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ORIGINAL ARTICLE

Superiority illusion in older adults: Volume and functional connectivity of the precuneus

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Abstract

Aim: Superiority illusion (SI), a cognitive bias where individuals perceive themselves as better than others, may serve as a psychological mechanism that contributes to well-being and resilience in older adults. However, the specific neural basis of SI in elderly populations remains underexplored. This study aims to identify brain regions partially associated with SI, exploring its potential role in adaptive psychological processes.

Methods: This study combined a behavioral task, voxel-based morphometry (VBM), and resting-state functional connectivity (rsFC) analyses to investigate the neural substrates of the SI in a cohort of 145 participants, including young ($n = 84$), middle-aged ($n = 37$), and older adults ($n = 24$).

Results: Our findings indicated that higher SI scores in older adults were correlated with greater gray matter volume in the right precuneus and stronger rsFC between the right precuneus and the left lateral occipital cortex. However, these correlations were not evident in younger and middle-aged groups.

Conclusion: Our findings underscore the importance of the right precuneus and its connectivity in the manifestation of the SI, particularly in older adults, highlighting its potential role in adaptive aging processes.

KEYWORDS
aging, positive bias, precuneus, resting-state functional connectivity, voxel-based morphometry

Yuki Shidei and Daisuke Matsuyoshi contributed equally to this work.

INTRODUCTION

Enhanced mental health has been significantly associated with increased life expectancy, a correlation well supported by epidemiological studies.[1] Indeed, studies have shown that psychological well-being promotes engagement in physical activities and adherence to nutritious diets, thereby augmenting lifespan.[2] Conversely, adverse psychological states, such as pessimism and chronic stress, detrimentally influence physiological processes and negatively impact lifestyle choices.[3] Positive thinking, a crucial facet of mental health, has been shown to enhance relationship quality and longevity.[4] Meanwhile, recent empirical evidence suggests that optimistic individuals likely experience a lifespan extension of approximately 5.4%.[5]

As individuals age, maintaining a positive self-evaluation becomes increasingly important for psychological well-being. One cognitive bias that contributes to this self-evaluation is the superiority illusion (SI)—the belief that one is better than others in various domains, such as intelligence, social skills, and personality.[6] Understanding the neural correlates of SI and its manifestation in healthy aging can provide insights into mechanisms that support mental health and cognitive resilience in later life.

Recent research has begun to uncover the neural underpinnings of self-perception and cognitive biases among younger populations, indicating a significant positive association between self-related cognitive biases and the volume of the anterior cingulate cortex (ACC).[7] Additionally, older adults who perceive themselves as younger exhibit preserved inferior frontal gyrus and superior temporal gyrus volumes.[8] However, studies focusing on older adults remain scarce. Especially, brain regions associated with SI in aging populations are not yet well understood.

The present study aimed to identify brain regions partially associated with SI and examine their relationships with regional brain volume and functional connectivity among adults of different age groups. We employed voxel-based morphometry (VBM) to assess correlations between regional brain volume and the SI, and utilized resting-state functional magnetic resonance imaging (fMRI) to examine functional connectivity. By integrating these approaches, we seek to clarify the relationship between positive mental states and the neuroanatomical and functional properties of the aging brain.

METHODS

Participants

For this study, 145 healthy volunteers were recruited from the general public at the National Institutes for Quantum Science and Technology. The participants were subsequently categorized into three age groups: young (<40 years; mean ± standard deviation [SD] = 23.8 ± 3.7 [range 20–37] years; *n* = 84, 11 females), middle-aged (40–59 years; 48.9 ± 5.8 [40–59] years; *n* = 37, 24 females), and older (≥60 years; 68.0 ± 4.7 [60–78] years; *n* = 24, 10 females). The age categorization was designed to capture differences across balanced 20-year intervals, thereby enabling a balanced assessment of age-related changes in SI. To ensure a more balanced distribution of sample sizes across groups, we chose a cutoff of 60 years for the older adults group. Although studies typically define older adults as those aged 65 years and above, this cutoff allowed for a more balanced sample while still capturing relevant age-related variations. The exclusion criteria included contraindications to MRI, diagnosed neuropsychiatric disorders, a history of significant head trauma, claustrophobia, and metal implants. Before the study, all participants received a full explanation regarding the objectives and methodology of the study, after which informed consent was obtained from them.

