Medial prefrontal cortex - dorsal anterior cingulate cortex connectivity during behavior selection without an objective correct answer

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Introduction

Life choices (e.g. Choosing an occupation) often include situations with two or more possible answers. How does the brain respond to such conflict-ridden situations?

● Previous studies have been predominantly on behavior selection with only one correct answer, as for instance during the Stroop task, and have documented that greater dorsal anterior cingulate cortex (dACC) activation is observed when participants are confronted with situations requiring detection of conflict[1].

● There are, however, situations in which we are confronted with many possible correct answers with none being a readily apparent erroneous answer. The absence of an objectively correct answer seems to go along with the additional recruitment of the medial prefrontal cortex (MPFC; Brodmann area 9, 10) accompanying activation in dACC [2].

● The dACC is thought to mediate the evaluation of conflict between possible correct answers, although the MPFC is thought to associate with reduction of the conflict by biasing either choice of behavior[3-5].
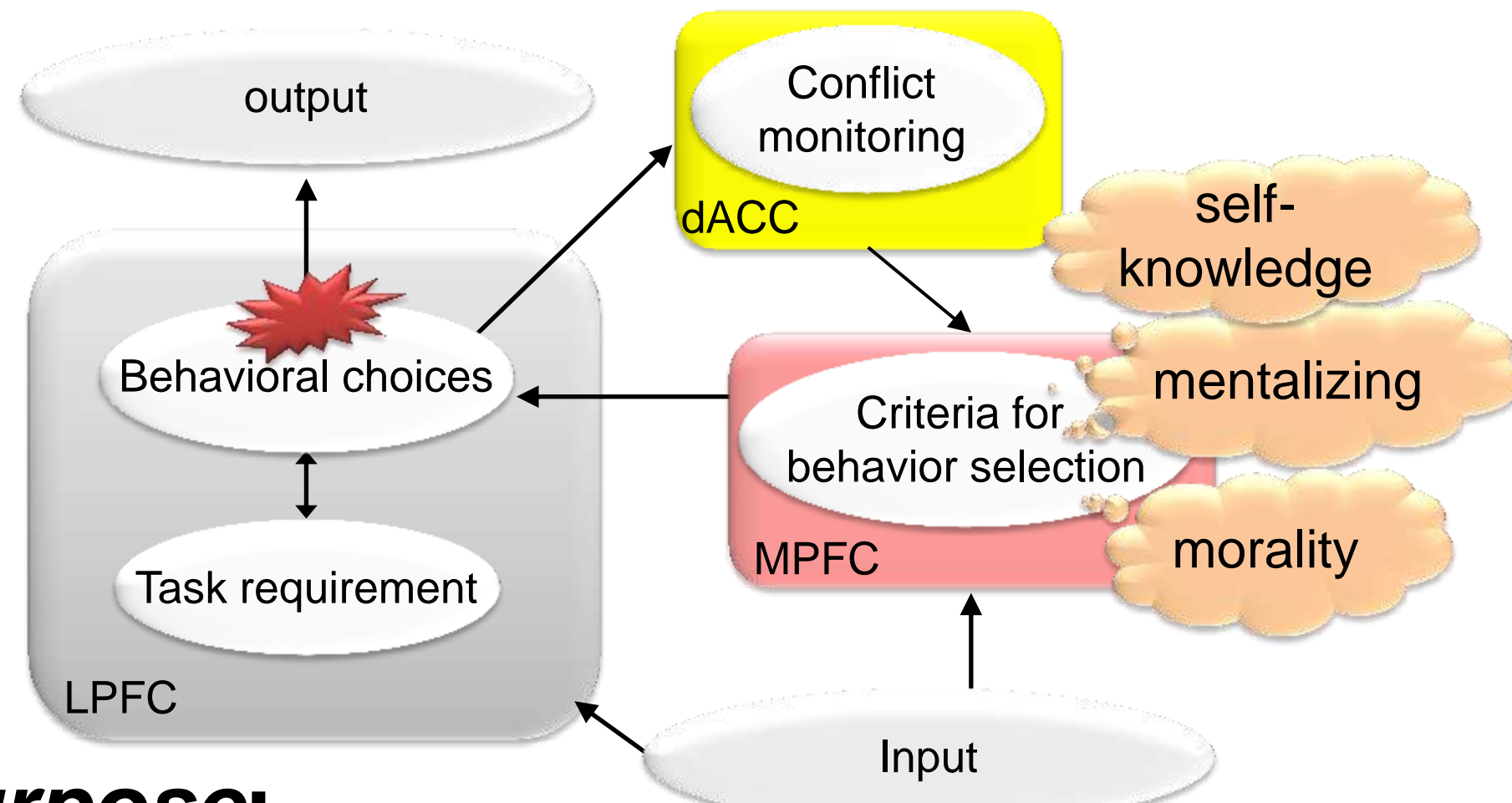
Fig.1. Schematic figure of relation among prefrontal region. To reduce conflict, the MPFC is activated in reaction to dACC activation, especially when no objective correct answer exists [3-5].

