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Running head: Posterior precuneus and general self-efficacy

Regional gray matter volume in the posterior precuneus is associated with general self-efficacy

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27 **Abstract**

28 Motivation in doing a task is influenced not only by the expected outcome of the task,
29 but also by the belief that one has in successfully executing the task. Over time, individuals
30 accumulate experiences that contribute to a general belief in one's overall ability to
31 successfully perform tasks, which is called general self-efficacy (GSE). We investigated the
32 relationship between regional gray matter volume and individual differences in GSE. Brain
33 anatomy was analyzed using magnetic resonance images obtained from 64 healthy
34 right-handed participants who had completed Sherer's GSE scale. After controlling for other
35 factors related to motivation, age, sex, and total gray matter volume of each subject, results
36 showed that regional gray matter volume in the posterior part of the precuneus significantly
37 and positively correlated with GSE score. These results suggest that one's accumulated
38 experiences of success and failure, which contribute to GSE, also influence the anatomical
39 characteristics of the precuneus.

40

41 **Keywords**

42 VBM; General self-efficacy; Precuneus; Motivation

43 **Introduction**

44 One is constantly making decisions about what actions to take, and each decision is
45 influenced by one's motivation to perform a given action. Motivation for completing a task is
46 based not only on the expected outcome of that action, but also on the predicted likelihood of
47 successfully completing that action. This concept of "self-efficacy," proposed by Albert
48 Bandura decades ago [1], has been used to explain the motivational aspects of behaviors such
49 as resilience to failure [2], amount of time spent doing a task [3] and actual performance [4].

50 As Bandura stated, self-efficacy is largely affected by past experiences with the same
51 task that the agent is about to do; experience of success will increase self-efficacy, and vice
52 versa [5]. There are individual differences in the strength of one's belief in their ability to
53 succeed in a variety of tasks, which is called general self-efficacy (GSE) [6]. GSE results
54 from past outcomes of tasks and will affect our motivation to do them. We process outcome
55 information of our actions, and our neural mechanisms change anatomically by this
56 processing [7]. Since GSE is a grand sum of these experiences, the brain regions that would
57 be most relevant to GSE would likely be regions that process outcomes of tasks and
58 expectation of future outcomes. Therefore we hypothesized that individual differences in
59 GSE may also be reflected in the brain structure.

60 In the present paper, we investigated the regional gray matter volume specific to GSE.
61 GSE correlates with other factors related to motivation, such as subjective evaluation of self
62 worth or self-esteem [8], desire for accomplishment or achievement motivation [9], and
63 sensitivity to punishment or behavioral inhibition [10]. Therefore, we used subjects' scores
64 on questionnaires related to these factors in order to exclude them. Thus we found a
65 significant correlation between gray matter volume in the posterior precuneus and GSE
66 specifically.

67 **Methods**

68 *Participants.* Sixty-four healthy participants [mean age = 20.1, SD = 1.4, 29 males] recruited
69 from Tamagawa University (Tokyo, Japan) took part in this study. All participants gave
70 written informed consent and the experimental protocol was approved by the Ethics
71 Committee of Tamagawa University.

72 *Questionnaire.* Self-reported GSE was measured using a questionnaire developed by Sherer
73 and colleagues [6], which was translated into Japanese and its reliability and validity was
74 demonstrated in Japanese subjects [11]. The GSE scale consists of 23 items, with responses
75 made on a 5-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). In
76 order to find a gray matter region that specifically correlates with GSE score, we used other
77 personality questionnaires that are related to motivation and hypothesized to correlate with
78 the GSE scale as controls. These questionnaires included a self-esteem scale [12; 13], a
79 behavioral inhibition system and behavioral activation system (BIS/BAS) scale [14; 15] and
80 an achievement motivation scale [16]. For each questionnaire used in the study, validity was
81 verified by correlation with the indexes that the questionnaire is predicted to reflect;
82 reliability was verified by correlation between two tests done within a few weeks [12; 14; 16].
83 The internal reliabilities for each questionnaire measured by Cronbach's alpha were: GSE, α
84 = 0.80; self-esteem, α = 0.79; BIS, α = 0.79; BAS, α = 0.75; achievement motivation, α =
85 0.72.

