not significantly related to episodic memory or prefrontal volumes.

Conclusions: Our findings indicate that most of the variance in wisdom (>95%) is unaccounted for by Gf. The independence of wisdom from cognitive functions that reliably show age-associated declines suggests that it may hold unique potential to bolster decision-making, interpersonal functioning, and other everyday activities in older adults.

Key words: aging, cognition, executive functioning, neuroimaging, processing speed

Introduction

Wisdom is a complex, multidimensional personality trait, involving cognitive, social, and emotional processes, which has been referenced in ancient texts for

thousands of years (Jeste and Lee, 2019; Jeste and Vahia, 2008). However, it was not until the 1970s that the construct of wisdom began to be systematically studied within the context of empirical research (Thomas *et al.*, 2019). Since then, wisdom has been shown to be associated with a range of positive health outcomes, including physical health, mental health, happiness, life satisfaction, social connectedness, and psychological resilience (Ardelt and Ferrari, 2019; Auer-Spath and Gluck, 2019; Jeste

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et al., 2020; Lee *et al.*, 2019; Webster *et al.*, 2014). It is among a relatively small number of characteristics that is popularly thought to increase (as opposed to decline) in older ages and may help explain why, from an evolutionary perspective, it is advantageous for members of certain species to live well beyond the age of reproductive capability (Jeste and Lee, 2019).

There is considerable and long-standing debate regarding the nature of the relationship between wisdom and the potentially overlapping construct of fluid intelligence (Gf) (Cattell, 1943). Gf, or “intelligence-as-process,” involves the ability to efficiently generate, transform, manipulate, and reason with novel information to accomplish goals and solve problems (McGrew, 2009). It is often measured by cognitive tests of information processing speed (Gf-PS) and executive functioning (Gf-EF) (Diamond, 2013; Kievit *et al.*, 2016; Sheppard and Vernon, 2008; Van Aken *et al.*, 2015). Clarifying the empirical delineation of wisdom and Gf as constructs is not only important from a theoretical perspective but carries important practical implications as well. In particular, Gf has been found to reliably decline in later life (Salthouse, 2004) and is the single greatest cognitive predictor of functional ability among older adults (Cahn-Weiner *et al.*, 2007). To the extent that wisdom is dissociable from Gf, wisdom may hold potential to compensate for age-related cognitive declines by bolstering decision-making, interpersonal skills, and other aspects of everyday functioning.

According to the “complementary” theory, wisdom and Gf may share some commonalities, but the degree of overlap is small, and the two constructs are by and large distinct (Jeste *et al.*, 2010). At most, Gf may help facilitate wisdom, but possessing intelligence is considered necessary but insufficient for being wise (Jeste *et al.*, 2020). Proponents of the complementary view point to the multidimensional nature of wisdom, which involves social and emotional processes (e.g. empathy, compassion, affect regulation, self-reflection, social advising) in addition to cognitive skills, and thus argue that wisdom is much broader than Gf (Jeste and Lee, 2019; Thomas *et al.*, 2019). Multidimensional measures of wisdom, such as the Three-Dimensional Wisdom Scale (3D-WS), have increasingly emerged over the last two decades to assess affective and reflective components of wisdom in addition to cognitive aspects (Ardelt, 2003). Importantly, such scales have demonstrated strong psychometric properties (validity and reliability), lending credence to a multidimensional approach to the wisdom construct (Ardelt, 2003).

The complementary view is further supported by findings that core aspects of Gf, such as Gf-EF and Gf-PS, consistently decline in later life (Diamond,

2013), whereas empirical studies of the relationship between age and wisdom have yielded inconsistent results. Although some studies have found negative age-wisdom correlations (Mickler and Staudinger, 2008; Thomas *et al.*, 2019), others have found positive correlations (Grossmann *et al.*, 2010; Happé *et al.*, 1998; Worthy *et al.*, 2011), no correlation (Smith and Baltes, 1990; Webster, 2007), or curvilinear effects (Ardelt *et al.*, 2018; Thomas *et al.*, 2017; Webster *et al.*, 2014). The observation that Gf and wisdom may show distinct trajectories in aging argues against their conceptualization as a unified construct.

