# The Neural mechanisms in relation to transfer effects of intensive shooting training to enhanced visuospatial working memory

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## Introduction

Recently, there is an increasing interest in training effect of working memory. Functionalneuroimagingstudies showed higher activation in fronto-parietal areas and striatum after working memory training [1], [2]. These studies revealed improvements in working memory capacity by training program. However, to the best of our knowledge, the plastic changes in working memory network associated with visuospatial working memory after sports training have been seldom studied. In the present study, we aim to investigate the dynamic neural changes related to transfer effects of shooting training on visuospatial working memory using judgment of line orientation (JLO) task. In this study, the difficult version of the JLO task was employed because the greatest training-related differences in processing visuospatial information would be seen at a higher task demand rather than at a lower cognitive demand.

## Subjects and Methods

Twenty-two healthy participants (10 males, 12 females) who had no previous shooting experience were included in this study. The mean age of all subjects was 22.6 ± 4.14 years and right-handed in accordance with the Edinburgh handedness scale. Each participant concluded a shooting training session lasting 90 h. The shooting performance was measured in terms of shooting score and target diametric dispersion. These behavioral measurements were taken before and after 60, 90 h shooting training. Functional magnetic resonance imaging was employed to assess cortical activities during the performance of JLO task (Figure 1) before and after 50, 90 h shooting training. BOLD functional images were acquired using a 3.0T GE HD scanner (EPI, TR=3000ms, TE=40ms, matrix=64x64, Thickness=3.0mm, FOV=220mm, no gap). A 3D T1-weighted anatomical scan was obtained for structural reference. Image processing and statistical analyses were carried out using MATLAB and SPM8. In fMRI data within-group analysis, contrast images from the analysis of individual subjects were analyzed by one-sample t-test, thereby generating a random-effects model, allowing inference to the general population. The differences of brain activations between the before and after 50, 90 h shooting training were analyzed by one-way within subject ANOVA and direct comparisons of brain activations between the before and after 90 h shooting training is analyzed by post hoc t-test. All analyses were thresholded at $P<0.05$, false discovery rate (FDR) corrected for multiple comparisons across the whole brain. Bonferroni correction was applied for post hoc testing which adjusted alpha level of 0.0167. Furthermore, Pearson correlation analyses were used to determine the correlations between the behavioral performances and the mean percentage changes in BOLD signal in the activated brain regions. All statistical analyses were performed using IBM SPSS 19 software. Statistical significance was defined at $p<0.05$.

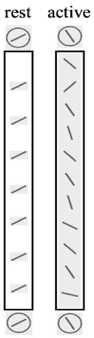

Figure 1. The JLO task.

## Results and Discussion

We found that within-group analysis showed higher activations in the dorsolateral prefrontal cortex, posterior parietal cortex and striatum during the JLO task after intensive shooting training than that before training. Also, the deactivations of the posterior cingulate cortex and amygdala are lower than that before training (Figure 2). One-way within-subjects ANOVA analysis revealed that compare differences of between the before and after 50, 90 h shooting training showed activations in the dorsolateral prefrontal cortex, striatum, amygdala, posterior cingulate cortex and middle occipital lobule (Figure 3). In addition, direct comparison of before and after 90 h shooting training, using post-hoc t-test, showed higher activations in the striatum and lower deactivations in the posterior cingulate cortex and amygdala during the JLO task after 90 h shooting training than that before training (Figure 4). It is therefore likely that while activity of the dorsolateral prefrontal cortex is more related to maintain and shifting attentional sets, activity in the posterior parietal cortex is more associated with visuospatial information processing and directing and sustaining attention over time while performing the difficult version of JLO task. Also, our finding of higher striatal activity during the JLO task after training suggest that training may enhance gating function of striatum in conjunction with increased signal-to-noise ratio by dopamine release. Thus, higher activity of fronto-parietal networks in this study might provide the basis for transfer effects of shooting training to the JLO task and increased activity of striatum together with increased release of dopamine might also provide a more general mechanism that mediates transfer effects of shooting training to the JLO task [1].

## References

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2. Dahlin E, et al. Transfer of learning after updating training mediated by the striatum. Science. 2008b;320:1510–1512.

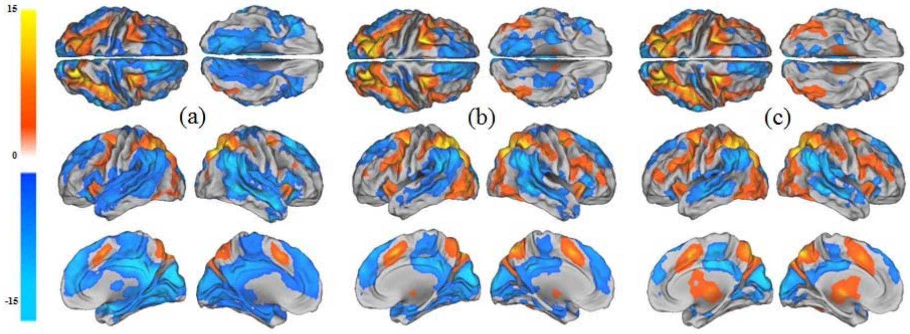

Figure 2. One-sample t-test showed brain activations during the JLO task in the before training (a), in the 50 h training (b), and in the 90 h training (c). The three shooting training groups of the JLO task related activation regions (red to yellow) and the JLO task related deactivation regions (blue to green) were represented in statistical parametric maps of brain regions (P<0.05, FDR corrected).

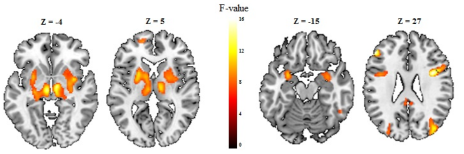

Figure 3. To compare differences of brain activations between the before and after 50, 90 h training were analyzed by one-way within subject ANOVA (P<0.05, FDR corrected).

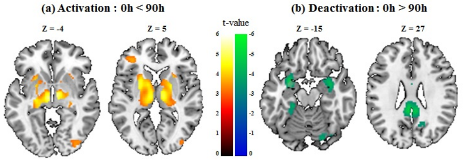

Figure 4. (a) Post hoc t-test group comparison showed higher activation brain regions of BOLD contrast (a) in the 90 h training relative to before training and (b) in the before training relative to 90 h training in response to the JLO task (Bonferroni corrected P<0.0167, FDR corrected).