Assessment of SI

The measurement procedure for the SI has been detailed previously.[6,9] Briefly, 52 traits identified in the literature as socially desirable (positive) or undesirable (negative) were selected and translated into Japanese. Participants then assessed their deviation from an average peer based on these traits using a standardized visual analog scale ranging from −1 to 1, where −1 indicates *feeling inferior to others* and +1 indicates *feeling superior to others*. This approach enabled us to calculate their SI scores. Negative trait ratings for each individual were reversed and combined with their positive trait ratings to determine the average deviation from the midpoint of 0.

Image acquisition

Structural and functional images were acquired using a 3.0-Tesla Siemens Verio MRI scanner (Siemens Healthcare Sector) equipped with a 32-channel head coil. Three-dimensional T1-weighted (T1w) structural images were obtained using a magnetization-prepared rapid gradient echo with the following parameters: repetition time (TR) of 2.3 ms; echo time (TE) of 1.95 ms; flip angle (FA) of 9°; slice thickness of 1 mm; field of view (FOV) of 256 × 256 mm^2; matrix size of 240 × 240; and isotropic voxel size of 1 × 1 × 1 mm^3. For resting-state functional images, an echo-planar imaging sequence was employed with the following parameters: TR of 2000 ms; TE of 25 ms; FA of 90°; 36 slices; FOV of 220 × 136 × 220 mm^3; matrix size of 72 × 74; voxel size of 3.0 × 3.0 × 3.0 mm^3; reconstructed voxel size of 1.72 × 1.72 × 3 mm^3, and a scan duration of 5 min. During imaging, participants were instructed to close their eyes, relax, refrain from engaging in specific cognitive tasks, and avoid falling asleep.

Structural MRI analyses

VBM analysis was conducted using the standard Diffeomorphic Anatomical Registration Through Exponentiated Lie Algebra (DARTEL)[10] processing pipeline in Statistical Parametric Mapping software (SPM12; Wellcome Trust Centre for Neuroimaging) with MATLAB 9.10.0 (MathWorks). All images underwent thorough quality control to identify and address artifacts. Each image was spatially normalized to the Montreal Neurological Institute (MNI) coordinate system. T1-weighted scans were segmented into gray matter (GM), white matter (WM), cerebrospinal fluid (CSF), and skull compartments using the segmentation method in SPM12. The DARTEL algorithm was employed to create study-specific templates, and GM images were normalized to the MNI space, resampled to 1.5-mm isotropic voxels, and smoothed using an 8-mm full-width at half maximum (FWHM) Gaussian kernel. Total intracranial volume (TIV) was estimated using the Tissue Volumes utility in SPM12.

Resting-state fMRI analyses

Resting-state fMRI data were analyzed using the CONN toolbox (Version 18b).[11] Data preprocessing involved several steps. Initially, the first 15 scans were excluded. Realignment and unwarping corrected for subject motion, whereas slice-timing correction addressed interslice differences in acquisition time. The Artifact Detection Tools method identified outlier scans for removal. Segmentation and normalization simultaneously segmented GM, WM, and CSF and normalized the structural data to MNI space. Subsequently, spatial smoothing was performed using a 6-mm FWHM Gaussian kernel. Denoising comprised bandpass filtering (0.008–0.09 Hz) to mitigate linear drift and high-frequency noise, alongside confounding factors, such as WM and CSF signals, six motion parameters and their derivatives, and scrubbing. Resting state functional connectivity (rsFC) analyses utilized clusters identified via VBM as regions of interest (ROIs), with the mean time series for each ROI serving as predictors during seed-to-voxel general linear model analysis.