In contrast to the complementary theory, the “interrelated” view posits that Gf is a central component of wisdom, with some theorists defining wisdom as the application of intelligence to achieve goals and uphold values (Sternberg, 2005). This stems in part from early empirical investigations of wisdom by Baltes and colleagues, who argued that wisdom is characterized by exceptionally high levels of intelligence and therefore, is possessed by very few people (Baltes and Smith, 1990). Proponents of the “interrelated” view emphasize the commonalities, rather than the differences, between wisdom and Gf: both entail reasoning, decision-making processes, insight, and self-regulation skills. Indeed, traits used to describe people who are “wise” tend to be highly correlated with traits used to describe people who are “intelligent” (Sternberg, 1985). There is also overlap in the putative neuroanatomy of Gf and wisdom, with both thought to rely heavily on prefrontal brain networks (Jung and Haier, 2007; Meeks and Jeste, 2009). Empirical support for the “interrelated” view is further derived from developmental studies suggesting that wisdom-like behavior and Gf may increase in tandem during adolescence, presumably paralleling the maturation of self-reflection and other executive skills (Luna *et al.*, 2010).

A paucity of research has empirically tested the relationship between wisdom and cognitive functioning, let alone cognitive skills specific to Gf, in older adults. Jeste and colleagues (2019) demonstrated that wisdom was positively associated with a global measure of cognitive and functional status in a sample of senior housing community residents. In addition, among middle-aged patients with schizophrenia, wisdom was positively related to cognitive performance, particularly on measures of Gf-PS (Van Patten *et al.*, 2019). However, a more detailed understanding of the association between wisdom and specific aspects of cognitive function, especially as related to Gf, is lacking in older adults. One potential confounder is of particular importance in this population. Alzheimer’s disease and other neurodegenerative conditions may have a long preclinical stage that often includes unrecognized

cognitive decline (Sperling *et al.*, 2011). Preclinical or otherwise undiagnosed neurodegenerative disease is known to diminish Gf and can be predicted to reduce wisdom, so failure to control for this potential confounder could induce spurious correlations between Gf and wisdom.

The preregistered primary aim of the proposed study was to further our understanding of the relationship between wisdom and Gf in a stringently characterized cohort of healthy older adults. Specifically, we aimed to empirically test the magnitude of the association between wisdom and Gf using an analytic plan with sufficient statistical power to detect at least a moderately sized correlation between these two constructs.

Secondary aims were to evaluate the relationships of wisdom with age, episodic memory performance (given the centrality of this cognitive function to aging and age-related neurodegenerative diseases), and brain structural volumes with a focus on prefrontal cortical regions (dorsolateral and ventromedial) that have been posited to subservise wisdom in the literature (Meeks and Jeste, 2009). Due to inconsistencies in prior findings and a generally limited research base, our secondary aims are exploratory and without specific *a priori* hypotheses.

Methods

The hypotheses and analytic plan for this study were preregistered using the Open Science Framework (<https://osf.io/h3pjax>). De-identified data (doi:10.17605/OSF.IO/EFJNR) for our primary analyses are publicly available within the Open Science Network repository (<https://mfr.osf.io/render?url=https://osf.io/dg8mk/?direct%26mode=render%26action=download%26mode=render>). The sample was drawn from a larger cohort of community-dwelling older adults enrolled in the Hillblom Aging Network (>400 active participants) – a longitudinal study of healthy brain aging at the University of California San Francisco (UCSF) Memory and Aging Center. Recruitment for the Hillblom Aging Network began in 2000 and has primarily involved flyers, newspaper advertisements, and community outreach events in the Bay Area. Participants in this cohort are verified as neurologically normal based on a multidisciplinary assessment including a neurological examination, in-person neuropsychological testing, and an informant interview. As part of the Hillblom Aging Network, participants complete online web-based tasks in addition to in-person neuropsychological testing and neuroimaging.

Inclusionary criteria for the current study were clinically normal per an informant-obtained Clinical Dementia Rating (CDR global score = 0) and

willingness to complete an online version of the San Diego Wisdom Scale (SD-WISE) that was distributed via email (described below). Because the online web-based tasks are sent to the Hillblom Aging Network asynchronously with the in-person measures, participants were required to have CDR, cognitive, and neuroimaging data within 2 years of completion of the SD-WISE in order to be included within our analyses.

The Hillblom Aging Network protocol was reviewed and approved by the UCSF Committee on Human Research. This study was conducted in full compliance with the ethical principles set forth by the Declaration of Helsinki. All participants provided written informed consent.

