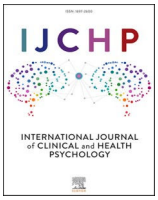
International Journal of Clinical and Health Psychology 24 (2024) 100521

Contents lists available at ScienceDirect

International Journal of Clinical and Health Psychology

journal homepage: www.elsevier.es/ijchp



Original article

Self-efficacy as a mediator of neuroticism and perceived stress: Neural perspectives on healthy aging

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ARTICLE INFO

Keywords:
Personality trait
Older adults
Structural MRI
Cortical thickness
Precuneus

ABSTRACT

The underlying mechanisms of the interconnections among neuroticism, self-efficacy, and perceived stress in younger and older adults are rarely studied simultaneously. Two hundred fourteen participants (128 younger adults aged 18–34 years and 86 older adults aged 60–89 years) were assessed using scales for neuroticism, self-efficacy, and perceived stress. A subsample (114 younger and 78 older adults) underwent brain magnetic resonance imaging scanning. Psychometric results suggested that older adults exhibited significantly lower levels of neuroticism and perceived stress, along with higher self-efficacy than younger adults. Mediation analyses revealed that self-efficacy significantly mediated the link between neuroticism and perceived stress in both age groups, demonstrating its protective role. Additionally, neuroimaging data suggested that the cortical thicknesses of several brain regions predicted perceived stress through the mediating role of neuroticism and self-efficacy, including the bilateral middle frontal gyrus, bilateral superior frontal gyrus, bilateral middle temporal gyrus, left superior temporal sulcus, bilateral anterior cingulate cortex, and right precuneus. In particular, the relationship between the right precuneus, neuroticism, and perceived stress suggested a reverse pattern across younger and older adults. These findings emphasize the importance of self-efficacy in mediating the impact of neuroticism on perceived stress and highlight the role of the right precuneus in guiding interventions that delay the transition from healthy to abnormal aging.

Introduction

Aging involves changes in the brain, thinking patterns, and how we perceive our surroundings (Paraskevoudi et al., 2018). Perceived stress, the most common subjective perception of the world, arises when environmental demands exceed an individual's coping ability, resulting in a feeling of pressure (Lazarus, 1974). This perceived stress is critical in both the onset and continuation of mental disorders (Zhu et al., 2022). For instance, prior research has indicated a link between higher levels of perceived stress and increased depressive symptoms among older adults (Cacioppo et al., 2006). Indeed, perceived stress serves as a negative indicator of diminishing executive function (Ihle et al., 2020) and, in turn, poorer mental health (Whitehead & Blaxton, 2021) in older adults.

The preference of an individual's coping style to stressors is a personality characteristic (Ursin & Eriksen, 2004). Neuroticism, a risk factor for stress-related disorders (Mohiyeddini et al., 2015), involves emotional instability and the experience of negative emotions (Ormel, Bastiaansen et al., 2013). Those with high neuroticism tend to worry and feel anxious, which is a trait associated with mental health problems such as depression and anxiety (Mohiyeddini et al., 2015). Previous research indicates that not only depressed patients exhibit higher levels of neuroticism than healthy people (Kotov et al., 2010), but also elevated neuroticism can lead to further depressive symptoms (Ormel, Jeronimus et al., 2013). These adverse effects may arise from how highly neurotic individuals manage stressors. Such individuals tend to perceive everyday situations as threats, report increased daily difficulties (Ebstrup et al., 2011), and evaluate events as extremely threatening while feeling low resources to cope (Carver & Connor-Smith, 2010). Consequently, those with elevated neuroticism exhibit heightened sensitivity to stressors (Mulders et al., 2018), and encounter greater negative affect, such as increased perceived stress, in their day-to-day life (Costa & McCrae, 1992; Curtis et al., 2015).

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https://doi.org/10.1016/j.ijchp.2024.100521
Received 20 October 2024; Accepted 7 November 2024
Available online 15 November 2024
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Research has shown a significant connection among personality traits, perceived stress, and coping styles (Bartley & Roesch, 2011; Besser & Shackelford, 2007; Bolger & Zuckerman, 1995; Conard & Matthews, 2008). Perceived self-efficacy involves individuals' judgments of their competence to handle challenging tasks in demanding situations (Scholz et al., 2002). As a positive appraisal outcome, it promotes healthy behaviors, fosters social connectedness, and enhances disease management skills (Schwarzer, 2014; Whitehall et al., 2021) by influencing the cognitive appraisal of stressful situations (Bandura & Wessels, 1997). Conversely, people with lower self-efficacy tend to rely on more passive coping strategies (Scheenen et al., 2017), perceiving stressors as overwhelming instead of challenging (Luszczynska et al., 2005). A meta-analysis has found that high neuroticism correlates with lower self-efficacy, plausibly because people's emotional instability hampers their choice for active coping with stressors (Barańczuk, 2021; Connor-Smith & Flachsbart, 2007). Meanwhile, self-efficacy was found to be negatively associated with perceived stress (Ebstrup et al., 2011; Şahin & Çetin, 2017), with higher self-efficacy modifying the appraisal process of stressful situations.