86 *Neural data acquisition & analysis.* A structural image of the brain was acquired for each
87 subject using a 3-tesla Siemens Trio A Tim MRI scanner with a 32-channel head coil. T1
88 weighted images were acquired using the 3D-MPRAGE sequence [TR = 2000 ms, TE = 1.98
89 ms, TI = 900 ms, Flip angle = 10 degrees, Echo space = 6.1 ms, Field of view = 256 × 256
90 mm, 192 slices, voxel size = 1 × 1 × 1 mm] which took about 5 minutes. To correct for
91 B1 inhomogeneities, images were reconstructed using pre-scan normalization. Image analysis

92 was performed using Statistical Parametric Mapping software (SPM version 8;
93 <http://www.fil.ion.ucl.ac.uk>). Preprocessing of the structural images was done by segmenting
94 the brain tissues into six categories (Gray matter, White matter, CSF, Skull, Soft tissue, Air)
95 based on the East Asian brain template. We used diffeomorphic anatomical registration using
96 exponentiated lie algebra (DARTEL) to improve the realignment of small inner structures.
97 Registered images were smoothed with a gaussian kernel (full width at half maximum = 8
98 mm) and were transformed to Montreal Neurological Institute (MNI) stereotactic space using
99 affine and non-linear spatial normalization.

100 In order to limit the analysis to voxels that would include gray matter, we created a
101 binary mask to include the voxels with a gray matter probability of over 30% in the gray
102 matter template (grey.nii), and we excluded all of the other voxels from the multiple
103 comparison [17]. In the whole-brain multiple regression analysis using a generalized linear
104 model (GLM), we tested for a relationship between GSE score and regional gray matter
105 volume. Age, sex, and total gray matter volume were included in the GLM as covariates of no
106 interest, in order to regress out the effects correlating with these variables. This was also true
107 for other personality scores related to motivation (i.e. self-esteem, BIS/BAS and achievement
108 motivation). The total gray matter volume was calculated for each participant as the total gray
109 matter within the voxels that were included in the multiple comparison. The threshold was set
110 to family-wise error (FWE)-corrected at a cluster-level of $p < 0.05$ after thresholding at $p <$
111 0.001 in the whole brain, in order to find a region specifically correlated with GSE, but not
112 with other similar personality concepts.

113 **Results**

114 The correlation analysis showed a significant correlation between GSE score and other
115 questionnaires as seen in previous studies: self-esteem, $r = 0.332$, $P = 0.007$; BIS, $r = -0.355$,
116 $P = 0.004$; BAS, $r = 0.296$, $P = 0.018$; achievement motivation, $r = 0.533$, $P < 0.001$ [6; 9; 10]
117 (Table 1). The GSE score positively correlated with the gray matter volume in the right
118 posterior precuneus ($x = 5$, $y = -72$, $z = 50$; $t = 4.85$; standard partial regression coefficients:
119 GSE: $\beta = 0.620$, self-esteem: $\beta = -0.114$, BIS: $\beta = 0.192$, BAS: $\beta = -0.218$, achievement
120 motivation: $\beta = -0.135$) (Fig. 1). Within the same GLM, other questionnaires showed no
121 significant relation with the gray matter volume in any part of the brain (including the
122 precuneus) that would exceed the threshold set for the multiple comparison.

123 **Discussion**

124 In the present study, we investigated the relationship between regional gray matter
125 volume and individual differences in GSE. We found that the gray matter volume in the
126 posterior precuneus showed a positive correlation with GSE across subjects. No significant
127 relation was found between other questionnaires related to motivation (i.e., Achievement
128 Motivation, Self-esteem, and BIS/BAS) and gray matter volume (which exceeded the
129 threshold for multiple comparison within the whole brain), even though these questionnaires
130 showed significant correlation with GSE score. Thus, the GSE appears to be specifically
131 correlated with the gray matter volume within the posterior precuneus.

132 Since GSE correlates with the other questionnaires, it is assumed that there is an
133 overlap between these traits. However, since we have identified that the precuneus has a
134 specific relationship with GSE, we discuss below the distinct features of GSE that may relate
135 to the function of the precuneus.

136 The precuneus, especially its posterior part, has been associated with episodic memory
137 [18]. Firstly, the precuneus shows activity during the retrieval of autobiographical events
138 compared to general memories about the past [19]. Secondly, it has been shown that when we
139 predict what will happen in the future, a neural network including the precuneus that is
140 needed to recall past experiences is activated [20]. Finally, the gray matter volume in a part
141 of the precuneus correlates with the tendency for an individual to take first-person
142 perspective when recalling autobiographical memories [21]. Thus, the precuneus seems to
143 accumulate past experiences and create a self-image in relation with the outside world. Since
144 the GSE is not determined by one's experience of a single task, but rather the accumulated
145 experiences that add up to a general expectation that an individual holds before executing a
146 task [1; 6], it seems reasonable that the precuneus is a key region involved in GSE.