Statistical analysis

All statistical analyses were conducted using SPSS (Version 24), SPM12, and the CONN toolbox. The distribution of SI scores and other variables was examined to assess normality. Nonparametric tests were applied where data deviated from a normal distribution. In the VBM analysis, we employed a multiple regression model to explore the association between regional brain volume and age-adjusted residual SI, adjusting for age, gender and TIV. In this model, regional brain volume served as the primary outcome measure, while SI was treated as a covariate of interest. We especially focused on the differences between the age groups in the relationships between regional brain volume and SI. Statistical significance was determined at a voxel-wise threshold of uncorrected $p < 0.0001$, with an extent threshold of 10 voxels. GM volumes from these ROIs were extracted and plotted against the SI score for visualization. Significant clusters were used as ROIs for subsequent rsFC analysis. For rsFC analysis, multiple linear regression models evaluated associations between SI scores and rsFC within these predefined ROIs in the elderly cohort. Significant voxel-wise associations were reported at $p < 0.001$, with false discovery rate (FDR) correction at the cluster level set at $p < 0.05$. Seed-to-voxel rsFC was compared across age groups using general linear models, adjusting for age and gender. Finally, SI scores were transformed to *z*-scores and plotted against rsFC strengths to visualize significant associations across ROIs.

RESULTS

Behavioral results

SI score analysis revealed the presence of SI across all age groups. The mean SI score was 0.15 ± 0.18, suggesting that our participants exhibited a prevailing sense of superiority regarding their abilities and traits across the age spectrum. Furthermore, a positive correlation was observed between age and the degree of superiority (Pearson's $r = 0.21$; $p < 0.05$), indicating a weak tendency for SI to slightly intensify with age (Figure 1).

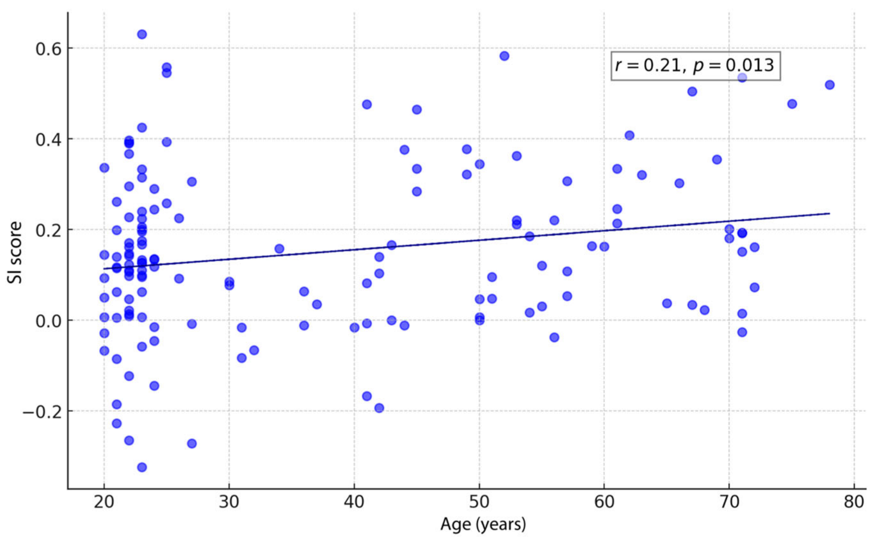

FIGURE 1 Relationships between the superiority illusion scores and age.

Structural brain regions linked to SI score in older individuals

The older group showed a significant positive correlation between SI score and GM volume in the right precuneus ($x = 10.5$, $y = -76.5$, $z = 48$; $T = 3.82$; voxel-level $p < 0.0001$; cluster size = 70; Figure 2a). However, this positive correlation was not observed in the young and middle-aged groups. Furthermore, no significant correlations were found between SI score and GM volume in other brain regions. We present a scatter plot of the SI effect across the three age groups in Figure 2b, with regression lines included for visualization purposes only.

rsFC analysis

Seed-to-voxel analysis was employed to investigate the relationship between the SI score and rsFC, focusing on the functional connectivity associated with the right precuneus cluster identified during VBM analysis. Although no associations were observed between SI scores and rsFC in the young or middle-aged groups, a significant negative correlation was observed between SI scores and connectivity within the left lateral occipital cortex among older participants ($x = -24$, $y = -88$, $z = 36$; cluster size = 60 voxels), with a voxel-wise uncorrected threshold of $p < 0.001$ and a cluster-wise FDR corrected $p < 0.05$). These findings have been illustrated in a graph plotting the SI score against the connectivity strength (Figure 3).