Furthermore, the Stress Transactional Model (Lazarus, 1990) suggests that individual characteristics, such as personality, perceived control, self-efficacy, and social skills, influence how people evaluate situations (i.e., appraisal) and cope with stressors, ultimately affecting perceived stress levels. Previous research supports this theory, indicating that self-efficacy mediates the connection between personality and perceived stress in young adults (Ebstrup et al., 2011; Şahin & Çetin, 2017; Wang et al., 2014). Contextual theory (Folkman & Lazarus, 1980) asserts that older adults encounter unique stressors that younger adults do not, primarily stemming from increased health-related demands. Mean-level personality traits, including neuroticism, shift throughout adulthood (Allemand et al., 2013), with neuroticism typically decreasing as age increases (Curtis et al., 2015; Simon et al., 2020). Fall-related self-efficacy has also been reported as a modifiable risk factor for healthy aging (Davis et al., 2012). Since older adults experience greater physiological vulnerabilities, they also demonstrate a reduction in coping resources and heightened feelings of stress (Chen et al., 2018). To our knowledge, no study has explored how self-efficacy affects the link between neuroticism and stress, despite the evidence available. It is essential to investigate whether the mediating effect of self-efficacy on the neuroticism-stress link extends to older adults. Given that neuroticism and perceived stress are potential risk factors for the onset of psychopathology, examining how age-related brain structure changes impact neuroticism and the mediating role of self-efficacy may illuminate the neurophysiological pathways through which neuroticism affects stress and help identify effective strategies for reducing stress perception in older age.

Neuroticism has been associated with regions in the frontal, parietal, and temporal lobes (Bjornebekk et al., 2013; Ueda et al., 2018). Existing neuroimaging studies demonstrated that personalities, including neuroticism, moderate the effect of age on brain structure (Bjornebekk et al., 2013; Jackson et al., 2011; Stolz et al., 2023; Wright et al., 2007). For example, higher neuroticism is linked to decreased gray matter volume in the lateral prefrontal and orbitofrontal cortices (Jackson et al., 2011) and is connected to variations in prefrontal cortical thickness in younger and also older adults (Wright et al., 2007, 2006). Moreover, neuroticism scores correlate negatively with the middle frontal (Britton et al., 2007; Kapogiannis et al., 2013), superior temporal (DeYoung, 2010), anterior cingulate, and parietal gyrus (Ueda et al., 2018). The prefrontal areas, particularly the superior prefrontal cortex, have been tied to perceived stress and are also related to neuroticism (Zhu et al., 2022). Additionally, the precuneus has been shown to play a role in processing emotional stimuli, engaging in self-referential mental processes (Kawakami et al., 2024), and contributing to subjective well-being (Sato et al., 2019). Given these findings, the precuneus likely influences how neuroticism affects stress perception. To our knowledge, current research primarily focuses on younger adults, and no study has examined age-related differences throughout the lifespan. As the brain structure of prefrontal regions and precuneus are altered with increased aging (Karas et al., 2007; Snytte et al., 2024), the impact of age-related changes on an individual's neuroticism remains uncertain. Furthermore, lower self-efficacy was related to decreased gray matter volume in older adults (Davis et al., 2012). It is not yet clear whether the protective benefits of self-efficacy can mitigate the effects of age-related structural brain changes on the relationship between neuroticism and perceived stress. Understanding how age impacts brain structure, neuroticism, and stress perception may enhance our insights into the role of brain structure in human emotional processing.

The current study aims to explore whether and how age affects the role of self-efficacy in the interplay between neuroticism and perceived stress. It focuses on several key questions: Are there differences across age groups in how self-efficacy mediates the link between neuroticism and perceived stress? If so, is it consistent between younger and older adults? How do age-related changes in brain structure affect the link between neuroticism and perceived stress? Furthermore, does the protective ability of self-efficacy help reduce the effects of age-related brain structure changes?

Methods

Participants

After excluding participants with missing data and those with MMSE scores below 27, two hundred fourteen participants were drawn from a public database (Spreng et al., 2022). These include 128 younger adults (18 - 34 years old) and 86 older adults (60 - 89 years old) (Table 1). Participants in this study were free from a history of neurological or other medical conditions that could affect cognitive function, as well as from acute or chronic psychiatric disorders. They had not received treatment with psychotropic medications and had not experienced significant health status changes at the time of the eligibility interview. No gender difference but significant differences in education and race were

Table 1
Demographic data of the participants.