SD-WISE

Participants were emailed a link inviting them to participate in an online version of the SD-WISE that was programmed in Qualtrics. The SD-WISE is a 24-item self-report-based scale covering the domains of social advising, emotional regulation, pro-social behaviors, self-reflection, acceptance of divergent perspectives, and decisiveness (Thomas *et al.*, 2019). Examples of individual items include the following: (1) “It is important that I understand the reasons for my actions”; (2) “I often don’t know what to tell people when they come to me for advice”; and (3) “I enjoy being exposed to diverse viewpoints”. Response options for each item are: “strongly disagree,” “disagree,” “neutral,” “agree,” or “strongly agree.” The total score reflects an average of the responses to individual items, taking into account reverse-coded items, with higher scores corresponding to higher levels of wisdom (score range = 1–5). The SD-WISE is firmly grounded in empirical data and theory, with item content carefully selected according to relevant ancient texts and modern scientific literature (Bangen *et al.*, 2013; Jeste and Vahia, 2008) as well as expert consensus using the Delphi Method (Jeste *et al.*, 2010). The SD-WISE has good-to-excellent psychometric properties, including convergent and discriminant validity, and its overall structure has been confirmed using factor analyses (Thomas *et al.*, 2019). With respect to reliability, omega (ω), omega hierarchical (ω_H), and internal consistency coefficient alpha (α) have been shown to be 0.93, 0.80, and 0.71, respectively, which compares favorably to other widely used wisdom scales in the literature (Thomas *et al.*, 2019).

Cognitive composite measures

Gf was quantified using sample-based composite measures of executive functioning (Gf-EF) and processing speed (Gf-PS), as described in detail in

prior publications (e.g. Lindbergh *et al.*, 2019; Stafaroni *et al.*, 2018). We elected to use composite scores to capture Gf given superior psychometric properties, including reliability, as compared with individual test scores, particularly in aging populations (e.g. Jonaitis *et al.*, 2019). Briefly, the Gf-EF composite comprises Stroop interference, modified trail making test, digit span backward, phonemic fluency, and design fluency (Delis *et al.*, 2001). The Gf-PS composite is derived from six computerized, visually mediated, speeded tasks, including Length Judgment, Visual Search, Distance Judgment, Abstract Matching 1, Abstract Matching 2, and Shape Judgment (Hale and Myerson, 1996; Kerchner *et al.*, 2012). Scores are normalized against healthy young adults as detailed by Kerchner and colleagues (2012).

For exploratory analyses, episodic memory was quantified using a sample-based composite measure of Benson Figure delayed recall (Kramer *et al.*, 2003) and performance on the California Verbal Learning Test, second edition (immediate recall total, delayed recall total, and recognition discriminability; Delis *et al.*, 2000).

Higher scores correspond to better performance for the Gf-EF and episodic memory composites. By contrast, lower scores indicate better performance (faster reaction times) on the Gf-PS composite.

Brain structural measures

A subset of participants underwent T1-weighted magnetization prepared rapid gradient-echo (MPRAGE) magnetic resonance imaging (MRI) on a 3.0 Tesla Siemens Prisma Fit scanner. The scans were acquired sagittally using the following parameters: repetition time (TR) = 2300 ms, inversion time (TI) = 900 ms, echo time (TE) = 2.9 ms, flip angle = 9°, field-of-view (FOV) = 240×256 mm with 1×1 mm in-plane resolution and 1 mm slice thickness. Image processing included correction of magnetic field bias via the N3 algorithm (Sled *et al.*, 1998). Tissue segmentation was achieved using SPM12's unified segmentation procedure (Friston *et al.*, 2011), and each participant's gray matter segmentation was warped using DARTEL (Diffeomorphic Anatomical Registration using Exponentiated Lie algebra) to create a study-specific template (Ashburner, 2007). Each participant's native space gray matter segmentation was normalized and modulated, via nonlinear and rigid-body transformations, to study-specific template space. A Gaussian kernel of 4-mm full width half maximum was applied for smoothing of images. Transformations (linear and nonlinear) between DARTEL's space and International Consortium for Brain Mapping (ICBM) space were conducted to enable statistical comparisons

(Mazziotta *et al.*, 1995). Finally, brain volumes of interest were quantified by translating a standard parcellation atlas (Desikan *et al.*, 2006) into ICBM space and summing the gray matter within each identified region. Dorsolateral prefrontal cortex (dlPFC) consisted of bilateral caudal and rostral middle frontal gyri (Sallet *et al.*, 2013), and ventromedial prefrontal cortex (vmPFC) consisted of bilateral medial orbitofrontal regions (Delgado *et al.*, 2016).

Statistical analyses

For primary aim analyses, bivariate correlation coefficients (Pearson's r) were calculated to evaluate the magnitude of the relationship between wisdom (SD-WISE scores) and Gf (Gf-EF and Gf-PS composite scores). In follow-up exploratory analyses, these relationships were also tested in multiple regression models covarying for age, sex, and educational attainment (in years). The *a priori* rationale for performing the analyses with and without demographic adjustment is that, on the one hand, the interrelated and complementary models posit that the constructs of wisdom and Gf are either related or not, regardless of demographic factors such as age, sex, or education. On the other hand, the exploratory multiple regression analysis helps inform whether core demographic variables may influence the relationship between wisdom and Gf, particularly given the paucity of empirical studies on this topic to date.