Purpose:

We investigated
1. whether the dACC evaluates the degree of conflict between possible answers.
2. whether the MPFC has a function in behavior selection without a correct answer.
3. whether the MPFC has functional connectivity with dACC only in a situation without a correct answer.

Method

Participants: Fourteen healthy participants(7 male; M= 22.1 years) volunteered.

Stimuli: The stimuli were 216 occupation-related words .

Task and design:

	Occupational choice task (no correct answer)	Word-length task (one correct answer)
Large conflict	**Which occupation do you think you would do well?** Politician Lawyer Word pairs with **equal differences in their respective <u>rating value</u>**	**Which word is longer?** Dentist Chemist Word pairs for which **the difference of the word lengths was one**
Small conflict	**Which occupation do you think you would do well?** Scientist Comedian Word pairs for which **the difference of the <u>rating value</u> was two or three**	**Which word is longer?** Chef Dancer Word pairs for which **the difference of word lengths was more than two**

Fig.2. Task and design

Procedure:

● The ratings were assigned by each participant 7-10 days before the fMRI experiment. Participants rated how well they thought they could perform the occupation using a scale of 1-4 for all occupational words.

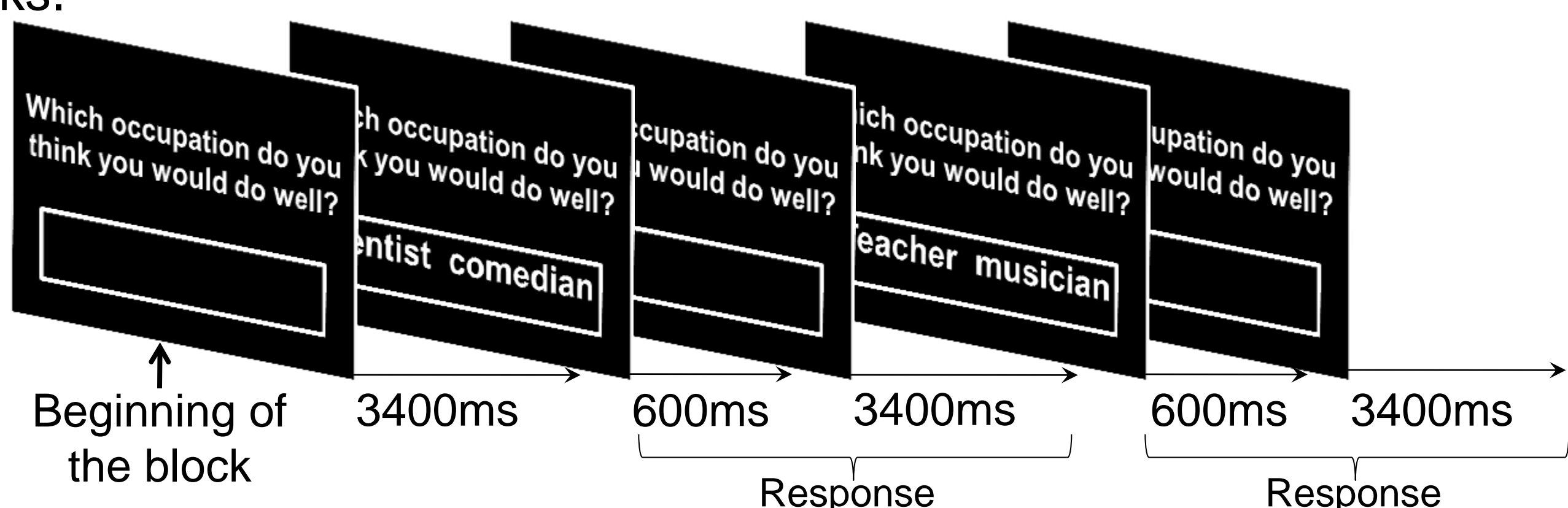● As the fMRI experiment, participants performed 12 blocks of 9 trials of tasks.