Characteristic	n (%)	Younger adults	Older adults	*P*-values
Overall	214 (100.00)	128 (59.80)	86 (40.10)	0.004
Gender				0.464
Female	116 (54.20)	72 (56.20)	44 (51.10)	
Male	98 (45.70)	56 (43.70)	42 (48.80)	
Age (years), mean (SD)	41.12 (22.98)	22.74 (3.42)	68.48 (6.35)	<0.001
Race				<0.001
White	156 (72.80)	77 (60.10)	79 (91.80)	
Asian	25 (11.60)	24 (18.70)	1 (1.16)	
Black or African American	13 (6.00)	11 (8.50)	2 (2.32)	
Other	9 (4.20)	6 (4.60)	3 (3.49)	
Not provided	3 (1.40)	3 (2.30)	0	
Mixed	5 (2.33)	5 (3.90)	0	
Education (years), mean (SD)	16.15 (2.57)	15.25 (1.88)	17.49 (1.88)	<0.001
Ethnicity				0.071
Non-Hispanic or Latino	186 (86.90)	106 (82.80)	80 (93.00)	
Hispanic or Latino	11 (5.10)	8 (6.20)	3 (3.40)	
Not Provided	14 (6.50)	12 (9.30)	2 (2.30)	
MMSE, mean (SD)	29.03 (0.10)	29.25 (0.90)	28.71 (1.05)	<0.001
Neuroticism	2.49 (0.69)	2.70 (0.68)	2.18 (0.59)	<0.001
Self-efficacy	50.39 (8.93)	49.27 (8.14)	52.07 (9.80)	0.028
Perceived stress	48.27 (10.21)	52.31 (9.35)	42.27 (8.35)	<0.001

found between younger and older adults. All participants provided informed consent following the guidelines of the Institutional Review Board at Cornell University and York University.

Measurement and analysis of perceived stress, neuroticism, and self-efficacy

Neuroticism was measured using selected items from the Big Five Aspects Scale (DeYoung et al., 2007). Questions were answered on a five-point Likert scale ranging from "strongly disagree" to "strongly agree." Self-efficacy was measured using the general self-efficacy scale (Schwarzer & Jerusalem, 1995), part of the National Institutes of Health (NIH) Emotion Toolbox surveys. People with high scores will choose to perform more challenging tasks, set themselves higher goals, be more persistent, and recover more quickly in the face of setbacks. Perceived stress was assessed using the perceived stress scale from the NIH Emotion Toolbox (Cohen et al., 1995). The scale includes 14 items, asking for levels of experienced stress during the last month, with higher scores indicating higher perceived stress.

All behavioral variables were checked for outliers, and scores of more than three standard deviations above or below the mean were deleted. Raw individual perceived stress and self-efficacy scores were transformed into sample-based normalised *T*-scores. Statistical analyses were conducted using SPSS 26.0 software. Age differences in demographic information and neuroticism, self-efficacy, and perceived stress were measured using independent samples *t*-tests. Pearson correlation analyses were performed between these behavioral variables for all participants, younger and older adult groups. To explore how self-efficacy affects the association between neuroticism and perceived stress, Model 4 in PROCESS was applied to construct simple mediation models to analyse whether self-efficacy (mediation variable) mediates the association between neuroticism (input variable) and perceived stress (output variable). The bootstrap method was used to randomly sample 1000 times from the original sample to estimate the value of the indirect effect. If the 95 % corrected confidence intervals (CI) of the indirect effect value do not include zero, the indirect effect is statistically significant at the 0.05 level.

Magnetic resonance imaging data acquisition and statistical analysis

All the participants received magnetic resonance imaging scanning. Imaging data were acquired on a 3T GE750 Discovery series MRI scanner with a 32-channel head coil at the Cornell Magnetic Resonance Imaging Facility in Ithaca, NY, or on a 3T Siemens TimTrio MRI scanner with a 32-channel head coil at the York University Neuroimaging Center in Toronto, Canada. Scanning protocols were closely matched across sites. Anatomical scans at Cornell were acquired using a T1-weighted volumetric magnetisation prepared rapid gradient echo sequence (TR = 2530 ms; TE = 3.4 ms; 7°flip angle; 1-mm isotropic voxels, 176 slices) with 2 × acceleration with sensitivity encoding. At York, anatomical scans were acquired using a T1-weighted volumetric magnetisation prepared rapid gradient echo sequence (TR = 1900 ms; TE = 2.52 ms; 9°flip angle; 1-mm isotropic voxels, 192 slices) with 2 × acceleration and generalised auto-calibrating partially parallel acquisition (GRAPPA) encoding at an iPAT acceleration factor of 2.