DISCUSSION

The current study found an increase in the inclination toward the SI with age. Moreover, among healthy older adults, the right precuneus volume correlated with the propensity for the SI. This association was not evident among the middle-aged or younger groups. Furthermore, a weaker rsFC between the right precuneus and visual cortex was observed among elderly individuals exhibiting higher levels of the SI.

Our finding of a more evident SI among older adults can be understood within the framework of the socioemotional selectivity theory, which posits that people prioritize emotionally meaningful goals and experiences as they age, leading to a greater focus on positive information.[12] This shift helps older adults maintain a positive self-perception and emotional well-being despite the challenges and losses associated with aging.[13,14] Brain imaging studies have further revealed that older adults show increased frontal lobe activity when processing positive information and increased brain reward system activity in response to positive stimuli.[15] These brain response patterns and the tendency to exhibit a positive bias suggest that the SI may serve as a cognitive strategy for maintaining a positive self-perception, thereby contributing to emotional well-being and resilience despite aging-related challenges.

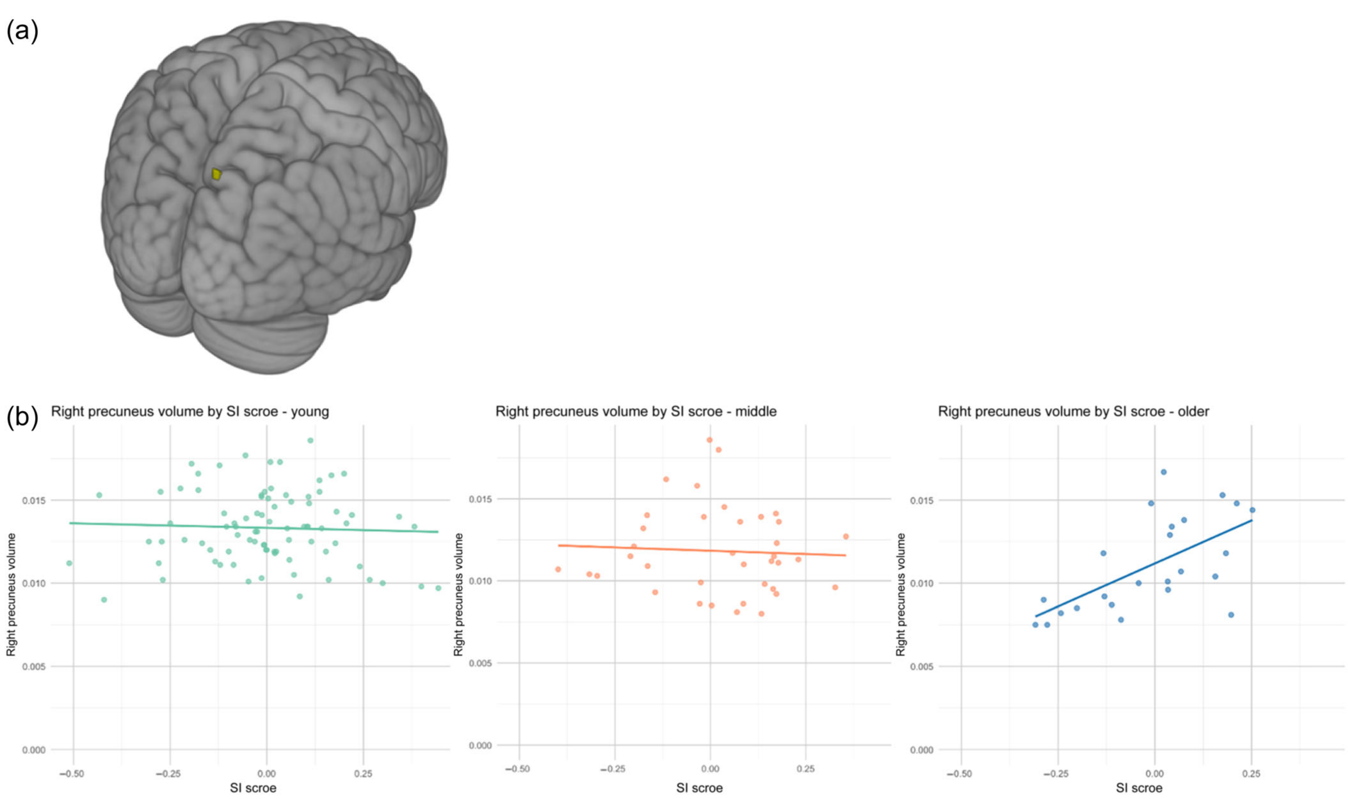

FIGURE 2 (a) Higher gray matter volume of the right precuneus was associated with superiority illusion (SI) in healthy older individuals. (b) Scatter plot representation of the SI effect in the three groups (regression lines are provided for visualization only).

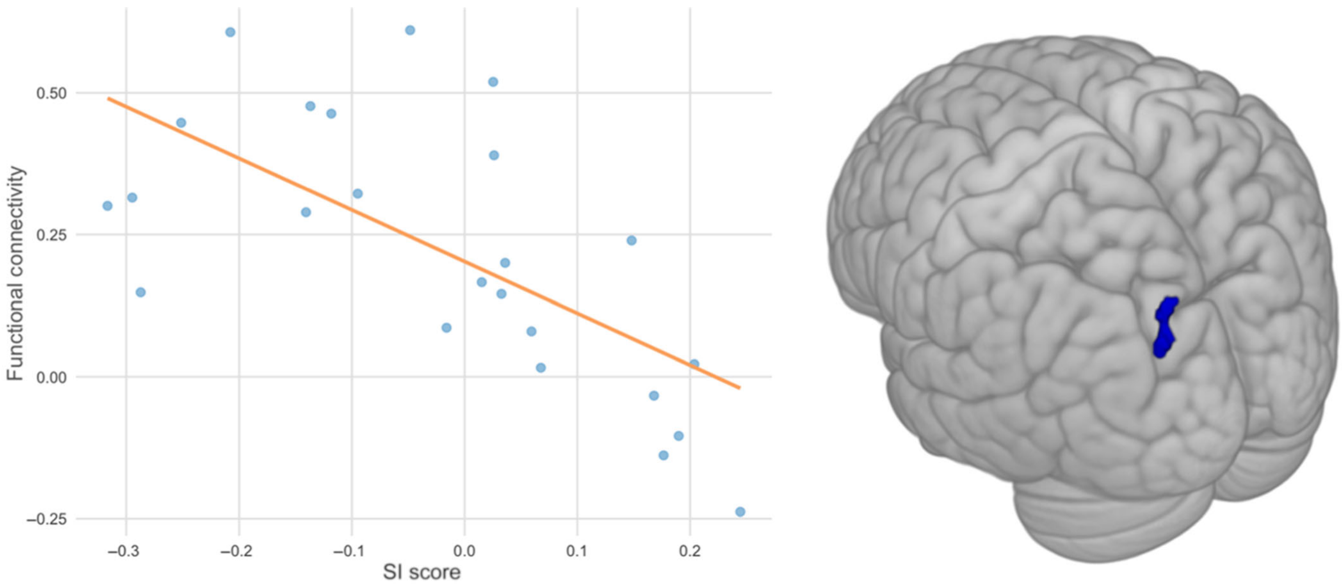

FIGURE 3 Association between superiority illusion scores and resting-state functional connectivity (rsFC) linking the right precuneus and left occipital cortex in the older group. Montreal Neurological Institute coordinate = −24 − 88 + 36. *Y* axis: rsFC strength between the right precuneus and left lateral occipital cortex (*z* score). For illustrative purposes, superiority illusion (SI) scores are represented as *z*-scores plotted against the strength of rsFC (Fisher-transformed correlation coefficients).

