Investigating the duration of brain response to acupuncture stimulation by using independent component analysis

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Introduction:

Many studies on functional magnetic resonance imaging (fMRI) findings related to acupuncture stimulation have been reported. Some of them showed that acupuncture stimulation induced negative BOLD responses; however, interpretation of the results was difficult, and a consensus was not reached. [1-3] A recent study showed the induction of negative BOLD hemodynamic responses by median nerve stimulation with an onset delay of several seconds and evaluated the temporal delay in stimulation by using an event-related design. [4] However, because acupuncture stimulation should persist for a certain duration, an event-related design could not be used in this study. On the other hand, a previous study showed that hemodynamic response models derived from task-related independent components (ICs) could be used as regressors to model the expected BOLD response by independent component analysis (ICA). [5] Therefore, we selected the time course of the acupuncture stimulation from ICs by using ICA. We examined the correlation between the selected ICs and some hypothetical general linear models (GLMs) and predicted the temporal delay in brain activation induced by acupuncture.

Materials and Methods:

This study included 26 healthy subjects (men, 16; women, 10; age, 20–33 years). Thirteen participants (8 men and 5 women) received manual acupuncture stimulation (real acupuncture), and the remaining 13 (8 men and 5 women) received tactile stimulation as the control. Acupuncture stimulation consisted of bidirectional needle rotation to approximately 180° with an even motion at a frequency of 1 Hz. Tactile stimulation was of 2 types: brushing the skin on the palm with a sponge and tapping the skin at the LI4 with a size 5.88 von Frey monofilament (sham acupuncture stimulation) at 4 Hz. All fMRI runs consisted of a block design with four 15-s stimulation blocks (on) interspersed between one 30-s and four 45-s rest blocks (off) as shown in Fig. 1. All experiments were performed using a General Electric 1.5 T Signa MRI system with a standard head coil. The subjects underwent GE-EPI scans using the following parameters: thickness, 5 mm; matrix, 64 × 64; FOV, 22 × 22 cm^2; TR, 3000 ms; TE, 50 ms and 30 axial slices, and 90 time points. Tensor-ICA was performed with MELODIC Version 3.10, part of FSL (www.fmrib.ox.ac.uk/fsl). Our method is summarized in Fig. 2. The following methods for analysis of fMRI data were used: (1) the fMRI data were analyzed using Tensor-ICA, and IC-related cerebral activity with each stimulation was selected to the activation area by referring to previous studies. [1, 6, 7] Typically, acupuncture stimulation involves the bilateral SI and SII cortices, insula, and anterior cingulate cortex, and control somatosensory stimulation involves the contralateral SI and the bilateral SII cortices. (2) GLM regressors were computed by convolving various duration block designs with standard hemodynamic response function (HRF). Various block designs hypothecated the duration of stimulation (15–45 s; scale-up every 3 s). (3) A cross-correlation analysis was performed between the time course of the selected ICs in (1) and GLM regressors in (2), for the different stimulations. (4) We selected the highest correlation coefficient for each stimulation.

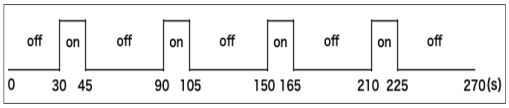

Fig 1. The fMRI block design paradigm

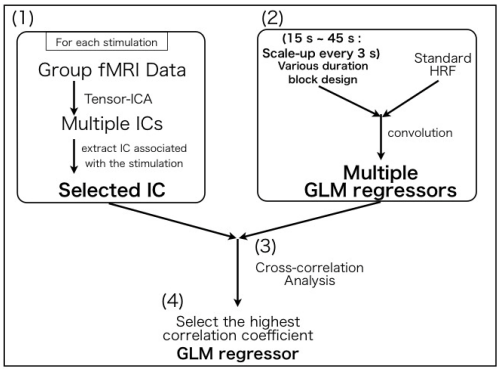

Fig 2. Schematic of the method (final result is in bold)

Results & Discussion:

The correlation coefficient between the GLM regressor and the ICs for the acupuncture stimulation was highest at 30 s (r = 0.91) and that for the tactical stimulation was highest at 15 s (r = 0.95, 0.88) (Table 1). Fig. 3 shows the t-score map of BOLD responses to acupuncture stimulation processed using a GLM in SPM8 with a different block design. Acupuncture stimulation for a duration of 15 s resulted in little cerebral activity; however, a duration of 30 s resulted in great cerebral activity in the predictable area (the bilateral SI and SII cortices, insula, and anterior cingulate cortex). On the other hand, control stimulation for a duration of 15 s resulted in definite cerebral activity in the predictable area (the contralateral SI and the bilateral SII cortices). In conclusion, we found that changes in BOLD signals caused by acupuncture stimulation lasted for around 15 s after the stimulation. Our method is useful for the analysis of brain activity in response to stimulation, without using an event-related design.

Duration (s)	Acupuncture (LI 4)	Sponge brush (palm)	Von Frey (LI 4)
15	0.56	0.96	0.88
18	0.68	0.91	0.84
21	0.76	0.82	0.76
24	0.83	0.73	0.69
27	0.88	0.64	0.64
30	0.91 (0.908)	0.57	0.60
33	0.91 (0.906)	0.50	0.56
36	0.88	0.44	0.51
39	0.83	0.39	0.45
42	0.78	0.34	0.38
45	0.71	0.28	0.32

Table 1. Correlation coefficients between IC and GLM regressors

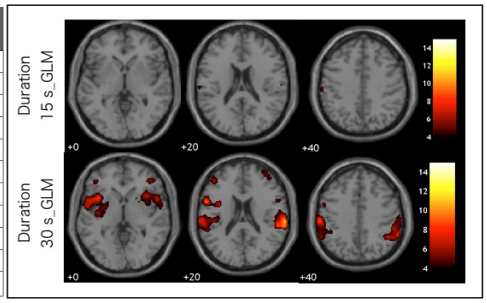

Fig 3. BOLD t-score map processed using a GLM (One-sample t-test, P < 0.001 uncorrected, T > 4.0)

References:

[1] Hui KK, et al. Hum Brain Mapp. 2000; 9(3):13-25, [2] Napadow V, et al. Hum Brain Mapp. 2005; 24(3):193-205, [3] Hui KK, et al. Neuroimage. 2005; 27:479-496, [4] Kingner CM, et al. Hum Brain Mapp; 32:127-140, [5] Penney TJ, et al. Conf Proc IEEE Eng Med Biol Soc. 2006; 1:723-726, [6] Hsieh JC, et al. Neurosci Lett, 2001; 13:105-108, [7] Dhond RP, et al. Pain, 2008; 136:407-418