Following a thorough quality check of the original structural and segmented images, we excluded fourteen younger adults and eight older adults, resulting in a total of 22 subjects removed for quality control. Consequently, the following analyses included one hundred ninety-two participants: 114 younger adults and 78 older adults. The structural images were analysed with Freesurfer version 7.4.1 using the pre-processing pipeline. After preprocessing, estimated total intracranial volume (eTIV) was extracted, and the gray matter thickness of the whole brain was parcellated with Destrieus atlas as the template (Destrieux et al., 2010). Based on previous studies, gray matter thicknesses of 12 brain regions were extracted as regions of interest (ROIs), including bilateral middle frontal gyrus, superior frontal gyrus, middle temporal gyrus, superior temporal sulcus, anterior cingulate cortex, and precuneus. Pearson correlation analyses were performed between behavioral variables and ROIs for all participants, the younger and older adult groups. Correction for multiple comparisons was performed using the Benjamini-Hochberg procedure (Benjamini & Hochberg, 1995). To examine how brain structure differences affect perceived stress, model 6 in PROCESS was adopted to construct chain mediation models to analyse whether neuroticism and self-efficacy (mediation variables) mediate the association between gray matter thickness of ROIs (input variable) and perceived stress (output variable). The bootstrap method and the significance level were set in the same way as the behavioral data analysis.

Results

Age differences in neuroticism, self-efficacy, and perceived stress

Compared to younger adults, older adults reported significantly lower scores in neuroticism ($t_{(212)} = 5.70$, $p < 0.001$), higher sense of self-efficacy ($t_{(212)} = -2.27$, $p < 0.05$), and less perceived stress ($t_{(212)} = 8.04$, $p < 0.001$).

Correlation and mediation model for neuroticism, self-efficacy, and perceived stress across age groups

In all participants, neuroticism was positively correlated with perceived stress ($r = 0.65$, $p < 0.001$) but negatively correlated with self-efficacy ($r = -0.34$, $p < 0.001$). Meanwhile, a negative correlation was observed between self-efficacy and perceived stress ($r = -0.44$, $p < 0.001$). The simple mediation analysis, with education and race as covariates, revealed the significant indirect effect of neuroticism on perceived stress via self-efficacy ($b = 1.62$, 95 % CI [0.06, 0.18]) and the significant direct effect ($b = 8.02$, 95 % CI [6.34, 9.60]) (Fig. 1a).

In younger adults, the simple mediation analysis reported a significant indirect effect of neuroticism on perceived stress via self-efficacy ($b = 1.01$, 95 % CI [0.02, 0.15]) and a significant direct effect ($b = 7.52$, 95 % CI [5.58, 9.46]) (Fig. 1b). The mediation analysis in older adults suggested a significant indirect effect of neuroticism on perceived stress via self-efficacy ($b = 1.26$, 95 % CI [0.00, 0.27]) and a significant direct effect ($b = 5.86$, 95 % CI [3.33, 8.39]) (Fig. 1c). These findings suggest the pathway "neuroticism—self-efficacy—perceived stress" in both younger and older adults.

Shared brain structural characteristics between perceived stress, self-efficacy, and neuroticism across age groups

Pearson correlation results (Table 2) reported positive correlations between the thickness of ROIs and neuroticism and self-efficacy. In addition, negative correlations were found between the thickness of ROIs and perceived stress. The following chain mediation analyses (Fig. 2a), which employ site, education, race, and estimated total intracranial volume as covariates, demonstrated that the thickness of all 12 ROIs except right superior temporal sulcus and left precuneus influences perceived stress via neuroticism and self-efficacy in all participants.

We examined whether the significant impact of those ten ROIs on behavioral variables in the chain model persisted in both the older and younger adult groups. The effect of thickness of the right precuneus in the pathway of neuroticism and self-efficacy between and perceived stress was significant in younger and older adults. In younger adults, the indirect effect was significant ($b = 12.87$, 95 % CI [0.04, 0.27]), and the direct effect was not significant ($b = 7.45$, 95 % CI [−4.66, 19.56]) (Fig. 2c). A similar pattern was reported in older adults, with the indirect effect showing significance ($b = -11.80$, 95 % CI [−0.32, −0.05]) and the direct effect reporting insignificance ($b = -0.88$, 95 % CI [−11.76,