Beginning of the block   3400ms   600ms   3400ms   600ms   3400ms
                                  Response   Response

Fig.3. Flow of the two trials of the Occupational choice task

Results and Discussion
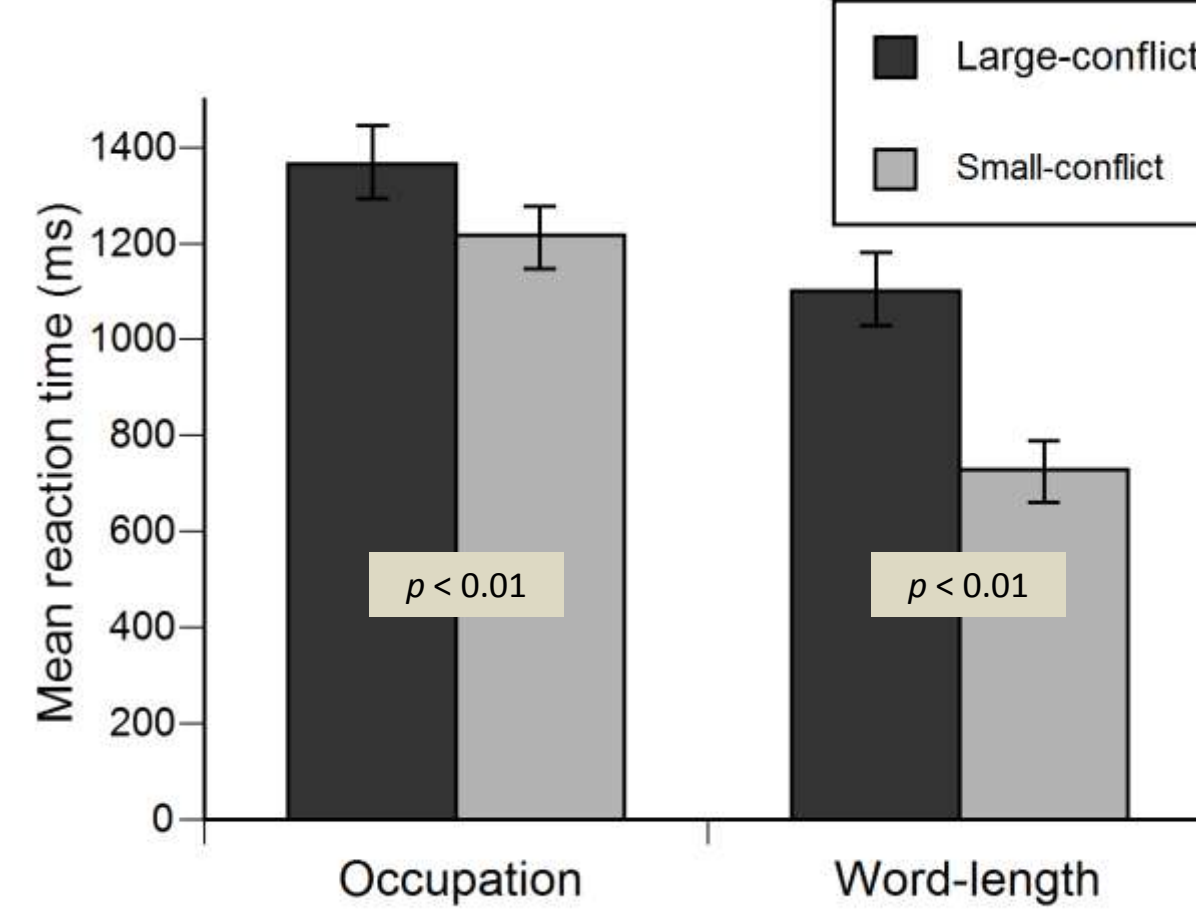
Behavioral Performance:

