Evidence for a decision making process at the cortical level during adaptation to changing loads

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Abstract

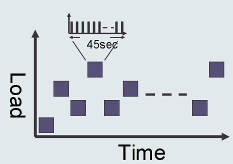
Movement-related potentials (MRPs) recorded from the scalp are the electrical signals generated by the brain related to the generation of voluntary movement. These potentials have been shown to vary due to the force exerted by subjects as well as their familiarity with the task.

It has recently been shown that when a subject adapts to a new motor task, the power of MRPs does not change monotonically, but instead there appears a large increase in its power after several repetitions of the task. This increase is most evident in MRPs recorded from locations over the prefrontal cortex.

In this study we investigate how this peak of activity is related to task parameters. Six subjects were asked to perform a motor task which required adaptation. By changing the number of alternative loads that appeared in the experiment and their type, we were able to show that both the number of task executions before the appearance of the peak of activity as well as its power are related to the number of loads the subjects knew were possible. This may suggest that the peak of activity is a manifestation of a decision making process designed to estimate the parameters of the current task.

Experimental setup

The subjects were seated approximately perpendicular to a lever attached to a vertical rod. The load needed to pull the lever was changed by controlling a motor connected to the lever. Changing the type and intensity of the feedback current to the motor under the lever controlled the load needed to pull the lever as well as its' type (spring-like or viscous-like resistance). Before the beginning of each experiment, the subjects were told the number of different loads they could expect to encounter during the experiment, and their type, e.g.: Two levels of spring loads and two levels of viscous loads.



Each experiment was divided into several recording runs, which lasted 45 seconds. Before each recording run the parameters for generating one of the possible loads were fed to the motor. The subject was then instructed to pull the lever, self paced, as quickly as possible, pausing approximately 3 seconds between each pull. Before the beginning of each run the load pulling the lever was changed randomly, but the subject could not feel the new load until the first pull of the lever. At least five recording runs from each of the loads possible in an experiment were recorded. A schematic diagram of the experimental procedure is shown below.

Modified matching-pursuit denoising

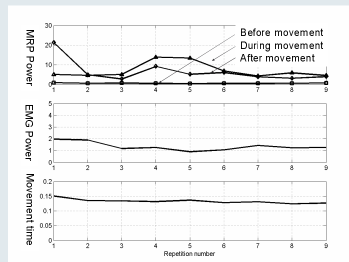
MRPs are recorded at a low signal-to-noise ratio (SNR) of -8 to -15dB. Therefore, denoising is required before they are examined. Traditionally, time-synchronized averages of many tens of MRPs are averaged to improve the SNR. However, averaging makes it impossible to observe temporal changes on a single- or even near single-trial basis.

Matching pursuit (MP) is a method for the sub-optimal expansion of a signal in a redundant dictionary (Davis et al., 1994). This algorithm, combined with a dictionary of Gabor functions, defines a time-frequency transformation. MP works by iterative subtraction of the best matching dictionary functions from the signal, with the appropriate amplitude and phase.

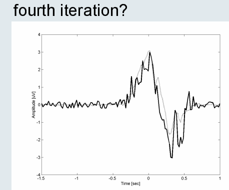
We modified the Gabor dictionary by removing functions who have most of their support in the times where most of the MRP energy is concentrated.

Our simulations (Yom-Tov et al., 2001) show that this method improves the SNR by approximately 10dB, thus making it possible to extract meaningful information from an average of only few MRPs.

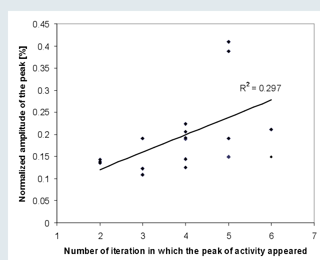
The power of the MRP changes during adaptation

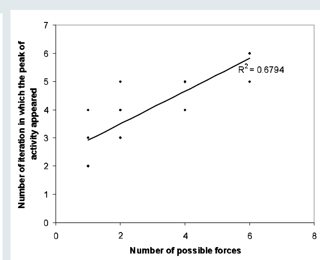


What happens during the fourth iteration?



Dependence of the MRP peak of activity on the number of (perceived) force levels





Summary

1. The peak of activity appears:
   - Mainly in electrodes over the *prefrontal* cortex
   - Mostly in times related to *comprehension*
   - Independent of the number of types of load
   - Correlated with the number of load values, possibly with the *perceived* number of loads
   - After EMG returned to its baseline activity
   - Uncorrelated with the speed of movement

2. When load changes after every move, no peak appears (Makienko et al., 2005).

We suggest that the peak of activity is the manifestation of a decision-making process related to the task. Once such a process is finished the subject might be able to switch from feedback control, based on a rough estimate of the load, to feedforward control.

The forward control is based on parameters that can be estimated when enough information about the load was collected while performing repetitions of the task.