Electrocorticography recording of motor sequence learning

Motor skill learning is happening in the brain. Recent work suggests that motor skill learning strengthens cortical representations of motor sequences (Wiestler and Diedrichsen, 2013), as measured by multi-voxel pattern analysis (MVPA) of functional magnetic resonance imaging (fMRI) activity (Norman et al., 2006). MVPA has shed light on a new model depicting how motor sequences are neurally represented in premotor cortex (PMC) and supplementary motor area (SMA) (Wiestler et al., 2014).

Electrocorticography (ECoG) uses electrodes placed on the exposed surface of the brain to record activity from the cortex. This technique, whereas being mainly used during presurgical planning, has recently arisen as a method for use in brain-computer interfaces (BCI) (Shenoy et al., 2008). Moreover, an ECoG study explicitly addressing oscillatory EEG changes revealed that a brisk, voluntary middle finger/wrist movement task induced neural activation, as specifically measured within the 18–22 Hz band in both, SMA proper and M1 areas (Ohara et al., 2000).

So far, neural correlate of motor sequences has not been investigated using ECoG. Yet, this technique has interesting features; despite having a limited field of view compared to fMRI, its temporal resolution is way higher. Furthermore, when fMRI gets the neural activation by measuring blood flow and oxygen levels, ECoG directly records neural electrical activity while having a greater sensitivity and precision than EEG (superior signal-to-noise ratio).

Thus, ECoG seems to be a relevant recording method in exploring finger sequences learning mechanisms in the brain. It will allow us to address the temporal component as well as the spatial component of neural activity associated with motor sequences. Specifically, we will be able to compare patterns of activity related to specific finger sequences as well as individual finger presses using a MVPA classifier. Our hypothesis is that these patterns become more distinct with learning (Wiestler and Diedrichsen, 2013).

Protocol:

In this experiment, participants will be using a custom force recording keyboard to execute 4 different finger sequences, similar in difficulty, displayed on a screen. They are laying on a bed with the keyboard on their lap, looking at the monitor in front of them. A keypress is recognized when the force of a finger exceeds a threshold of 2 N, while the other fingers are below 1.7 N. Movement time (MT) will be recorded as well as frame-by-frame force inputs. The experiment is divided as follows:

- 5 executions per trial (22.5 sec total)
- 20 trial per run (7.5 min)
- At least 4 runs per session but it can go up to 8 (1h) depending on the participant motivation/fatigue.

A trial corresponds to 5 executions of the same finger sequence, as fast as possible but right. At the beginning of each trial, the sequence is announced by five centrally presented numbers inside a box, for 2.7 seconds. Each number refers to a finger as follows: 5 for the thumb, 4 for the index, …, 1 for the little finger. Participants have to memorize the pattern during this period. After that, the numbers disappear and a fixation cross appears inside the box as well as five asterisks above. This is the starting signal. They have 3 seconds to execute the sequence. Each mistake leads to the corresponding asterisk to turn red whereas each correct input turns it green. The participants have to keep their fingers on the keys during the run and complete the sequence even when mistakes have been made. Having completed a single sequence execution (5 presses), the central fixation-cross changes its color: ‘Green’ if the sequence was correct (+1 point), ‘Red’ if one or more mistakes have occurred (-1 point), and ‘Blue’ if the sequence was produced 20% slower than the median MT in the previous executions (0 point). In contrast, 3 green crosses appear when the sequence is produced 20% faster than the median MT (+3 points).

After the end of each execution, the asterisks turn white again to signal the start of a new execution. Once 5 executions of the same sequence are reached, the trial ends and the next sequence is displayed as the next trial starts. In addition to the 4 different sequences, one trial is set as a resting period. In that case, the numbers displayed on the screen are all zeros. The order of appearance of each trial is randomized within a single run.

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