Towards developing a portable, safe optical system to measure brain activity in patients with consciousness disorders

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There has been an increasing interest in developing brain computer interfaces (BCI) for patients who are aware but lack the physical ability to follow commands. Owen and colleagues previously showed using functional magnetic resonance imaging (fMRI) that some patients in a vegetative state can still communicate by performing a motor imagery task in response to commands.\(^1\) Although promising, this work highlights the need to explore alternative techniques such as functional near infrared spectroscopy (fNIRS) which is inexpensive and portable and enables bedside studies. Furthermore, brain regions associated with motor imagery (the supplementary motor area (SMA) and the premotor cortex (PMC)) can be interrogated by NIRS. However, the reliability of fNIRS – which is critical to this application – is challenged by a number of factors, most notably signal contamination from the scalp that can potentially mask true activation. Time-resolved (TR) NIRS has been proposed as one a way to enhance the sensitivity of fNIRS to brain activity since late-arriving photons have a higher likelihood of interrogating the brain. The objective of this study was to assess the feasibility of TR-fNIRS in detecting brain activity associated with motor imagery. For validation, all participants performed the same task in a 3T MRI scanner.

Data were acquired with a TR-NIRS system developed in house consisting of one emission fiber (\(\lambda = 830\) nm) and four detection channels. The detection fiber bundles were placed at a distance of 3 cm around the emission fiber, each in a separate quadrant, to interrogate the SMA and PMC. Fifteen healthy subjects were recruited (5 females, mean age 26, right handed). The experimental paradigm consisted of five 30-s cycles of rest and motor imagery. The order of fMRI and fNIRS were randomized to avoid possible training effects.

14 of the 15 subjects showed significant (p<0.05) fNIRS and fMRI activity either at the whole brain level or after applying small volume correction to the fMRI data. The remaining subject showed fMRI activity only. By using TR-NIRS, we were able to increase our sensitivity to brain activity by analyzing the late-arriving photons. The excellent agreement between the two techniques demonstrates the robustness of fNIRS for detecting brain activity during motor imagery. The next aim is to apply the same fNIRS protocol to disorders-of-consciousness patients who are fMRI responsive.