Exploring the potential of fNIRS in capturing subjective cycling experiences

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Challenge Addressed / Research Problem Investigated

We need a robust way to understand people's subjective experiences while they cycle to increase cycling participation, which has remained low in many developed countries despite proven benefits.

Abstract

INTRODUCTION

Despite proven environmental, economical, and health benefits, cycling participation remains low in many developed countries. Subjective experiences have been identified as a key deterrents to cycling participation; unpleasant weather conditions and sense of unease from exposure to motorised traffic are commonly reported factors (Sanders & Judelman, 2018; Useche et al., 2019). This study investigated the potential of functional near-infrared spectroscopy (fNIRS) to capture and enable understanding of subjective experiences while cycling, and discussed its implications for enhancing cycling participation.

fNIRS is a type of non-invasive neural imaging sensor that measures changes in blood oxygenation levels in the brain to infer neural activity. Its portability and relative ease of setup make it particularly suitable for studying cycling in real-world conditions. This study stands out in its novelty as it is the first to employ fNIRS to explore subjective experiences within the context of cycling. Acknowledging the complex nature of experience, the present study employed a mixed methods approach, combining quantitative fNIRS data with subjective on-ride self-reports. Sensor data is neccessary as self-reports are prone to biases.

For simplicity, subjective experiences were simplified to positive and negative emotions, commonly referred to as *valence* in psychology. Existing literature on the neural correlates of valence highlights the significance of the prefrontal cortex (PFC) (Lindquist & Barrett, 2012; Machado & Cantilino, 2016), which leads to the following hypotheses: Both positive and negative valence are associated with heightened activity throughout the PFC; positive valence in particular corresponds to further increased activity in the left PFC and reduced activity in the right PFC.

EXPERIMENT DESIGN

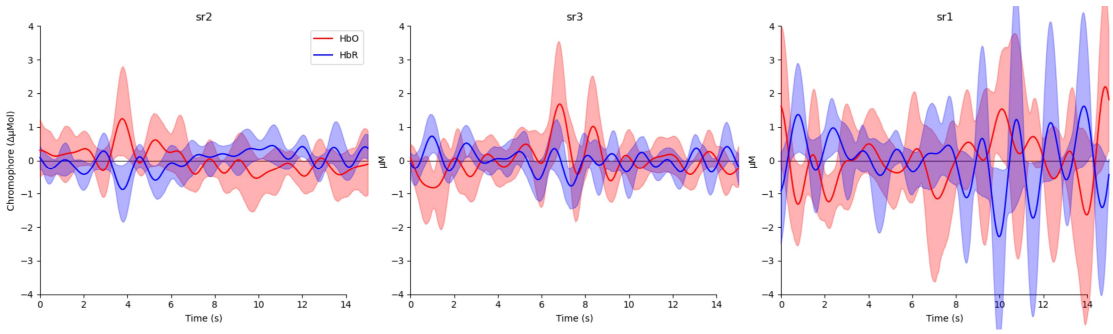
17 healthy participants were involved in the experiment, with each trial conducted individually during non-rush hours to minimise bias from varying traffic conditions. Participants were

equipped with an Artinis Brite MKII, a two-wavelength continuous wave fNIRS system placed over the prefrontal cortex (PFC). The fNIRS device measured oxygenated (HbO) and deoxygenated (HbR) blood levels, collecting data at a rate of 50 Hz. Once equipped with the fNIRS device, participants were taken outside to their bikes. An action camera and a mobile phone were attached to the participant's bike near the center of the steering bar. The camera faced forward, while the mobile phone, preloaded with the PIEL Survey experience sampling app (pielsurvey.org) configured for the experiment, was positioned for visibility to the rider.