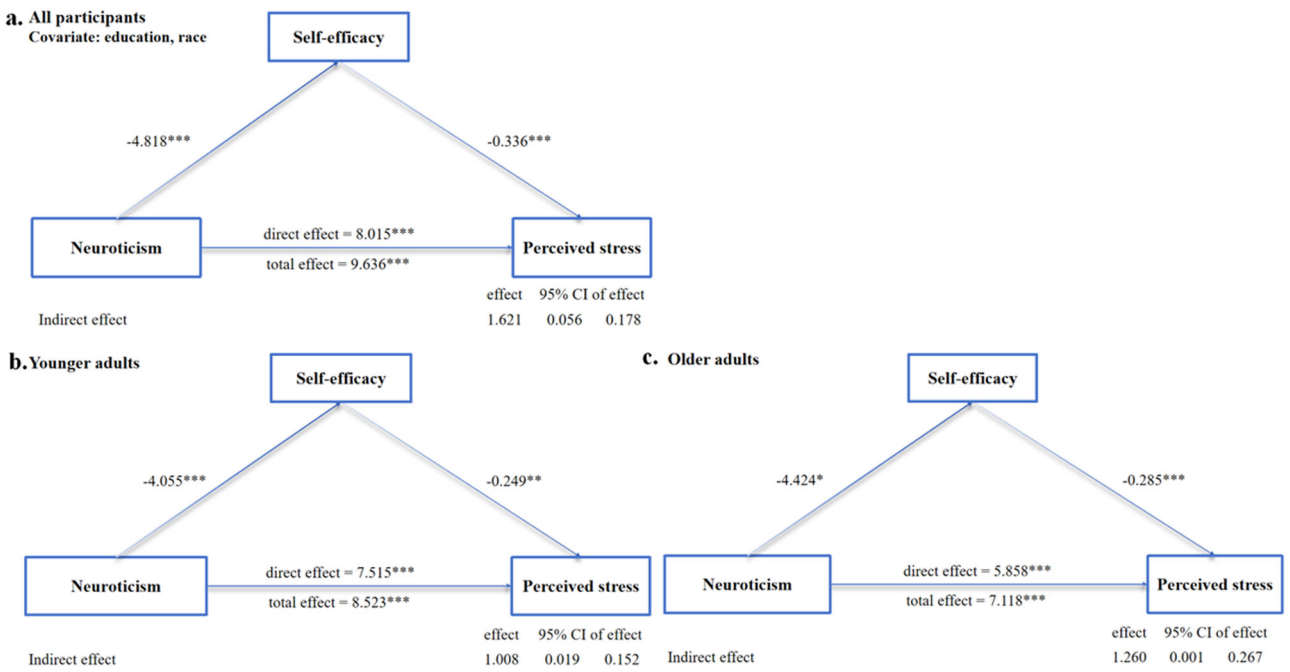

Fig. 1. Mediation models for neuroticism, self-efficacy, and perceived stress in all participants, older and younger adults.
Notes. The simple mediation model of self-efficacy mediated the relationship between neuroticism and perceived stress in all participants (a), younger adults (b), and older adults (c). CI, confidence intervals. *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

Table 2
The correlation between age, neuroticism, perceived stress, self-efficacy, and gray matter thickness of ROIs in all participants.

Thickness	Age	Neuroticism	Self-efficacy	Perceived stress
Left middle frontal gyrus	−0.668**	0.286**	−0.172*	0.389**
Right middle frontal gyrus	−0.600**	0.236**	−0.066	0.322**
Left superior frontal gyrus	−0.627**	0.264**	−0.158*	0.357**
Right superior frontal gyrus	−0.648**	0.236**	−0.106	0.330**
Left middle temporal gyrus	−0.592**	0.178*	−0.142	0.243**
Right middle temporal gyrus	−0.560**	0.198**	−0.140	0.294**
Left superior temporal sulcus	−0.627**	0.223**	−0.150*	0.334**
Right superior temporal sulcus	−0.594**	0.064	−0.032	0.227**
Left anterior cingulate cortex	−0.403**	0.172*	−0.042	0.219**
Right anterior cingulate cortex	−0.465**	0.156*	−0.058	0.220**
Left precuneus	−0.408**	0.141	−0.031	0.211**
Right precuneus	−0.554**	0.216**	−0.087	0.288**

Note. Corrected (Benjamini-Hochberg) two-tail Pearson correlation coefficients reported. *FDR $p < 0.05$, ** FDR $p < 0.01$, *** FDR $p < 0.001$.

10.00]) (Fig. 2d). This chain-mediated effect was not observed in younger and older adults in other ROIs than the right precuneus.

It is noteworthy that, despite the similarities in the models observed between the two age groups, the path coefficient from cortical thickness of the right precuneus to neuroticism exhibited an inverse relationship. Regression analyses revealed a positive association between right precuneus thickness and neuroticism in younger adults ($B = 1.48$, 95 % CI [0.37, 2.59], $b = 0.24$, $t = 2.61$, $p = 0.010$) contrasting with a negative association in older adults ($B = -0.98$, 95 % CI [−1.90, −0.06], $b = -0.23$, $t = -2.09$, $p = 0.040$). Similarly, regression analyses revealed a positive association between right precuneus thickness and perceived stress in younger adults ($B = 19.28$, 95 % CI [4.50, 34.06], $b = 0.24$, $t = 2.56$, $p = 0.01$) contrasting with a negative association in older adults ($B = -14.04$, 95 % CI [−27.30, −0.79], $b = -0.23$, $t = -2.08$, $p = 0.04$). The relationships between the gray matter thickness of the right precuneus and neuroticism and perceived stress are illustrated in Fig. 3.