For our secondary aims, the relationship between wisdom and episodic memory composite scores was similarly investigated in both bivariate correlational analyses (Pearson's r) and multiple regression models with demographic (age, sex, and education) adjustment. The association between wisdom and brain volume regions-of-interest (ROIs; dlPFC and vmPFC) was evaluated in multiple regression analyses controlling for total intracranial volume (TIV), with and without demographic covariates in the model. Finally, bivariate correlational analyses and multiple regression models adjusting for sex and education were performed to test the relationship between age and wisdom. Based on prior literature suggesting the possibility of curvilinear associations (Ardelt *et al.*, 2018; Thomas *et al.*, 2017; Webster *et al.*, 2014), the relationship between age and wisdom was probed in both linear and quadratic regression models.

In addition to our preplanned ROI-based analysis involving dlPFC and vmPFC, we performed an exploratory whole-brain voxel-based morphometry (VBM) analysis to help advance knowledge of the neuroanatomy of wisdom in older adults, given the lack of prior studies on this topic. The VBM analysis was performed in SPM using standard settings

recommended by the developer (Friston *et al.*, 2011). In parallel with the ROI-based analysis, the VBM analysis evaluated the association between wisdom (SD-WISE scores) and TIV-adjusted gray matter volumes with and without inclusion of demographic covariates (age, sex, and education). For statistical thresholding, the model implemented a voxelwise $p < .005$ as well as a cluster size $p < .05$ based on a Monte Carlo simulation with 1,000 permutations.

Power analysis

A power analysis was conducted to determine the minimum sample size necessary to reject the null hypothesis ($\rho = 0$), if it were in fact false, for our primary aim analyses evaluating the relationship between wisdom and Gf. The power analysis revealed that at least 84 participants would be required to detect a medium-sized effect ($\rho = 0.30$) with power ($1 - \beta$) of 0.80 and alpha (α) set to .05 (two-tailed). The available sample size for our primary analyses surpassed this threshold (see Results section, below).

Results

In total, 217 participants within the Hillblom Aging Network completed the SD-WISE. Of these 217 participants, 141 had a global CDR score of 0 and Gf-EF data within 2 years of completion of the SD-WISE. Gf-PS data were available for 99 of these participants. Accordingly, for our primary aim analyses, the achieved power was 0.86 for Gf-PS ($n = 99$) and 0.95 for Gf-EF ($n = 141$) to detect a medium-sized effect ($\rho = 0.30$) with α set to .05 (two-tailed). For our exploratory analyses, 141 participants had episodic memory data and 82 had structural MRI data within the 2-year window.

Descriptive statistics for the overall sample of eligible participants ($N = 141$) are provided in Table 1. The study sample was highly educated (>17 years on average) and predominantly Caucasian (92%) with a mean age of 76 years. Measures of central tendency (e.g. mean) and dispersion (e.g. standard deviation) on the SD-WISE were comparable to those reported in other older adult cohorts, supporting its reliability (Jeste *et al.*, 2019). Consistent with prior findings (Thomas *et al.*, 2019), males and females demonstrated similar levels of wisdom ($t = -0.108$, $p = .914$), and educational attainment and wisdom were not significantly correlated ($r = .124$, $p = .145$).

Gf and wisdom

Wisdom demonstrated a positive and small but statistically significant association with Gf-EF

Table 1. Descriptive Statistics

	MEAN (SD) OR %	RANGE
Age (years)	76.66 (7.57)	51.84, 92.27
Sex (% female)	56%	n/a
Education (years) ^a	17.74 (1.99)	12.00, 20.00
Race (% White) ^b	92%	n/a
SD-WISE (total score)	4.08 (0.36)	3.13, 4.88
Gf-EF (z-score)	0.31 (0.67)	-1.77, 1.91
Gf-PS (z-score) ^c	2.54 (1.61)	-0.12, 7.65
Episodic memory (z-score)	0.06 (0.81)	-2.38, 1.48

Note. Descriptive statistics are presented as mean (standard deviation) with ranges (minimum, maximum) or percentages for participants who met inclusionary criteria ($N = 141$).