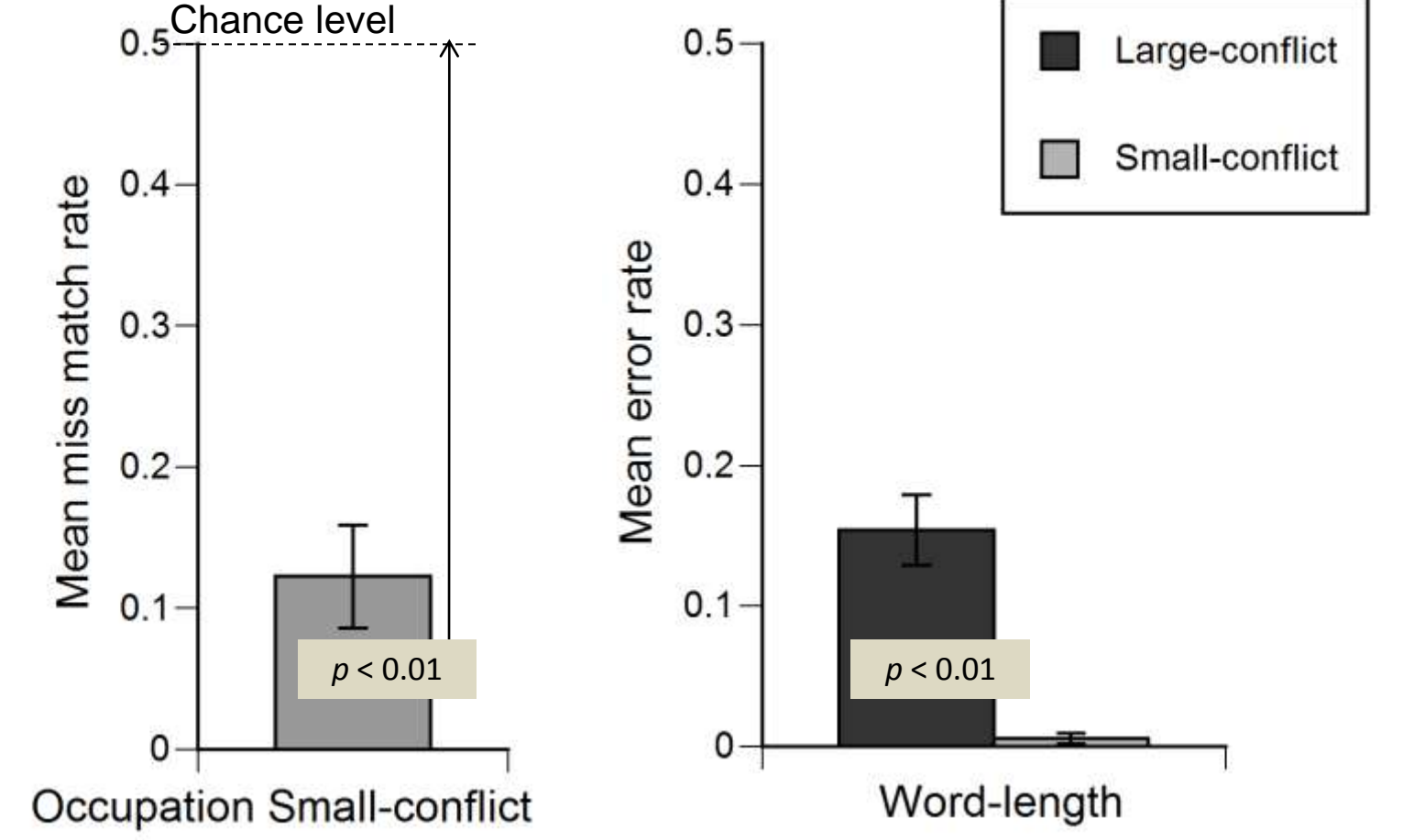Fig. 4. Mean response time as a functions of task type and degree of conflict.