Discussion

The current study provided evidence of the mediation effect of self-efficacy on the relationship between neuroticism and perceived stress in younger and older adults. To our knowledge, our study is the first to explore the underlying brain structure contributing to the pathway "neuroticism—self-efficacy—perceived stress." Results revealed that age-related variations in gray matter thickness of the bilateral prefrontal and temporal regions, anterior cingulate cortex, and right precuneus impacted the pathway. Notably, the right precuneus thickness positively predicted neuroticism and perceived stress in younger adults but exhibited an opposite trend in older adults. The findings indicated that an increased thickness of the right precuneus in younger adults was associated with a higher degree of neuroticism, which in turn was linked to reduced self-efficacy and elevated stress levels. In contrast, a higher reserved structure of the right precuneus in older adults is associated with decreased neuroticism, linked to enhanced self-efficacy and diminished stress. The current results enhance understanding of the neural mechanisms through which neuroticism and self-efficacy interact with precuneus in relation to perceived stress throughout healthy aging.

Consistent with previous research (Ebstrup et al., 2011; Şahin & Çetin, 2017; Wang et al., 2014), we found that self-efficacy can buffer perceived stress caused by neuroticism. This protective role of self-efficacy was further confirmed in both younger and older adults, demonstrating that this psychological mechanism is consistent across ages, as supported by the Stress Transactional Model (Lazarus, 1990). Individuals with high self-efficacy are likely to perceive stressful encounters as challenges and less likely to perceive them as threats (Bandura & Wessels, 1997). The negative impact of neuroticism on perceived stress can easily lead to subsequent adverse consequences