SD-WISE = San Diego Wisdom Scale (higher scores = greater wisdom). Gf-EF = executive functioning composite measure of fluid intelligence, presented in sample-based z-score units (higher scores = better performance). Gf-PS = processing speed composite measure of fluid intelligence, presented in z-score units normalized against healthy young adults (higher scores = slower reaction times or worse performance). Episodic memory is presented as a sample-based z-score composite measure (higher scores = better performance).

^a $N = 140$. ^b $N = 137$. ^c $N = 99$.

composite scores ($r = 0.181$ [95% CI 0.016, 0.336], $p = .031$; see Figure 1). In other words, approximately 3.28% of the variance in wisdom was accounted for by Gf-EF. Exploratory multiple regression analyses indicated that the relationship between wisdom and Gf-EF was reduced to non-significance upon controlling for age, sex, and education ($\beta = 0.114$, $p = .214$).

Wisdom and Gf-PS were not significantly related in zero-order bivariate correlations ($r = 0.019$ [95% CI -0.179, 0.216], $p = .854$; see Figure 2), sharing only 0.04% of the total variance with one another. Wisdom and Gf-PS continued to be unrelated in demographically adjusted multiple regression analyses ($\beta = 0.094$, $p = .375$).

Episodic memory and wisdom

Wisdom was not significantly related to episodic memory composite scores ($r = 0.109$ [95% CI -0.057, 0.269], $p = .200$). This relationship remained nonsignificant upon controlling for age, sex, and education in multiple regression analyses ($\beta = 0.086$, $p = .321$).

Age and wisdom

Age and wisdom demonstrated a small yet statistically significant negative linear correlation ($r = -0.197$ [95% CI -0.351, -0.033], $p = .019$; see Figure 3), which remained significant upon adjusting for sex and education ($\beta = -0.171$, $p = .049$). There were no quadratic associations between age and wisdom

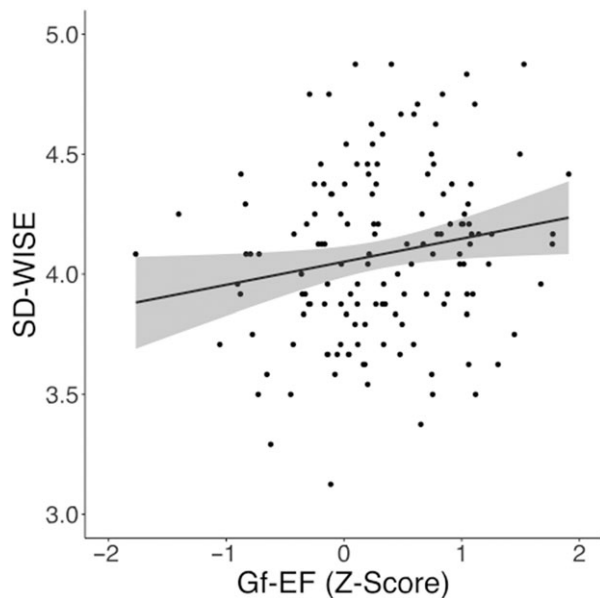


Figure 1. The relationship between executive functioning and wisdom.

The executive functioning composite measure of fluid intelligence (Gf-EF) demonstrated a positive and small yet statistically significant association with wisdom, as assessed by the San Diego Wisdom Scale (SD-WISE). Gf-EF is plotted on the x-axis in sample-based z-score units (higher scores = better performance), and SD-WISE is plotted on the y-axis (higher scores = greater wisdom). A fitted regression line with 95% confidence intervals is displayed to help visualize the association.

($\beta = 0.129$, $p = .907$), including when adjusting for sex and education ($\beta = 0.219$, $p = .845$).

Brain structure and wisdom

dIPFC volumes were not significantly associated with wisdom in multiple regression analyses adjusted for TIV ($\beta = 0.033$, $p = .827$). dIPFC volumes and wisdom remained unassociated when additionally adjusting for age, sex, and education ($\beta = 0.096$, $p = .538$). Similarly, vmPFC volumes were not significantly associated with wisdom ($\beta = -0.010$, $p = .943$), including when controlling for demographics ($\beta = 0.023$, $p = .875$).

The exploratory, whole-brain VBM analysis did not yield any significant associations between brain structure and wisdom, regardless of whether demographic variables were included within the model.

