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2 Running head: Posterior precuneus and general self-efficacy

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5 with general self-efficacy

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21

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

Introduction

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

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

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

Methods

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 $\times$ 256

90   mm, 192 slices, voxel size = 1 $\times$ 1 $\times$ 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.

Discussion

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.

171 **Acknowledgement**

175 **References**

176 1. Bandura A. Self-efficacy: Toward a unifying theory of behavioral change.
177   *Psychological Review* 1977; **84**: 191–215.

178 2. Lyman RD, Prentice-Dunn S, Wilson DR, Bonfilio SA. The effect of success or failure
179   on self-efficacy and task persistence of conduct-disordered children. *Psychol Schs*
180   1984; **21**: 516–519.

181 3. Brown I, Inouye DK. Learned helplessness through modeling: The role of perceived
182   similarity in competence. *JPSP* 1978; **36**: 900–908.

183 4. Phillips JM, Gully SM. Role of goal orientation, ability, need for achievement, and
184   locus of control in the self-efficacy and goal-setting process. *J Appl Psychol* 1997; **82**:
185   792–802.

186 5. Bandura A. *Social foundations of thought and action: A social cognitive theory.*
187   Englewood Cliffs, NJ, US: Prentice-Hall, Inc; 1986.

188 6. Sherer M, Maddux JE, Mercandante B, Prentice-Dunn S, Jacobs B, Rogers RW. The
189   Self-Efficacy Scale: Construction and Validation. *Psychol Rep* 1982; **51**: 663–671.

190 7. Zatorre RJ, Fields RD, Johansen-Berg H. Plasticity in gray and white: neuroimaging
191   changes in brain structure during learning. *Nat Neurosci* 2012; **15**: 528–536.

192 8. Judge TA, Erez A, Bono JE, Thoresen CJ. Are measures of self-esteem, neuroticism,
193   locus of control, and generalized self-efficacy indicators of a common core construct?
194   *JPSP* 2002; **83**: 693–710.

195 9. Bartels JM. Dispositional Positive and Negative Affect and Approach-Avoidance
196   Achievement Motivation. *Individ Differ Res* 2007; **5**: 246–259.

197 10. Fennis BM, Andreassen TW, Lervik-Olsen L. Behavioral Disinhibition Can Foster
198   Intentions to Healthy Lifestyle Change by Overcoming Commitment to Past Behavior.
199   *PLoS ONE* 2015; **10**: e0142489.

200 11. Narita K, Shimonaka Y, Nakazato K, Kawaai C, Sato S, Osada Y. A Japanese Version
201   of the Generalized Self-Efficacy Scale. *The Japanese Journal of Educational*
202   *Psychology* 1995; **43**: 306–314.

203 12. Rosenberg M. *Society and the adolescent self-image*. Princeton, N.J: Princeton
204   University Press; 1965.

205 13. Hoshino A. Psychology of emotion and education Ⅱ (in Japanese). *Child Study* 1970;
206   **24**: 1445–1477.

207 14. Carver CS, White TL. Behavioral inhibition, behavioral activation, and affective
208   responses to impending reward and punishment: The BIS/BAS Scales. *JPSP* 1994; **67**:
209   319–333.

210   15.   Takahashi Y, Yamagata S, Kijima N, Shigemasu K, Ono Y, Ando J. Gray's
211   Temperament Model : Development of Japanese Version of BIS/BAS Scales and A
212   Behavior Genetic Investigation Using the Twin Method. *The Japanese Journal of*
213   *Personality* 2007; **15**: 276–289.

214   16.   Jackson DN. *Personality Research Form Manual*. Research Psychologists Press; 1974.

215   17.   Fleming SM, Weil RS, Nagy Z, Dolan RJ, Rees G. Relating introspective accuracy to
216   individual differences in brain structure. *Science* 2010; **329**: 1541–1543.

217   18.   Cavanna AE, Trimble MR. The precuneus: a review of its functional anatomy and
218   behavioural correlates. *Brain* 2006; **129**: 564–583.

219   19.   Addis DR, McIntosh AR, Moscovitch M, Crawley AP, McAndrews MP.
220   Characterizing spatial and temporal features of autobiographical memory retrieval
221   networks: a partial least squares approach. *NeuroImage* 2004; **23**: 1460–1471.

222   20.   Addis DR, Wong AT, Schacter DL. Remembering the past and imagining the future:
223   Common and distinct neural substrates during event construction and elaboration.
224   *Neuropsychologia* 2007; **45**: 1363–1377.

225   21.   Freton M, Lemogne C, Bergouignan L, Delaveau P, Lehéricy S, Fossati P. The eye of
226   the self: precuneus volume and visual perspective during autobiographical memory
227   retrieval. *Brain Struct Funct* 2014; **219**: 959–968.

228   22.   Themanson JR, Pontifex MB, Hillman CH, McAuley E. The relation of self-efficacy
229   and error-related self-regulation. *Int J Psychophysiol* 2011; **80**: 1–10.

230   23.   Margulies DS, Vincent JL, Kelly C, Lohmann G, Uddin LQ, Biswal BB, et al.
231   Precuneus shares intrinsic functional architecture in humans and monkeys. *PNAS*
232   2009; **106**: 20069–20074.

233   24.   Zhang S, Li C-SR. Functional connectivity mapping of the human precuneus by
234   resting state fMRI. *NeuroImage* 2012; **59**: 3548–3562.

235   25.   Mechelli A, Price CJ, Friston KJ, Ashburner J. Voxel-Based Morphometry of the
236   Human Brain: Methods and Applications. *CMIR* 2005; **1**: 105–113.

237

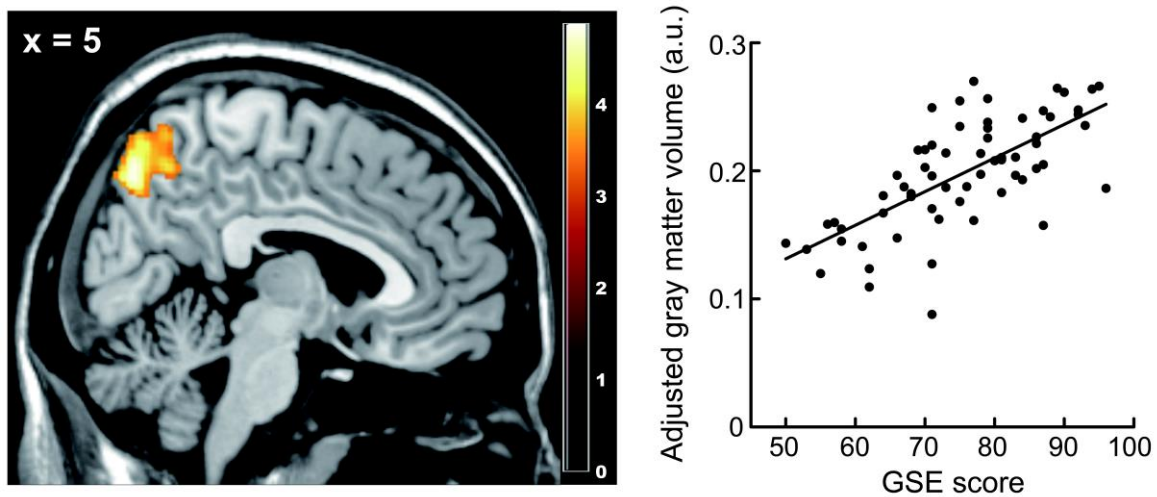238   Table 1 Correlation between GSE scale and other questionnaires
239

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.