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Mental Calculation in the Experts of Soroban (a Japanese Traditional Calculator): An Event-related Functional Magnetic Resonance Imaging Study

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Abstract

Introduction:

Soroban (abacus) is a traditional tool for calculation widely used in Japan. Experienced abacus operators can solve a huge amount of arithmetic problems with no use of the instrument and their calculations are always accurate. Although it was suggested that the experts store digits using a visuo-spatial image of an abacus in the visuospatial sketchpad of the working memory, functional neural networks activated during the mental calculation in abacus experts has never been studied.

Objectives:

1. To investigate the region which is activated on the mental calculation task in non-expert subjects.

2. To investigate the difference in the activated regions between expert and non-expert groups.

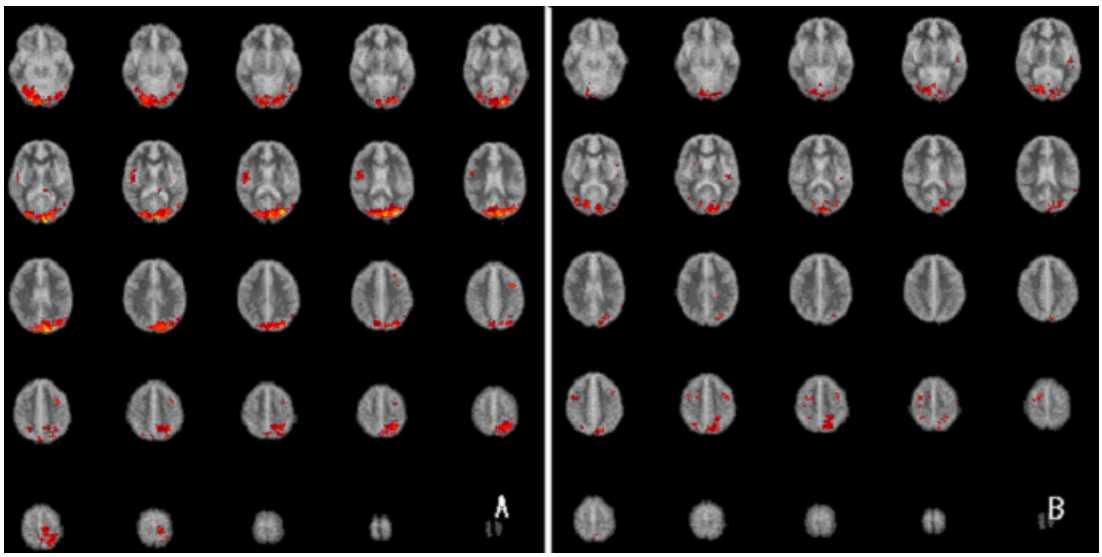
Materials and Methods:

Ten male abacus experts (mean age •} SD; 22.1 •} 2.3 years) and 10 male IQ matched non-experts (22.1 •} 2.7 years) participated in this study. The mean ranking of Abacus skill in experts was 6.2-Dan (the ranking that is officially certificated by the Japan•fs Abacus Association). We used a jittered event-related paradigm with variable interstimulus intervals (ISIs) (Amaro et al. 2002). The subjects were instructed to mentally calculate addition of 2-digit numbers and overtly state the result of them, presented visually for 2 seconds, at an ISI peak average of 9 seconds. The control stimulus was a visually paired stimulus with no numbers. All data were acquired with 1.5T whole-body MRI scanner. A total of 14 slices oriented according to the AC-PC plane were acquired (BOLD gradient EPI; TE 40 ms, TR 2000 ms, FA 75^{O}, FOV 240 mm, 64*64 matrix; thickness 7.0 mm, gap 0.7 mm). The total scan time was 288 sec in a single run (20 events of each type). •@

The responses at each voxel were modeled by Poisson functions. The distribution of the model statistics was calculated by wavelet-based resampling and refitting the models to the resampled data. Activations were detected by randomization inference testing (Bullmore et al. 1996). Generic group activation maps were constructed by mapping each individual into the standard stereotactic space and between group calculations were performed by ANCOVA (Bullmore et al. 1999; Bullmore et al. 2001).

Results:

All subjects responses were correct in both groups. In general, the expert and non-expert subjects produced activation in the same areas (precuneus, extraestriate visual cortex, cerebellum, and left DLPFC) (Figure 1). The right DLPFC was activated only in the experts. When the two groups were directly compared at a $p < 0.001$ cluster level, the control group had a higher amplitude of the activation in the areas, which were commonly activated in both groups, and the activated area was more extensive in the control than expert group.



Conclusions:

The two groups shared a common pattern of brain activation. However, more amplified and extensive activation was noted in the control than expert group, and the latter showed an additional active node in the right DLPFC. These results suggest that abacus experts more efficiently use the neural network engaged in mental calculation than non-experts and, in addition, they may use a different strategy to perform calculations which is represented by the unique activation in the right DLPFC.

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