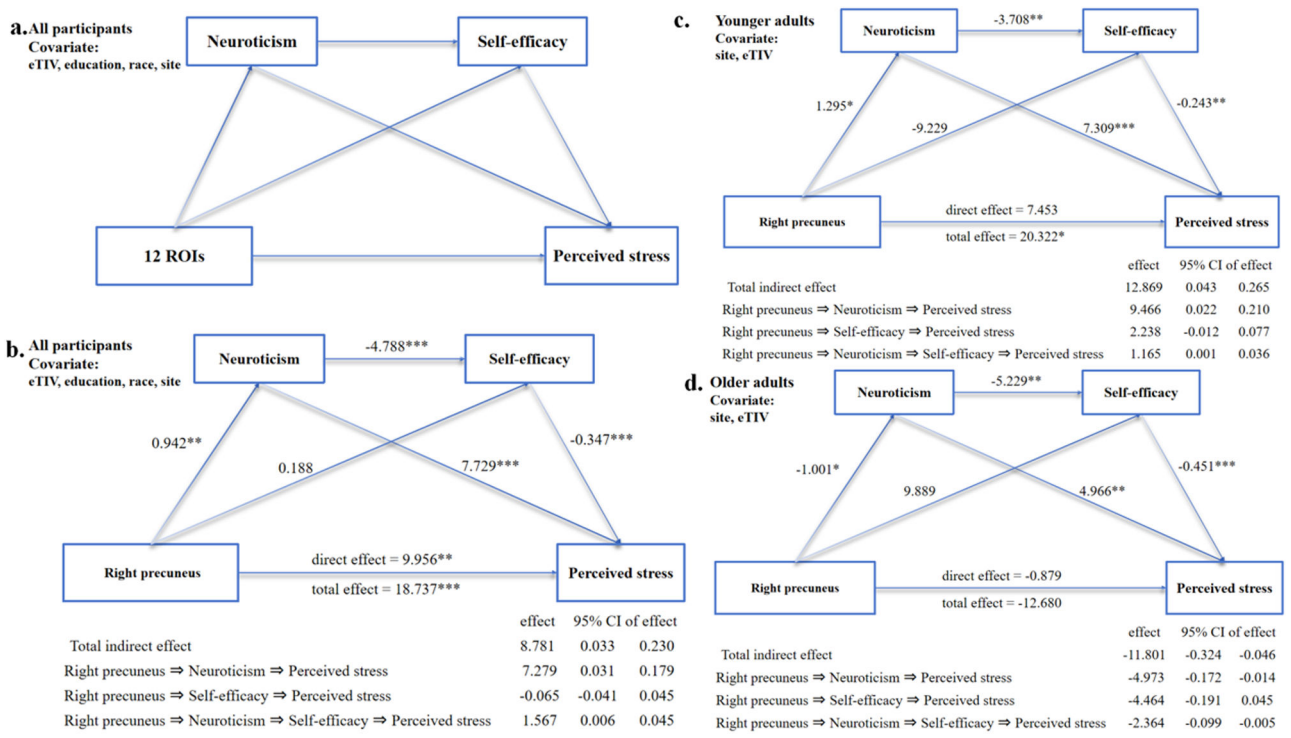

Fig. 2. Chain mediation between the cortical thickness of brain regions, neuroticism, self-efficacy, and perceived stress.
Note. **a.** The chain mediation effect of neuroticism and self-efficacy between the thickness of ROIs and perceived stress includes bilateral middle frontal gyrus, bilateral superior frontal gyrus, bilateral middle temporal gyrus, left superior temporal sulcus, bilateral anterior cingulate cortex, and right precuneus. **b/c/d.** The chain mediation effect of neuroticism and self-efficacy between the cortical thickness of the right precuneus and perceived stress in all participants (b), younger adults (c), and older adults (d). eTIV, estimated total intracranial volume. CI, confidence intervals. $*p < 0.05$, $**p < 0.01$, $***p < 0.001$.

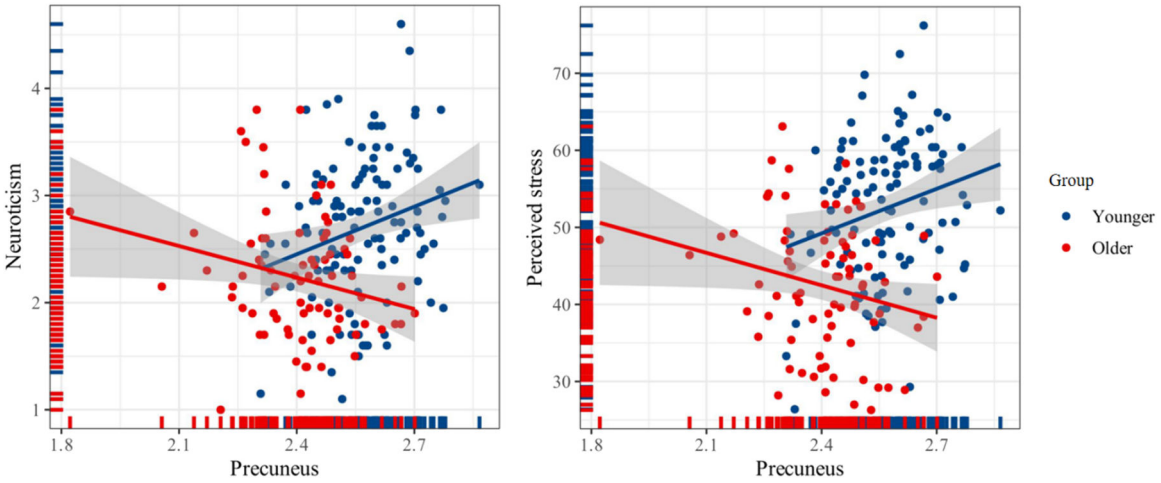

Fig. 3. Relationship between changes in neuroticism and perceived stress and the cortical thickness of the right precuneus in younger and older adults.

(Şahin & Çetin, 2017). The cognitive model of depression suggests that individuals with higher neuroticism, when activated by stressors, are more likely to develop ruminatively biased thinking and subsequently increase depressive severity (Kawakami et al., 2024). In addition, self-efficacy protects individuals against the negative effect of neuroticism on increased perceived stress (Şahin & Çetin, 2017).

The neuroimaging data supported the mediation effect of self-efficacy on the relationship between neuroticism and perceived stress in all participants. They revealed that the left superior/middle frontal and temporal regions predicted the pathway from neuroticism and self-efficacy to perceived stress in both age groups. Consistent with previous studies, the superior frontal and upper parts of the middle frontal cortex represent the dorsolateral and dorsomedial prefrontal cortex, relating to neuroticism and perceived stress. The lateral and dorsomedial prefrontal cortex has been suggested to integrate multisensory processing within temporal cortices (Petrides, 2023), which is involved in attention and episodic control, such as retrieving specific past experiences to trigger specific actions (Levy, 2024). Thus, increased lateral and dorsomedial prefrontal cortex support subjective awareness of neuroticism (Jackson et al., 2011; Wright et al., 2007) and are sensitive to the detrimental effects of stressors, resulting in perceived stress (Zhu et al., 2022).

