# Dexterity and Implicit Learning of Sequential Movements

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**Introduction**

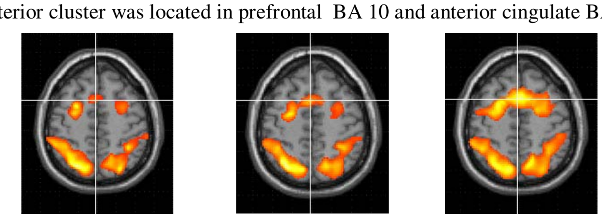
The present study was designed to identify the dynamic activation changes within cortical and subcortical related motor regions during the initial implicit learning of sequential finger movements. The cortical and subcortical network recruited during motor learning and its roles, although it has been widely studied, is not fully understood. Dexterity influences accuracy and speed of movement performance. Combining in one study right, left and bimanual sequence learning, we aim to compare the effect of sequential movement repetition.

**Materials and Methods**

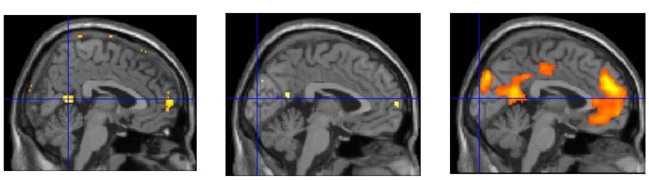
Fourteen right-handed volunteers, mean Oldfield dexterity scale 47 out of 50, ranking from 20 to 31 years old (average age=24.4 years old) were studied. The protocol was approved by the ethical committee of the University of Navarra Hospital. Men and women were recruited in equal proportions. Subjects were asked to learn different sequential finger movements with the right, left and both hands in different sessions inside the scanner. A time-course series of 200 volumes was acquired in every session using T2*-weighted gradient echo-planar imaging (EPI) sequences with a 3.0 Tesla MR imager (Siemens TRIO). Each volume consisted of 50 axial slices with a slice thickness of 3 mm and no gap, to include the entire cerebral cortex and cerebellum. The time-interval between two successive acquisitions of the same image was 3000 ms, the echo time 30 ms. Images' resolution was 3×3×3 $mm^3$. Statistical analysis was performed at two levels. First, individual task-related activation was evaluated using a general linear model. Second, in order to make inferences at the population level, individual data were incorporated into a random-effects model. The task consisted in learning a visually presented sequence and reproducing it by pressing a response box with alternating four fingers of the hand. The subject was required to perform the sequence of movements with the right, left and bilaterally in different sessions. The control was interleaved in the presentation with the alternating finger sequence (task) and consisted on an eight finger sequence: little finger, ring finger, middle finger, index finger, little finger, ring finger, middle finger, index finger.

**Results and Discussion**

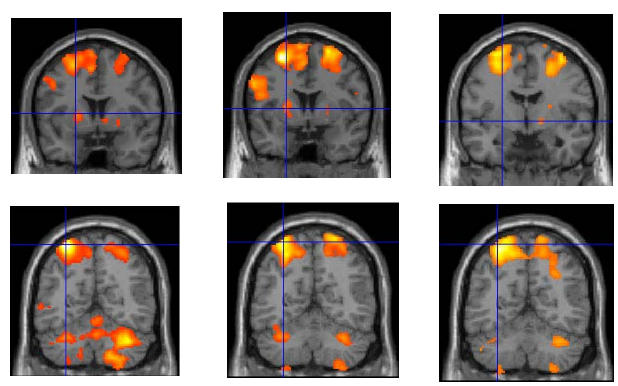
Similar activation areas were obtained with left, right and bimanual movement sequence. The difference between executing a sequence with the left and right hand was a greater activation linking pre-SMA and left premotor cortex, whereas bimanual movements required a more significant activation between pre-SMA and premotor areas of both hemispheres (see Fig. A1-A3). Other common areas involved were the bilateral posterior parietal cortex (precuneus), inferior parietal cortex, bilateral anterior insulae, visual association cortex (V3). Activation of DLPC was stronger in bimanual movements. Cerebellar areas corresponded somatotopically to the somestesic association cerebellar cortex and the motor cerebellum. To analyse the effects of movement repetition, we analysed BOLD signal modulation introducing a regressor related to repetition number of each sequence. The regressor for the right-hand sequence (see Fig. B1) showed activation in bilateral dorsal premotor cortex, DLPC and pre-SMA connected with left premotor cortex, bilateral anterior insulae, bilateral precuneus, bilateral putamen (predominantly on the left), substancia nigra and thalamus. Somestetic cerebellar cortex was activated in both hemispheres, although predominant activation was found in the right hemisphere. The regressor for the left-hand sequence (see Fig. B2)showed similar clusters with lower activation in the cerebellar hemispheres and in right insulae. The regressor for the bimanual sequence (see Fig. B3) movement showed more significant activation of the dorsal premotor cortex and lower activation of the left ventral premotor cortex, basal ganglia and cerebellar hemisphere. Dexterity involves surprinsingly a more significant recruitment of posterior parietal and premotor areas, including left DLPC and cerebellar somatosensory cortex when performing right hand hand sequential movement repetition. Areas decreasing with repetition were part of the spatial attentional network in the cingulate cortex for both right, left and bimanual movements, being greater the decrement for bimanual performance repetition (see Fig. C1-C3). An anterior cluster was located in prefrontal BA 10 and anterior cingulate BA 32 and a posterior cingulo-retrosplenial one in BA 23/29/30.



A1 A2 A3



C1 C2 C3



B1 B2 B3

**Figure A.** T1 Axial canonical sections depicting BOLD activations in the group of fourteen subjects centered in pre-SMA for right hand (A1), left hand (A2) and bimanual (A3). (p (FDR corrected) < 0.05). **Figure B.** T1 Canonical coronal sections depicting BOLD activations linearly related to sequential movement repetition in the group of fourteen subjects centered for the right hand in left putamen (upper B1) and cerebellum (lower B1), left hand in left putamen (upper B2) and cerebellum (lower B2) and bimanual in left putamen (upper B3) and cerebellum (lower B3). (p (FDR corrected) < 0.05). **Figure C.** T1 Canonical sagittal sections depicting BOLD decrements related to sequential movement repetition in the group of fourteen subjects centered for the right hand (C1), left hand (C2) and bimanual (C3).

**Conclusions**

Dexterity influences the effect of sequential movements repetition. When performing repetitive sequential movements with the right hand compared with the left hand and bimanually the recruitment of posterior parietal and premotor areas including left DLPC was greater. Cerebellar somatosensory cortex activation was also directly related with repetition. The areas attenuated with sequence repetition involved mainly the spatial attentional network needed for a visuospatial learning task, with subsequent movement sequence performance.

**Bibliography**

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