SOME CONCLUSIONS ON BRAIN TRAINING FOR BRAIN-MACHINE-IINTERFACE USING MOTOR IMAGERY

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ABSTRACT:
We would like to report observations collected during the monitoring of long-term brain training using standard EEG from motor cortex. The purpose of the experiment was to determine if the reliability of noninvasive EEG, applied for controlling a computer, can be improved by repetition. Study of five subjects trained with no feedback over 1000 trials demonstrated the intuitive hypothesis that repeatability of cortical motor imagery reaction time to visual stimulus is improved. The "improvement" was quantified by computing the cross-correlation. An unexpected observation was that the average cortical reaction time is the same for all subjects and does not change with number of training repetitions. This behavior suggests that the cortical reaction time is "hard wired" and thus a property of the nervous system. The long lasting repetitive training process did not adversely affect the reaction signal amplitude even after some "automation" of the reaction had been observed.

Keywords: Brain-Machine-Interface, brain training, motor imagery

MOTIVATION:
People with fully functional brains, but who are unable to move due to damage to their nervous or muscular systems, may benefit from the ability to control their environment directly from the brain. A non-invasive enabling approach to detecting brain signals and using them for controls could prove advantageous. This approach, Brain-Machine-Interface (BMI), uses standard EEG detection and massive signal processing.

The presence of electrical current in the brain was discovered by an English physician, Richard Caton, in 1875. It was not until 1924 that Hans Berger, a German neurologist, used ordinary radio equipment to amplify the brain's electrical activity. The concept of BMI was created not much later; however, there is still no reliable product available on the market that could be used for controlling the environment directly from the brain.

Two possible conclusions could be drawn from this situation: either the approach is hopeless or something important is missing which researchers have neglected to consider. We assumed the latter and looked for the missing element. Review of relevant publications showed that brain training for EEG detection improvement was rarely documented in the literature [1- 11]. Generally, the cortex is responsible for strategizing and for conscious decision-making processes. When we learn physical activities, we initially make a conscious effort. However, after several repetitions, the activity becomes "automatic" and we stop thinking about it. We considered the possibility that the activity is no longer controlled from the cortex for this reason, and thus, is not available for noninvasive EEG monitoring. On the other hand, we counted on brain "plasticity" and perhaps the possibility of amplification of motor-cortical signal strength. The outcome of testing these two possibilities would determine if using the EEG for BMI is sensible. A long-term training experiment was designed in which we wanted to determine if after 1000 repetitions of motor imagery, the EEG signal was reliable enough to be applied as a control signal for BMI. Three EEG parameters were the focus of this study: reaction time, event-related-potential (ERP) of motor imagery, and the difference between right and left motor imagery, all following a visual stimulus.

METHODOLOGY:
Subjects: Five healthy subjects of different ages (from 19 to 63 years) and backgrounds (sciences and arts) were involved.

Setting: The experiment was carried out in an electromagnetically shielded chamber. The subjects sat on a comfortable armchair that provided support for the arms and head. A monitor screen (27cm x 16cm) displaying visual stimuli was placed approximately 60cm from the subjects. After having three sets of electrodes placed in bipolar combination at Cz, C3, and C4 according to the 10-20 system, the subjects were asked to relax and remain relatively motionless for the EEG acquisition. A commercial EEG unit, NIHON KOHDEN Neurofax EEG 2110, was used to collect event-related-potentials (ERP) from the subjects

Data acquisition: Subjects were exposed to a sequence of signs appearing on the screen: a cross, an arrow, and a blank. A similar pattern, although with subtle differences, was presented in [7]. The participants focused on a centered cross for three seconds and then imagined tapping their right or left hand, respectively, following 1 sec of either a right or left pointing arrow. A blank screen lasting 4 seconds provided a relaxation break.
Each subject participated in 20 sessions spread over a week. Each session consisted of 50 trials, 25 to the right and 25 to the left, in a random manner. No feedback was provided to the subjects.

RESULTS:

All collected data were statistically processed in the time domain. Two parameters were obtained: correlation of motor-imagery signal strength and reaction time.

From the correlation coefficient, the results from 2 subjects showed improvement in signal strength, one with a linear slope value of 0.0004μV/trial and the other with 0.0012μV/trial. One subject had a constant EEG signal through all the trials, another had consistent (high correlation) signals from the left motor imagery and scattered results on the right motor imagery, and finally the last subject presented no consistency in the correlation coefficient results. Comparison of left and right motor imagery signal strength showed no difference with respect to arrow directionality, neither in reaction time nor in correlation for all subjects. In no case, did the signal intensity deteriorate at the end of the study.

All reaction times for all subjects and for all sessions are contained between 0 and 1.5 seconds. The average reaction time (delay time) from all measurements and from all subjects is 0.592 sec and does not change with the number of sessions.

DISCUSSION:

1. Motor imagery is still present in the cerebral cortex after 1000 training repetitions.
2. The average reaction (delay) time is roughly the same for different subjects and does not change with training, suggesting the possibility of reaction times being "hard-wired".
3. The changes in ERP over training time suggest that there are three groups of people:
   - Those who are able to improve their EEG signals for BMI applications
   - Those who will not improve, but will retain consistent signals sufficiently good for BMI
   - Those who are unable to concentrate their thoughts on the task at hand.

Similar studies should be performed on people with motor disabilities as they may have different motivation to improve their EEG parameters for BMI.

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