Fig. 5. Mean miss match rate of small conflict condition in Occupational choice task.

Fig. 6. Mean error rate as a functions of degree of conflict in word-length task.

✓ Manipulation of conflict during occupational choice was successful.
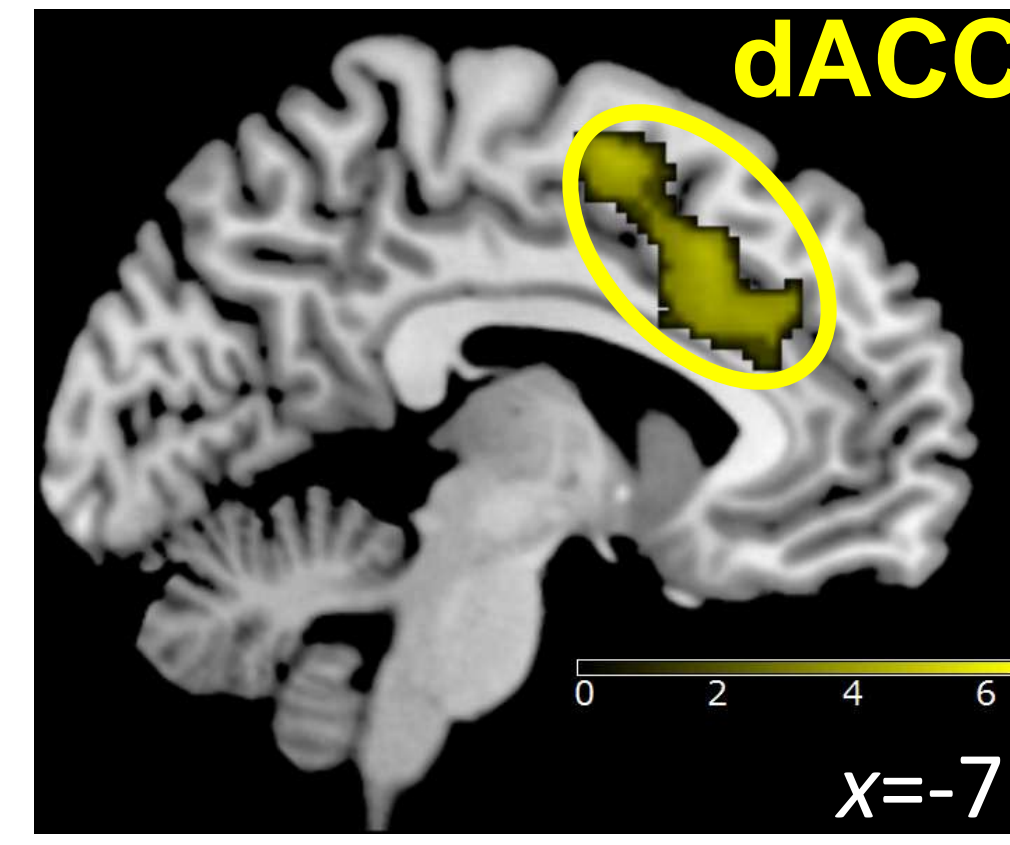
fMRI:

