Real-world neuroimaging: the use of a fiberless and wearable fNIRS system to monitor brain activity in the real-life on freely moving participants

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Introduction

- Cognitive abilities supported by the prefrontal cortex are traditionally studied through the use of lab-based neuropsychological tests.
- However, there can be situations in which conventional lab-based tests are not sensitive enough in unveiling prefrontal cortex dysfunctions, with significant disagreement between measurement taken in everyday life and the lab[1].
- This is most apparent for Prospective Memory (PM) as it requires novel and open-ended situations, which are hard to recreate successfully in the lab[1].
- Monitoring brain activity to real-world tests can provide a unique insight in the processes involved in everyday life underlying PM failures.

Aim

To investigate the feasibility of a wireless and fiberless functional Near Infrared Spectroscopy (fNIRS) device to monitor prefrontal cortex hemodynamic activity during a real-world PM task conducted outside the lab on freely moving participants.

Materials and Methods

fNIRS and Physiological Data Acquisition

- A 16-channels fiberless and wearable fNIRS system (WOT, Hitachi High-technologies Corporation, Japan; sampling frequency=5 Hz) monitored prefrontal cortex activity (Figure 1).

Figure 1. WOT system

- Walk-related Heart Rate, Breathing Rate and Acceleration changes were measured through a monitoring belt worn on participants' chest.

Experimental Protocol

- Participants performed a PM task outside the lab[2] composed by the following conditions:
  - Rest 1: cognitive task + no walking;
  - Rest 2: walking + no cognitive task;
  - Baseline: exploring the experimental area;
  - Ongoing (OG): counting items around the square;
  - Social PM: OG task + face bumping an experimenter (Figure 2 A);
  - Non-social PM: OG task + face bumping parking meters (Figure 2 B).

Figure 2. Social (A) and Non-social (B) PM conditions

- Three cameras recorded the experimental session for behavioural examinations and for the validation of the proposed method.

fNIRS signal preprocessing

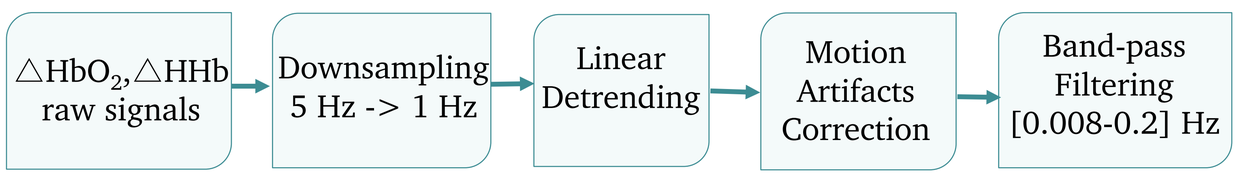

Figure 3. Oxy- (HbO_2) and deoxy- (HHb) hemoglobin signals preprocessing steps.

Results

- Although participants were free to walk and move the head to accomplish the task, raw fNIRS data did not present remarkable motion errors and a good Signal-to-Noise ration was achieved (Figure 4).

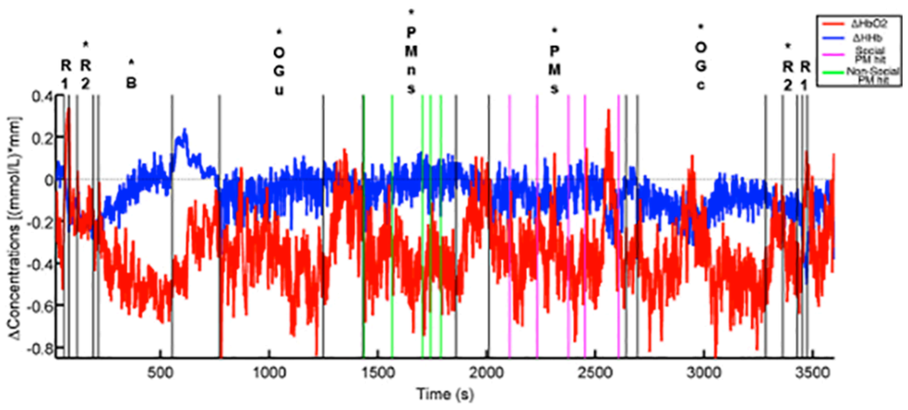

Figure 4. Example of raw fNIRS data.