147 Since the degree of self-efficacy one experiences in a task is related to past and present
148 success or failure, it makes sense that the parts of the brain where feedback is processed
149 would show a correlation with GSE score. In fact, Themanson and colleagues found that the
150 amplitude of error-related negativity (ERN), which is generated in the medial prefrontal
151 cortex after an error is made during a task, positively correlates with self-efficacy and
152 post-error performance on that task [22]. The present results concerning GSE, however, point
153 to a gray-matter region that stores episodic memories (posterior precuneus), rather than
154 regions that are involved in feedback processing. One possibility is that the degree of
155 self-efficacy one experiences in various tasks is gathered in the precuneus and sums up to
156 determine a person's degree of GSE, which is represented by the gray matter volume in the
157 posterior precuneus. This idea is supported by the fact that the precuneus is functionally and
158 anatomically interconnected with regions including the medial prefrontal cortex [18; 23; 24].

159 This study is subjected to the limitations of the method of voxel-based morphometry
160 (VBM). Since there is only the information about the volume of gray matter within the voxel,
161 how the gray matter is structured within that voxel cannot be assumed from VBM.
162 Differences in gray matter volume may result from folding within that voxel rather than from
163 actual differences in thickness [25]. The underlying biological structure of the differences
164 between gray matter volume between individuals needs further investigation.

165 Our finding opens the door to new questions in both neuroscience and psychology,
166 challenging ideas about how personality affects decision-making and how decisions affect
167 personality. Specifically, we hope to address three new questions raised by the current
168 findings: 1) how is information integrated in the precuneus, 2) how could differences in GSE
169 be represented by precuneus gray matter volume differences, and 3) how might accumulated
170 information in the precuneus actually affect our actions or decisions.

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- 237

238 Table 1 Correlation between GSE scale and other questionnaires
 239

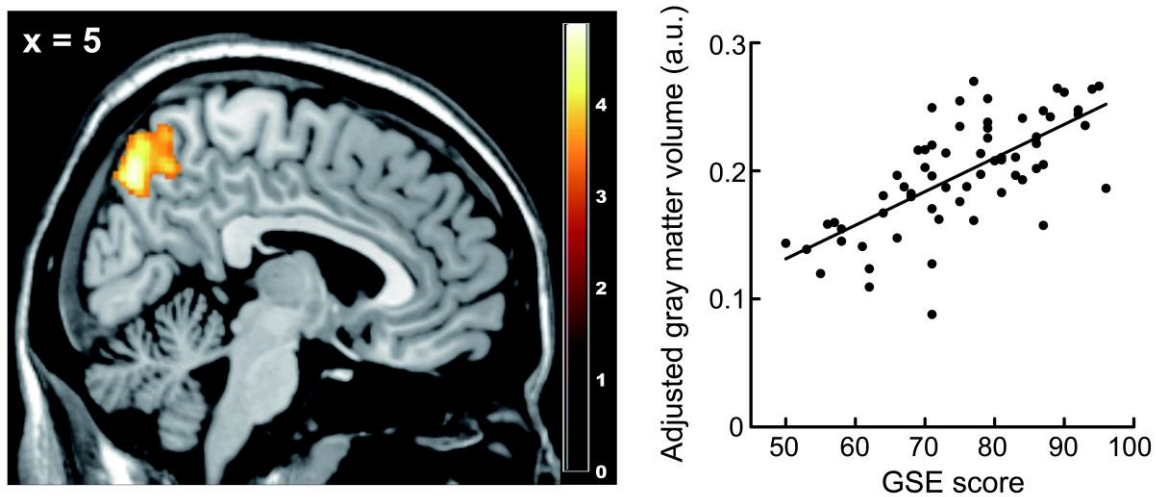
Self-esteem	BIS	BAS	Achievement motivation
0.332 **	-0.355 **	0.296 *	0.533 ***

240

241 * P < 0.05, ** P < 0.01, *** P < 0.001

242 GSE = general self-efficacy, BIS = behavioral inhibition system, BAS = behavioral activation
 243 system

244



245

246 Fig. 1 Region where gray matter volume showed significant association with GSE score

247 Left: Gray matter volume in the right posterior precuneus (x=5, y=-72, z=50; t = 4.85)

248 showed significant positive correlation with GSE scale. Scale shows the t-value. Right: A

249 scatter plot of the adjusted gray matter volume taken from the peak voxel, as a function of

250 GSE score. This plot is shown only for illustrative purpose and was not used for any

251 statistical inference.