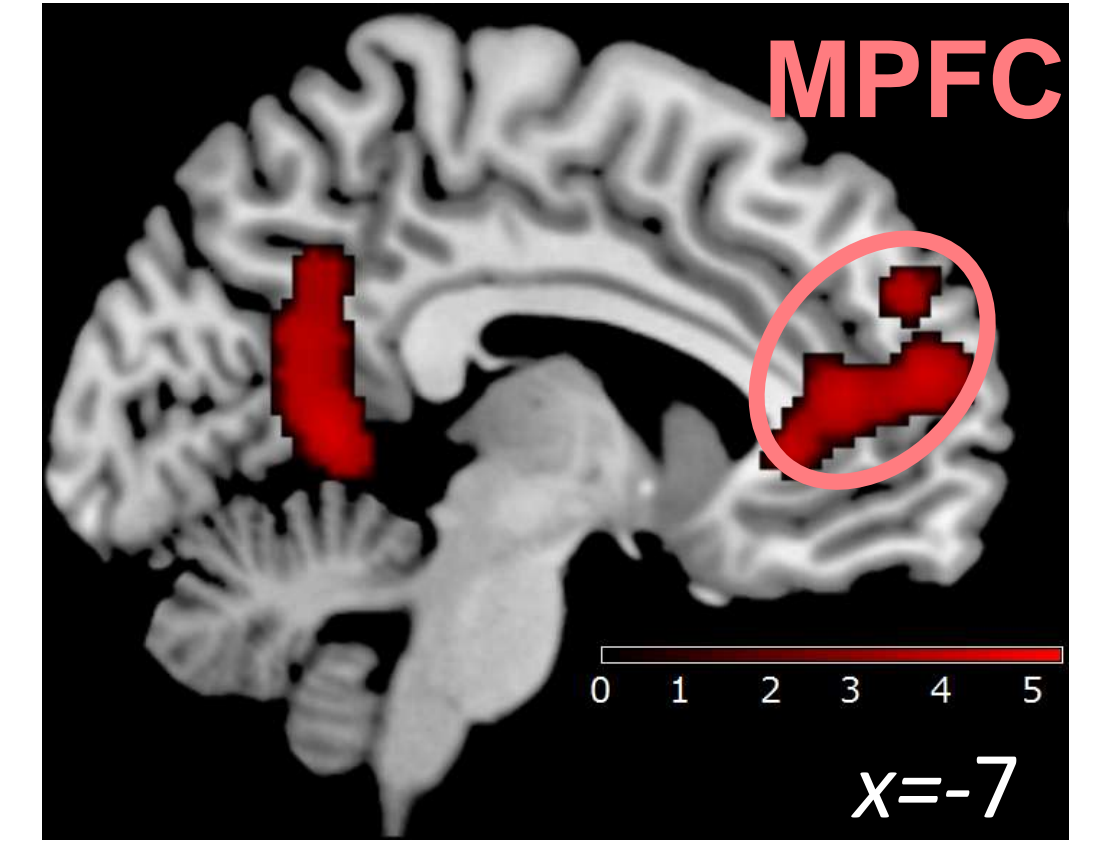Fig. 7. Activated regions in **large-conflict>small-conflict contrast of occupational choice task**.

Fig. 8. Activated regions in **occupational choice task>word-length task** contrast.