Discussion

We empirically tested the magnitude of the relationship between wisdom and Gf using a preregistered analytic plan in a well-characterized cohort of healthy older adults without markers of neurodegenerative disease. The primary findings were

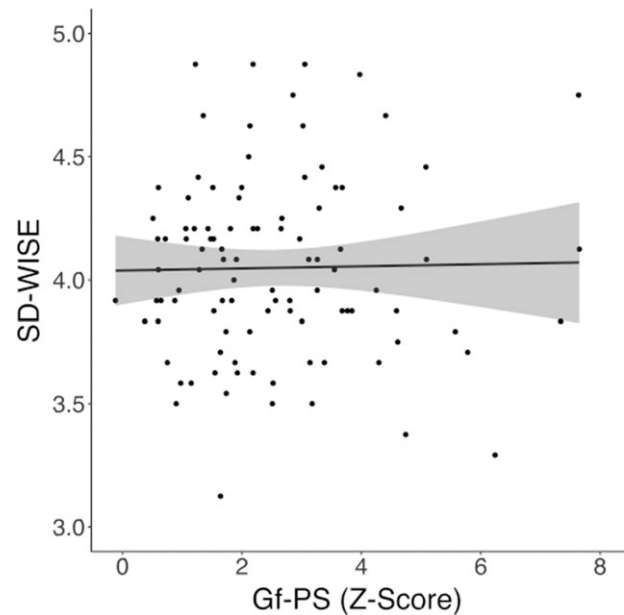


Figure 2. The relationship between processing speed and wisdom. The processing speed composite measure of fluid intelligence (Gf-PS) was not significantly associated with wisdom, as assessed by the San Diego Wisdom Scale (SD-WISE). Gf-PS is plotted on the x-axis in z-score units normalized against healthy young adults (higher scores = slower performance), and SD-WISE is plotted on the y-axis (higher scores = greater wisdom). A fitted regression line with 95% confidence intervals is displayed to help visualize the lack of association.

twofold. First, wisdom demonstrated a small, positive association with Gf-EF that was reduced to nonsignificance upon controlling for age, sex, and education. Second, wisdom and Gf-PS were not significantly related, regardless of demographic covariates. Given that over 95% of the variance in wisdom was unaccounted for by Gf-EF and Gf-PS, the present findings do not support an “interrelated” view of wisdom and Gf as largely overlapping constructs. This conclusion is bolstered by the fact that we were adequately powered to detect relationships between wisdom and both Gf-EF (power = 0.95) and Gf-PS (power = 0.86), if present, of at least medium effect size.

Our findings are consistent with conceptualizations of wisdom as a multidimensional trait that is far broader than Gf, presumably due to its involvement of a host of social and emotional processes, such as empathy, compassion, affect regulation, and self-reflection, in addition to cognitive skills (Jeste and Lee, 2019). Beyond the obvious theoretical implications of these findings, the observation that wisdom is largely distinct from Gf carries important practical implications. Perhaps most notably, Gf is the strongest cognitive predictor of everyday functioning in older adults (Cahn-Weiner *et al.*, 2007) and consistently declines in later life, with the average

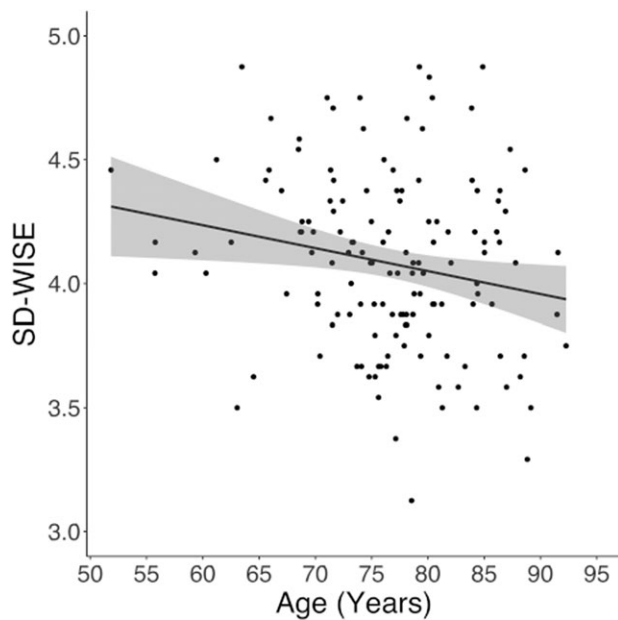


Figure 3. The relationship between age and wisdom.

Age demonstrated a negative and small yet statistically significant association with wisdom, as assessed by the San Diego Wisdom Scale (SD-WISE). Age is plotted on the x-axis, and SD-WISE is plotted on the y-axis (higher scores = greater wisdom). A fitted regression line with 95% confidence intervals is displayed to help visualize the relationship.

