An fNIRS-based brain-machine interface for remote robot control

B. Sorger1*, K. Tumanov2*, A. Benitez Andongueil, M. Lührs1, H. Boeijens3, G. Weiss2, R. Goebel1, R. Möckel2

1 Department of Cognitive Neuroscience, Maastricht University, Maastricht, the Netherlands
2 Department of Data Science and Knowledge Engineering, Maastricht University, Maastricht, the Netherlands
*Both authors equally contributed to the project.

Introduction

Patients with severe motor impairments (e.g., “locked-in” patients) may benefit from using brain-computer/machine interface (BCI/BMI) applications that could replace the patients’ lost motor function. Functional near-infrared spectroscopy (fNIRS), a portable, relatively easy-to-apply and safe functional-neuroimaging method, constitutes a promising BCI/BMI input modality. While fNIRS-based communication and computer control have been explored in several BCI studies1-4, comparatively little research has been done in the context of fNIRS-based remote robot control in real-time.

Methods and Results

Here, we developed and tested a BMI system for establishing control of a remote robot (located in 3-4m distance) allowing its intentional navigation to one of four different target locations (kitchen, charger, door, or work room). For this purpose, we combined brain-based intentional encoding of the robot’s target location based on brain hemodynamics (using differently timed motor imagery and fNIRS) and otherwise autonomous robot navigation.

Our successful proof-of-principle study demonstrates the general feasibility of fNIRS-based remote robot control in real-time.

Encoding of robot-target location (Figure 2)

- performing 1x (single-trial approach) or 3x in a row (multi-trial approach) mental drawing for 10s during one of four consecutive time periods
- each time period corresponds to one of the four different robot target locations
- intention encoding guided by visual stimulation (presentation of dynamic map with robot target locations successively highlighted according to the encoding scheme)

Participants and pre-training

- n = 5 (4 right-handed, all female, mean age = 28.8 years)
- short training of mental-task performance (right-hand mental drawing) and encoding of robot target locations

Experimental design/implementation

1. Localization of most-promising fNIRS-recording channel
- 1 short localizer run (8:30min)
- 50 s initial baseline period
- alternation between 10 s-mental drawing and thirteen 20 s resting periods

2. Brain-based encoding of robot target location and robot feedback
- 50 s initial baseline period
- 4-8 multi-trial runs (encoding one robot target location each)
- 4-6 single-trial runs (encoding 4-6 robot target locations each)
- 20-40 s resting periods separating individual encoding trials
- online decoding of participants’ intentions during resting periods and immediate transfer of the command via the internet to the remote robot
- autonomous navigation of the robot (Figure 2; TurtleBot 2; Clearpath Robotics Inc., Ontario, Canada)
- participants traced the robot’s navigation via real-time videoconferencing

fNIRS data acquisition

- NIRScout-816 system (NIRx Medizintechnik GmbH, Berlin, Germany)
- 8 light sources and 8 detectors covering large parts of the scalp above left-hemispheric sensorimotor cortex (Figure 3)
- equidistant optode positioning, 22 fNIRS-recording channels

Decoding results

**Figure 4. Individual and group decoding results.**
The figure demonstrates the online- (continuous lines) and offline-obtained (dashed/dotted lines) results for experimenter (human) and automated (machine) decoding. Achieved accuracies are separately plotted for the single- (panel A) and multi-trial (panel B) encoding procedure. Panel C displays the overall single-trial accuracies. Asterisks (for human results) and circles (for machine results) indicate decoding performance significantly above chance level.

Conclusion

The suggested fNIRS-based BMI for remote robot control constitutes a promising approach which may allow disabled patients to (re-)engage in specific social activities. After further advancement (e.g., increasing automated-decoding accuracy by employing multi-variate analysis) and more extensive validation, we will test the BMI system in motor-disabled patients.

References