1. **The degree of conflict between two possible answers is also reflected in dACC activity.**
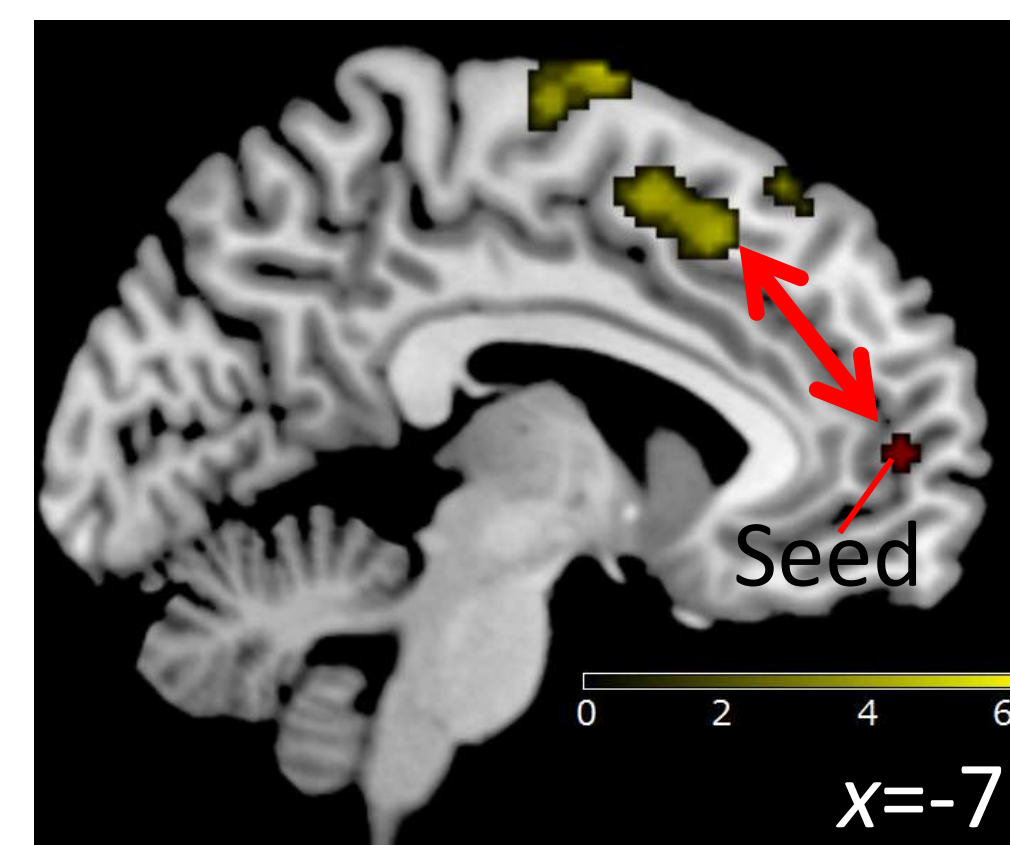2. **The MPFC has a function in behavior selection in a situation where no correct answer exists.**

Fig. 9. Regions showing increased connectivity with the MPFC during occupational choice.
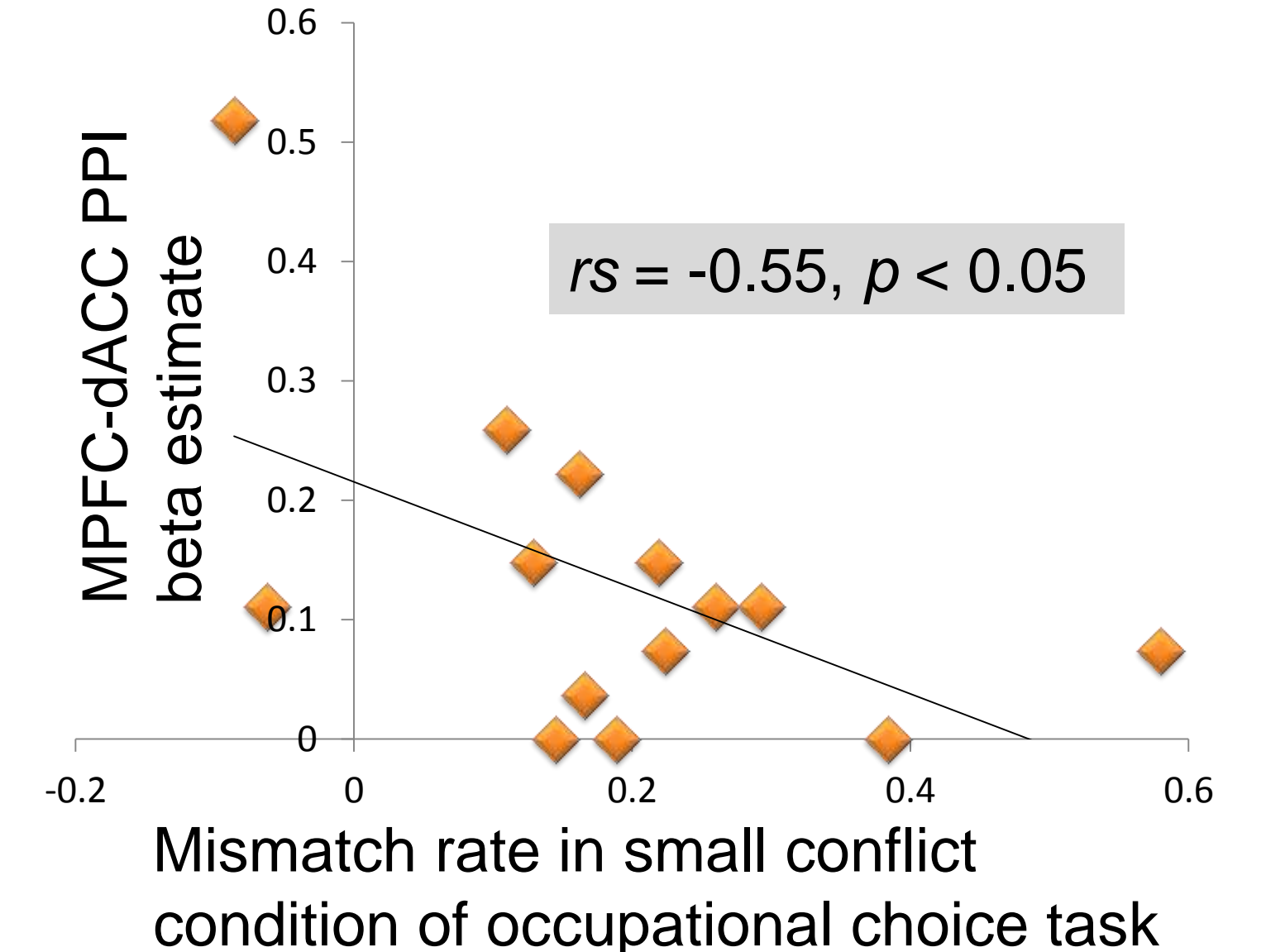
rs = -0.55, $p < 0.05$
Fig. 10. Correlation between PPI beta estimate and mismatch rate.

