An fMRI study of induced plasticity in S1 in the human brain

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Introduction
Cortical plastic changes allow the brain to adapt to changes in sensory inputs. Cortical reorganisation due to synchronous co-activation can be related to Hebbian mechanisms. These mechanisms suggest an increase in synaptic efficacy due to persistent and repeated activation that is temporally correlated. This is best shown in studies performed in rats via clipped vibrissae (1) and paw representation (2) across a relatively short period of activation. Human behaviour studies have shown a significant improvement in subjects' spatial discrimination ability after 3 hours of finger activation (3). Further work has shown co-activation on neighbouring digits causes representations in S1 to move together (4). This study aimed to use high resolution fMRI to measure topographical and BOLD amplitude changes in S1 in the human brain following synchronised activation to Digit 2 and Digit 4.

Methods
12 right handed subjects took part (7 female, 5 male, mean age 23.3 ±3 years). There were 3 phases to the study: a pre training scan, a 3 hour training period, and a post training scan. The entire protocol was carried out on the same day.
Training phase: Vibrotactile stimuli were placed on the index (Digit 2) and ring (Digit 4) finger of the right hand and secured by tape. Brief pulses of 30 Hz vibration were applied for 50ms with a variable interstimulus interval between 100 and 3000 ms in a pseudorandomised order, giving a mean stimulation frequency of 1 Hz.
Scanning sessions: MR data was acquired on a Siemens 3 T Trio system. T2* BOLD data were acquired with a TR of 2 seconds; TE: 35 ms, 2 mm isotropic voxels in addition to high resolution T_1-weighted structural images that were acquired at each scan session. The task paradigm consisted of each tactor vibrating in turn for an ON period of 6 seconds at 30 Hz and an OFF period of 10 seconds in a randomised order.

Analysis
All BOLD data were motion corrected, temporally filtered and spatially smoothed using a 4mm Gaussian kernel in Brainvoyager (Brain Innovation, The Netherlands). Structural scans were converted to Talairach space and fMRI data was superimposed to identify the cortical areas relating to Digit 2 and Digit 4. Only data showing activation at p<0.05 (FDR corrected) was recorded, causing data from two subjects to be discarded as they did not show significant activation. Centre of gravity (COG) values were obtained from cortical areas relating to the separate digits in pre and post training sessions, and the distance between the digit representations was calculated. Beta weights were also obtained from the digit regions as a measure of the BOLD amplitude.

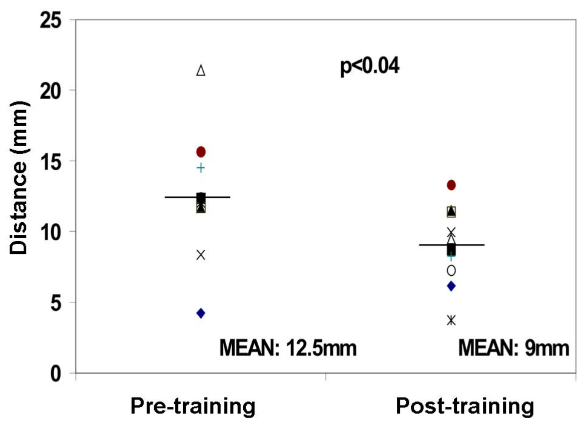

Figure 1 (left) shows the distance between the digit representations calculated from COG values in individual subject pre and post training. A paired t-test revealed a significant reduction post-training (p<0.04).

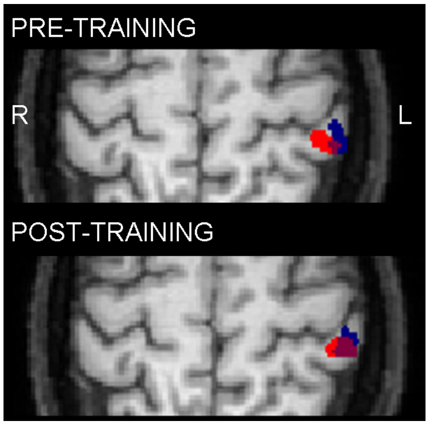

Figure 2 (right) shows the localization of digit 2 (blue) and digit 4 (red) on an individual subject. Overlap between the regions increases post-training.

The BOLD amplitude was significantly larger (p<0.04) for digit 2 compared to digit 4 pre training. The BOLD amplitude of both digits decreased post-training.

Discussion
This study successfully confirmed induced plasticity in S1 following 3 hours of synchronized stimulation of Digits 2 and 4 as suggested by Godde et al (2,3) and Pilz (4). Previous work has considered neighbouring digits only, so it is interesting that these shifts in cortical representation are maintained between more distant digits. We saw a significant reduction in distance between the digit representations post-training (Figure 1) resulting in a clear overlap of digits post-training (Figure 2). We postulate that these shifts are caused by increased synaptic weightings between the neurons in the two regions, brought about by synchronized co-activation during training. Further work will consider whether connectivity between the regions is increased.

References
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