Interestingly, gray matter thickness of the right precuneus was found to predict perceived stress through the mediation of neuroticism in all participants, as well as younger and older adults. Precuneus has been

suggested to be related to mentalizing (Hyatt et al., 2015) and ruminative self-referential processing (Jones & Bhattacharya, 2014), while increased activity in precuneus was associated with decreased subjective well-being (Sato et al., 2019). The role of precuneus in neuroticism and perceived stress suggests excessive self-reference and ruminative thinking increase neurotic cognitive tendencies, thus increasing perceived stress (Kawakami et al., 2024). Moreover, consistent with previous findings reporting a correlation between neuroticism and precuneus (Ueda et al., 2018), the current study demonstrated that higher cortical thickness of the right precuneus suggests higher neuroticism and perceived stress in younger adults. As a rich hub of the default mode network, precuneus functionally facilitates episodic memory and self-referential thinking (Dadario & Sughrue, 2023). Increased gray matter thickness of the precuneus is positively correlated to depression/anxiety scores in young adults (Ducharme et al., 2014). Also, the precuneus connects with other brain regions to be the para-cingulate network, supporting multiple self-referential processes, including emotional face recognition, self-knowledge, interoception, fear, grief, and interference control (Dadario & Sughrue, 2023). The connections can induce hyperactive processing of negative faces in depression patients (Stuhrmann et al., 2011).

Notably, the connections we identified between the cortical thickness of the right precuneus, neuroticism, and perceived stress were reversed in older adults, indicating negative trends. This age-dependent brain-behavior relationship could be tied to the extensive alterations in the precuneus in late adulthood (Karas et al., 2007), alongside decreased neuroticism and increased self-efficacy that might influence perceived stress. In our cohort of older adults, the preserved structure of the precuneus supports its structural connectivity for efficient complex processing within cortical regions (Cavanna & Trimble, 2006; Dadario & Sughrue, 2023). Cortical thickness loss of the precuneus among older adults may disrupt its links to other brain areas, resulting in dysfunctions within the default mode network and impairing higher-order cognitions, emotion regulation (Ferri et al., 2016; Utevsky et al., 2014), and perceived stress (Archer et al., 2018). For example, the diminished thickness of the precuneus has been observed in individuals showing higher trait anxiety (Knowles & Olatunji, 2020) and those with early-onset Alzheimer's disease (Karas et al., 2007). This study indicated that healthy aging in our sample is significantly associated with lower neuroticism, greater self-efficacy, and reduced perceived stress. Within healthy aging, the brain structure of the right precuneus differs between successful aging individuals and those at risk (Grennan et al., 2022), potentially serving as a risk factor for perceived stress.

This evidence indicates that the precuneus may play a significant role in depressive symptoms (Dadario & Sughrue, 2023) through the pathway involving neuroticism, self-efficacy, and perceived stress. In the current study, the pathway encompassing "right precuneus - neuroticism - self-efficacy - perceived stress" comprised four levels of evidence: brain structure, personality traits, cognitive appraisal, and emotional state. The relationship among these levels represents a top-down process, starting from physiological alterations in the brain at the highest level, transitioning through comparatively stable personality traits to mid-level self-efficacy (which includes knowledge, appraisals, and self-perspectives), and ultimately affecting perceived stress, which is most sensitive to environmental changes. Especially in healthy aging, this approach can provide a unique perspective on examining alterations in the structure and function of the precuneus during healthy aging. Such alterations may be a potential risk factor for psychopathological and neurocognitive disorders. Understanding and mapping this progression is crucial for guiding interventions that delay the transition from normative to non-normative aging.

This study has several limitations. Firstly, the cross-sectional design limits the capacity to draw causal links between brain structure, neuroticism, self-efficacy, and perceived stress. Longitudinal studies are essential for gaining a clearer understanding of temporal relationships. Secondly, the research focused solely on healthy adults living in the community, which might restrict the relevance of the results to clinical groups where neuroticism and stress perceptions may differ. Additional studies should incorporate individuals with diagnosed psychological disorders to investigate the variations in neuroticism and perceived stress. Furthermore, using self-reported measures for neuroticism, self-efficacy, and perceived stress can lead to response biases because participants may not accurately reflect their experiences or may be swayed by social desirability. To overcome the limitations of subjective measurements, incorporating more objective indicators—like skin conductance or the rate of medical visits—can yield a more thorough assessment.

In conclusion, this research offers important insights into how neuroticism, self-efficacy, and perceived stress interact in the context of healthy aging. The results indicate that neuroticism is positively linked to perceived stress, while self-efficacy serves as a protective factor that can lessen this connection. Furthermore, the study highlights that older individuals may experience stress perception through mechanisms different from those of younger people. Recognizing the relationship between brain structure and perceived stress in aging is essential for creating targeted interventions that promote better mental health and enhanced subjective well-being. Future investigations should delve into the neurophysiological mechanisms behind these relationships and explore the potential for interventions that strengthen self-efficacy to reduce stress perceptions among older adults.

Declaration of competing interest

The authors declare that they have no competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

This work was supported by Start-up Research Grant (SRG2022–00025-FSS) and Multi-Year Rearch Grant (MYRG2022-00130-FSS) funded by the University of Macau. This work was performed in part at the High Performance Computing Cluster (HPCC) which is supported by Information and Communication Technology Office (ICTO) of the University of Macau.

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