80-year-old performing over 1.5 standard deviations below the average 20-year-old on Gf measures of executive functioning and processing speed (Salt-house, 2004). Yet despite these well-documented declines in Gf, many healthy older adults do not show significant declines in everyday functioning, suggesting a mismatch between cognitive trajectories and functional trajectories. Wisdom may be one critical factor that helps to explain this cognitive-functional mismatch by bolstering decision-making, interpersonal functioning, and ultimately performance in various daily activities. Consistent with this idea, it has previously been demonstrated that wisdom buffers against functional decline in people with schizophrenia (Van Patten *et al.*, 2019). Future research is warranted to empirically evaluate whether wisdom is similarly protective in older adult populations. Investigating the relationship between wisdom and more “crystallized” aspects of intelligence (Gc), such as the breadth and depth of one’s general knowledge base about the world, may also be of interest (McGrew, 2009). For example, it is possible that wisdom helps support overall intellectual, cognitive, and everyday functioning in later stages of life by continuously facilitating the acquisition and application of relevant information to inform behavior and achieve goals (Jeste *et al.*, 2020).

In secondary, exploratory analyses we tested the relationship between wisdom and episodic memory, given the centrality of this cognitive function to aging and many age-associated neurodegenerative disorders (Gorbach *et al.*, 2017). Episodic memory performance was not significantly associated with wisdom. This suggests that, at least in cognitively normal older adults, wisdom may be dissociable from both Gf and non-Gf cognitive functions.

Age and wisdom demonstrated a small, negative correlation, which remained significant upon adjusting for sex and educational attainment. Although wisdom is popularly thought to increase in later life, this has not been consistently supported in the empirical literature, with several prior studies demonstrating weakly negative associations (Mickler and Staudinger, 2008; Thomas *et al.*, 2019) or no associations (Smith and Baltes, 1990; Webster, 2007). More recent work has suggested a curvilinear relationship between age and wisdom across the life span, whereby wisdom peaks in the fifth or sixth decade and then slowly declines thereafter (Ardelt *et al.*, 2018; Thomas *et al.*, 2017; Webster *et al.*, 2014). These discrepant findings likely reflect widespread variability in how wisdom is measured across studies, including which specific subcomponents are assessed (e.g. cognitive, social, and/or emotional), as well as in the age range of the subjects included in a study. In addition, age-related neurodegenerative diseases have been inconsistently ruled out in prior work, which may explain why some studies have suggested a precipitous decline in wisdom among the oldest-old in particular, when risk of dementia is the highest (Staudinger, 1999). Our findings suggest that if wisdom does decline in *healthy* older adults, the rate of decline is gradual and likely much slower than that of Gf, even among the oldest-old. However, conclusions are limited by the cross-sectional design of the present study.

Although vmPFC and dlPFC have been proposed as two key neuroanatomical substrates of wisdom (Meeks and Jeste, 2009), we did not find any significant associations in the current study. Our null findings do not imply that vmPFC and dlPFC are unimportant for wisdom, but rather that normal variations in gray matter volumes within these regions may be less determinant of wisdom levels among neurologically healthy older adults. It remains possible that a relationship would emerge in patient populations with more significant brain structural changes, such as individuals with neurological injury or disease preferentially impacting prefrontal cortex. For example, patients with behavioral variant frontotemporal dementia, stemming from underlying frontotemporal lobar degeneration, show symptoms that are diametrically opposed to wisdom, such as social inappropriateness,

impulsivity, apathy, loss of empathy, and lack of insight (Rascovsky *et al.*, 2011).

Beyond our *a priori* prefrontal brain ROIs, we also performed an exploratory whole-brain VBM analysis to more comprehensively evaluate potential neuroanatomical underpinnings of wisdom, given the lack of prior empirical research on this topic. As with the ROI analyses, the VBM analysis did not yield significant associations. Although we report the VBM findings here in the interest of publishing null results, we acknowledge that we may have been underpowered to detect an effect due to the stringent correction for multiple comparisons that this type of an analysis requires (to avoid inflated Type 1 error rates). Future studies using larger sample sizes will be necessary before drawing any definitive conclusions. In addition, future research may benefit from evaluating relationships between wisdom and more sensitive markers of brain structure and function, such as white matter microstructural integrity or functional connectivity changes, which can precede frank loss of gray matter volume (Sheline and Raichle, 2013). Given the complex, multidimensional nature of wisdom, it is possible that it is subserved by large-scale brain networks working in concert, rather than individual regions.