- After a proper signal preprocessing flow, typical –but anticipated– functional activation trends can be found in close proximity to non-social (Figure 5 A) and social(Figure 5 B) PM targets.

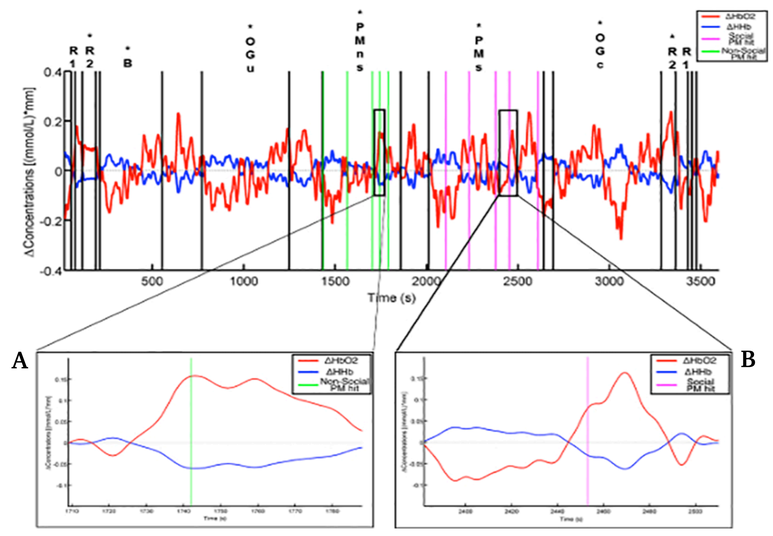

Figure 5. Preprocessed fNIRS signals and hemodynamic responses to non-social (A) and social (B) PM hits.

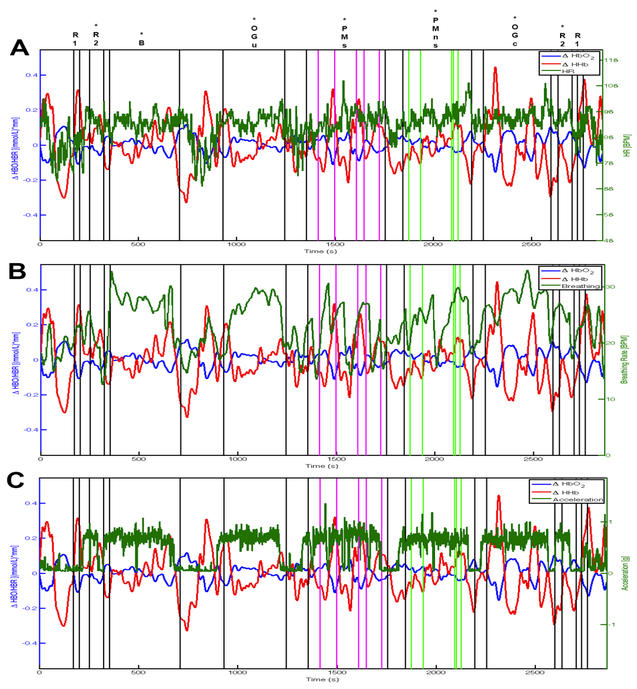

Figure 6. Heart rate (A), Breathing rate (B) and Acceleration (C) changes during the experiment.

- Changes in Heart rate, Breathing rate and Acceleration (Figure 6) are appreciable during the experiment and may interfere with fNIRS cortical signals.

Conclusions

- The present study demonstrated the feasibility of fiberless fNIRS to monitor functional brain activity in real-world PM experiments conducted outside the lab and on freely moving participants.
- Anticipated hemodynamic responses suggest that event onsets recovery from video recordings can be not accurate enough and new methodologies are needed.
- Results show that walk-related physiological changes occur during this type of experiment and need to be taken into account when analysing real-world fNIRS data.

1. Burgess, P.W., et al. "Mesulam's frontal lobe mystery re-examined." *Restorative neurology and neuroscience* 27.5 (2009), 493-506.
2. Pinti, P., et al. "Using Fiberless, Wearable fNIRS to Monitor Brain Activity in Real-world Cognitive Tasks." *JOVE* 106 (2015).