THE EFFECT OF TRAINING IN LEFT HAND MIRROR WRITING ON BRAIN ACTIVATION - A SIMULTANEOUS fMRI AND KINEMATICS STUDY

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Background: Hand writing is a highly specialized, language related, human specific skill that is closely linked to brain hemispheral dominance. Mirror writing (MWr) is frequently seen in the early developmental stage in children in whom hemispheric laterality has not yet been established, in patients with cerebral injury such as that due to vascular disorders, and occasionally in healthy adults or in patients with functional psychological disorders. In individuals with right hemiplegia MWr is frequently noted in text written with the nondominant left hand, and reports of MWr with the dominant right hand are rare (1). Most papers report that MWr appears more frequently in ambidextrous or left-handed individuals and in those whose languages are written leftward. Functional neuroimaging has been used to investigate finger and hand movements in left- and right-handers, including left-handers who write with their right hand, and also to investigate mirror reading but not MWr. Such studies in turn may further understanding of the links between hemisphere specialization, handwriting, and handedness (2). We have recently improved our magnet-compatible 2D movement monitoring system (3), which we now implemented for the investigation of hand writing in general and modulations of brain activation following training MWr with the left hand in particular.

Aims: 1. To test the quality of activation maps and kinematics data obtained while practicing handwriting inside the magnet. 2. To investigate the patterns of activation induced by regular and left hand MWr, and the modification of these maps following training in left hand MWr.

Methods: fMRI measurement of T2* weighted BOLD contrast (TR/TE 3000/35, FA 90^{o}, SW 3 mm, 0.4 mm gap, FOV 22 cm, matrix 64X64 resulting in 3.4X 3.4 mm^2 in plane resolution) were acquired using 3T MRI (GE EXCITE 3 HD) and 8-channels head coil. Eight (4 males, 4 females), right handed subjects participated in two sessions: one prior to and the other following one week of daily practices in left hand MWr. A single event fMRI paradigm consisted of auditory presentation of lists of 32, three-letter words or three-digit numbers. In four separate experiments (110-120 acquisitions of whole brain volumes each), subjects responded by writing either the middle sign or the whole word (or number) with either their right hand or with left hand MWr. The response was recorded by the handwriting monitoring system and back projected to provide a real-time feedback for the subjects. fMRI data was analyzed using SPM2.

Results: All subjects accommodated well to the handwriting monitoring system after short instructions and practice. The quality of fMRI data was satisfactory with acceptable movement levels and yielded clear statistical maps demonstrating activations in occipital, parietal and prefrontal areas (fig. 1). In addition, there was a pronounced activity in the midbrain and subthalamic areas which may be specifically related to the writing activity. Only a moderate effect of the MWr practice was found on the overall level of basic kinematics parameters**,** e.g statistically significant, 1.5 fold increase in writing velocity of whole word MWr. Accordingly, the general brain activation patterns were similar in all conditions. However, there was an obvious improvement in the morphology of letters in MWr both subjectively and as reflected in a low index of similarity between pre-post traces, based on cross covariance analysis. This improvement may be associated with the modification of relative activity of MWr compared to the activation induced by regular writing. Before practice, MWr resulted in over activation of sensory-motor areas in the left hemisphere (fig 2), whereas following practice the over activity was mainly restricted to the motor areas in the right hemisphere (fig 3). Interestingly, over activity in the right perisylvian region was induced by regular handwriting following practice of MWr.

Conclusions: To our knowledge this is the first fMRI study of MWr. A successful implementation of an MRI compatible hand writing monitoring system enabled simultaneous collection of kinematics and fMRI data as well as providing real time feedback to the subjects. Both kinematics and fMRI data revealed that simple statistical parametric analysis provides limited insight into the process of attaining proficiency in MWr. This process seems to involve redistribution of the activation in a large neural network encompassing extensive area of the brain that merits further investigation with more advanced analysis techniques.

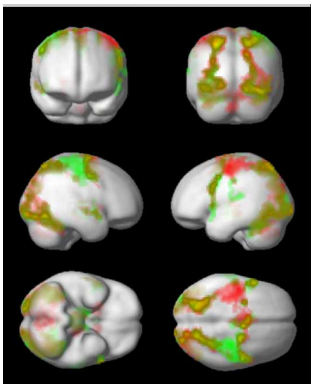

Fig 1. Green: Rt. hand writing. Red- MWr. (> Lt. motor area pointing forward)

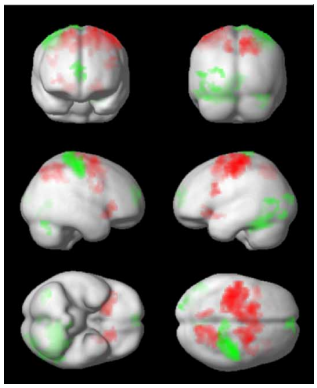

Fig 2. Pre training- Green: Rt hand>Lt hand. Red: Lt. hand>Rt. hand

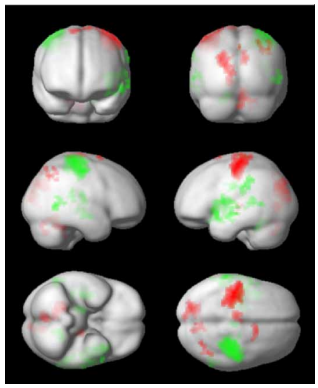

Fig 3. Post training- Green: Rt hand>Lt hand. Red: Lt. hand>Rt. hand

References: 1. M Nakano et al, *Brain and Cognition* 53 (2003) 9–14.
2. GD Schott et al, *Arch Neurol*. 61 (2004) 1849-1851.
3. Kushnir T et. al, ISMRM 14th Scientific Meeting, Seattle, WA, 2006, p. 2801.