3. **The MPFC has functional connectivity with dACC only in a situation without a correct answer.**
4. **Participants who had strong functional connectivity between MPFC and dACC showed consistent judgment.**

Conclusion:

MPFC may have a function to reduces conflict detected in dACC by biasing either choice of behavior, especially when no objective correct answer exists.

Reference
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[2] J. Moll, F. Krueger, R. Zahn, M. Pardini, R. de Oliveira-Souza, J. Grafman, Human fronto-mesolimbic networks guide decisions about charitable donation, Proc. Natl. Acad. Sci. U.S.A. 103 (2006) 15623–15628.
[3] T. Nakao, T. Takezawa, M. Miyatani, H. Ohira, Medial prefrontal cortex and cognitive regulation, Psychologia 52 (2009) 93–109.
[4] T. Nakao, T. Osumi, H. Ohira, Y. Kasuya, J. Shinoda, J. Yamada, Neural bases of behavior selection without an objective correct answer, Neurosci. Lett. 459 (2009) 30–34.
[5] T. Nakao, M. Mitsumoto, H. Nashiwa, M. Takamura, S. Tokunaga, M. Miyatani, H. Ohira, K. et al. Self-knowledge reduces conflict by biasing one of plural possible answers. Pers. Soc. Psychol. Bull., 36 (2010) 455-469.

Image acquisition:

● Images were acquired using a 1.5-T MRI scanner (SIGNA MR/I Echo Speed 1.5 T CV, NV Option; GE). fMRI was conducted using single-shot, echo planar imaging (EPI) with whole-brain coverage.
● The scanning parameters were the following: echo time (TE) = 40ms, repetition time (TR) = 4400ms, flip angle = 90°, matrix size = 64 × 64, field of view (FOV) = 220mm, slice thickness = 3.44mm, inter slice gap=0mm. Within the TR at each time point, 50 slices of the brain were acquired axially.

Data Analysis:

● The functional images were motion-corrected, normalized to a standard MNI template, and spatially smoothed (9-mm FWHM) using SPM5.
● Statistical images were acquired using an uncorrected voxel threshold of $p < 0.005$ and corrected cluster threshold of $p < 0.05$.