There are other limitations to the present study that should be considered. Although our findings indicate a dissociation between wisdom and Gf, the cross-sectional design hinders conclusions about how wisdom and Gf may relate to one another over time during the aging process; longitudinal studies are needed to this end. In addition, our sample was predominantly Caucasian (over 90%) and highly educated (greater than a college degree, on average). Future research is needed in samples that are more diverse while evaluating the potential influence of demographic and cultural factors on expressions of wisdom and its correlates. Finally, it should be acknowledged that wisdom, similar to other personality traits, was assessed by a validated but self-report-based measure, which can be subject to inaccuracies stemming from lack of insight, social desirability, and other forms of response bias (Rosenman *et al.*, 2011), whereas Gf was assessed by performance on objective tests. This difference in administration modality (subjective report versus objective test performance) could have influenced our findings, and future studies may benefit from using performance-based measures of wisdom. That said, cross-modality comparisons are standard practice in the aging literature, particularly when studying personality traits such as wisdom, and it is encouraging that the SD-WISE is a carefully constructed scale with strong theoretical and empirical bases, as well as robust psychometric properties (Thomas *et al.*, 2019). Furthermore, social desirability

has not been found to be a significant contributor to SD-WISE scores.

Despite its limitations, the present study is the first to empirically test the magnitude of the relationship between wisdom and Gf in a well-powered study of older adults characterized as neurologically normal. The observation that over 95% of the variance in wisdom is unaccounted for by measures of Gf helps to delineate and define the construct of wisdom, including its relationship to intelligence, which has been a topic of theoretical debate for decades (Jeste *et al.*, 2020). A better understanding of the wisdom construct also carries important practical implications. Indeed, a growing literature suggests that wisdom plays a central role in successful aging (Lee, 2019) and is associated with a wide range of physical and mental health outcomes in older adults, as well as an overall sense of mastery and purpose in life (Ardelt and Ferrari, 2019). Emerging research further suggests that wisdom promotes healthy social relationships (Auer-Spath and Glück, 2019) and protects against loneliness across the life span, the latter of which is a risk factor for cognitive decline, mood disorders, and mortality (Lee *et al.*, 2019). Given our findings that wisdom appears to be relatively independent from cognitive functions that reliably decline in aging and age-associated neurodegenerative diseases, wisdom may hold unique potential as a target for interventions to bolster decision-making, social relationships, everyday functioning, and overall health in older adult populations.

A rapidly growing literature provides exciting support for the amenability of various aspects of wisdom to intervention. For example, a meta-analysis of randomized controlled trials (RCTs) showed that nearly half of the psychosocial/behavioral interventions improved components of wisdom such as emotional regulation, empathy, and compassion with medium-to-large effect sizes (Lee *et al.*, 2020). Intervention programs in healthy older adults have also been found to significantly increase overall “emotional intelligence,” which encompasses various wisdom-related skills such as emotion regulation and awareness (Delhom *et al.*, 2020). A recent RCT of a group intervention labeled “Raise Your Resilience” improved not only resilience and perceived stress but also overall wisdom, using SD-WISE in 89 older residents of five senior housing communities (Treichler *et al.*, 2020). Interestingly, artificial technology has recently been proposed as a novel means of bolstering wisdom in humans, particularly among vulnerable older adult populations with cognitive or psychiatric disorders, and represents an exciting avenue for future research (Jeste *et al.*, 2020).

Taken together, it has become increasingly clear that wisdom holds relevance to numerous health

outcomes in older adults, and an expanding literature supports its promising potential as a novel target for intervention. However, the success of wisdom-promoting interventions will likely depend, at least in part, on a thorough understanding of exactly what this complex, multidimensional trait is and how it relates to other abilities that are highly relevant to the aging process, such as Gf. The present study builds upon prior literature and provides an important step in this direction.

Conflict of interest

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Description of author(s)' roles

Dr. Lindbergh assumed a leading role in formulating the research questions, designing the study, analyzing and interpreting the data, and writing the manuscript. Ms. Romero-Kornblum assisted with collecting the data, analyzing the data, and editing the manuscript. Ms. Weiner-Light was involved in data collection, data management, and editing the manuscript. Mr. Young contributed to data collection, data management, visualization of the results, and editing the manuscript. Ms. Fonseca assisted with data collection, data management, and editing the manuscript. Ms. You contributed to study coordination, data collection, data management, and editing the manuscript. Ms. Wolf was involved in data collection, data management, and editing the manuscript. Dr. Staffaroni contributed to data analysis and editing the manuscript. Ms. Daly assisted with

data collection and editing the manuscript. Dr. Jeste was involved in designing the study, interpreting the results, and editing the manuscript. Dr. Kramer contributed to study design, formulating the research questions, supervising data collection, interpreting the results, and editing the manuscript. Dr. Chiong was involved in formulating the research questions, designing the study, supervising data collection, interpreting the results, and editing the manuscript.

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