The observed positive correlation between the SI and right precuneus volume may indicate that this region is critical in maintaining positive self-perceptions in older adults. This finding is consistent with the notion that the precuneus plays a role in self-awareness and introspection—processes crucial for maintaining a positive self-view.[16] Previous studies have suggested that the right precuneus is specifically involved in self-related cognitive processes, including self-evaluation and self-referential thinking. For example, research has shown that right precuneus volume is associated with the visual perspective taken during autobiographical memory retrieval, indicating its role in self-related processing and the maintenance of a stable self-image.[17] The aforementioned finding also supports the idea that the precuneus is involved in positive affect and life satisfaction, thereby contributing to the experience of positive emotions and contentment with life.[18] The observed decreased rsFC between the right precuneus and the lateral occipital cortex among older adults with higher SI may reflect a specific neural configuration associated with self-referential processing. This reduced connectivity could indicate less reliance on external visual information during self-related cognitive processes, as the precuneus and lateral occipital cortex are involved in integrating self-referential thought and visual information.[17]

These findings align with the broader literature on aging and brain function.[18–21] The concept of "brain maintenance" suggests that certain brain regions may retain their volume as part of an adaptive response to aging, which supports the preservation of cognitive and emotional functions.[22] In this context, the preserved volume of the right precuneus may reflect an age-related structural adaptation that contributes to maintaining positive biases, such as the SI, in older adults. This explanation emphasizes the role of structural resilience in the precuneus as a potential factor in sustaining positive self-perceptions in later life.

Several limitations must be considered in this study. Initially, the small sample size of older participants may limit the generalizability of the findings. Moreover, all participants in this study were recruited at a single research institute. This recruitment method may introduce selection bias, limiting the generalizability of the findings and not fully representing the broader population. Furthermore, the distribution of the sample was uneven, with a larger proportion of younger participants exhibiting low SI scores. This imbalance may have led to a potential floor effect, influencing the observed correlation between SI score and age. Additionally, the study did not assess cognitive and intellectual abilities, which may be closely related to SI. Prior research has demonstrated that individuals with lower levels of competence tend to overestimate their abilities, a phenomenon known as the Dunning–Kruger effect.[23] This may be further supported by evidence of reduced blood flow in the precuneus in early-stage Alzheimer's disease, suggesting that our findings could reflect cognitive decline.[24] Our study did not account for several potentially influential factors, such as cognitive functioning, educational background, health status, lifestyle choices, and psychological stress. Thus, future research should consider these variables to provide a more comprehensive understanding of the factors influencing the SI and its neural correlates. Finally, the cross-sectional nature of this study precludes conclusions about causality. Longitudinal studies are therefore necessary to determine the temporal dynamics of these associations.

CONCLUSION

Taken together, the current study highlights the critical role of the right precuneus in the positive distortion of self-perception associated with aging. Our findings contribute to a growing body of literature on the neural correlates of positive cognitive biases and their adaptive functions in older adults. Further research is needed to deepen our understanding of these phenomena and develop strategies that enhance the aging population's mental health and overall well-being.

AUTHOR CONTRIBUTION

Yuki Shidei: Writing—review and editing; writing—original draft; project administration; methodology; investigation; formal analysis; data curation; conceptualization. **Daisuke Matsuyoshi**: Writing—review and editing; project administration; methodology; investigation; formal analysis; data curation; conceptualization. **Ayako Isato**: Writing—review and editing; project administration; data curation. **Genichi Sugihara**: Writing—review and editing; project administration; methodology; investigation; formal analysis; conceptualization. **Hidehiko Takahashi**: Writing—review and editing; supervision; project administration; methodology; investigation; formal analysis; conceptualization. **Makiko Yamada**: Writing—review and editing; supervision; project administration; methodology; investigation; funding acquisition; formal analysis; data curation; conceptualization.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

DATA AVAILABILITY STATEMENT

The data supporting the findings of this study are subject to restrictions and cannot be shared publicly due to institutional policies.

ETHICS APPROVAL STATEMENT

The study was approved by the Committee of Ethics, National Institutes for Quantum Science and Technology, Japan.

PATIENT CONSENT STATEMENT

The data used in this study were collected under comprehensive consent for future research.

CLINICAL TRIAL REGISTRATION

N/A

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