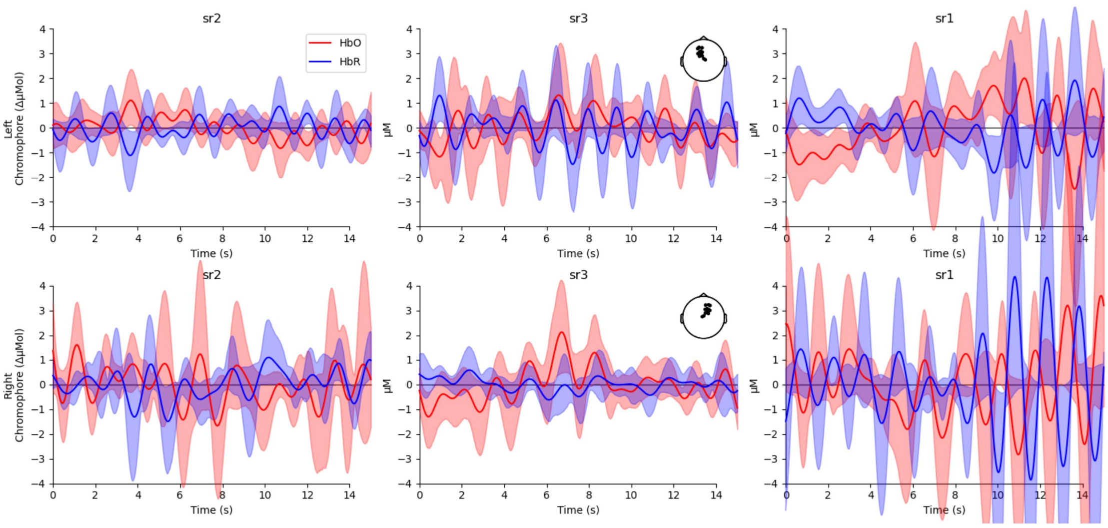
Camera recording and fNIRS measurement began as each participant cycled a 7.5 km looped route. The route was designed to include both a 'busy route' along a main road with motorised traffic, stops, and intersections, and a 'peaceful route' consisting of a dedicated bicycle highway with natural surroundings. The intention was for the busy route to elicit more negative valence, while the peaceful route was expected to evoke more positive valence. To prevent bias, the direction in which participants cycled was randomly determined. Throughout the cycling session, the PIEL Survey app on the mobile phone emitted a notification sound every 3 minutes, prompting participants to rate their current feelings as positive, neutral, or negative. After completing the ride, participants were guided indoors for a brief video-stimulated interview to gather contextual information that could help explain the observed results.

RESULTS

For each participant's data, 15-second windows were extracted, excluding noisy channels and corrupted portions. These windows were then averaged by rating based on the on-ride ratings. Analysis of the average window responses across all participants and channels revealed higher levels of variability and uncertainty in both HbO and HbR signals in response to rating 1 (negative) compared to ratings 2 (neutral) and 3 (positive). No other patterns were identified by visual inspection.



Grand average window responses: The average window responses specific to each hemisphere (left vs right PFC) demonstrated similar findings. Rating 1 exhibited signals with higher variability and uncertainty compared to ratings 2 and 3. Visual inspection suggested that the signals from the right PFC during rating 1 appeared slightly more erratic than those from the left PFC.



Hemisphere-specific average window responses: The quantitative analysis, conducted using a mixed-effects linear model, did not yield significant results, thereby failing to support the hypotheses. Furthermore, as part of an exploratory analysis, a Pearson correlation coefficient test revealed that the busy route did not evoke the expected negative valence, nor did the peaceful route evoke the expected positive valence.

DISCUSSION

The fact that the quantitative analysis did not yield statistically significant findings could be explained by several factors. Based on the post-ride interviews, the broad definition of positive and negative valence might have resulted in neurologically distinct experiences being grouped together, making it challenging to identify specific features accurately. The naturalistic approach of the experiment, combined with the inherent physicality of cycling, likely introduced various confounding factors that were not fully mitigated or accounted for in the experiment design, data preprocessing, and analysis. Additionally, the quality of the connection between the sensor and the scalp could have influenced data quality and led to insignificant results. Nonetheless, the visual correlation between negative ratings and higher variability in HbO and HbR should not be disregarded. This pattern suggests a potential relationship between subjective experiences and physiological measures, notably cerebral oxygen consumption, which warrants investigation in future research.

It became evident that the type of surroundings was insufficient to consistently evoke positive or negative valence. Participants commonly associated negative valence with headwind, which occasionally occurred on both the busy route and the peaceful route (an uncontrolled factor). Manipulating valence by altering the physical surrounding alone is not a reliable solution for a naturalistic cycling study.

This study contributes to the groundwork for future research to develop more effective and robust frameworks for conducting naturalistic fNIRS experiments involving physical activities. The study also faced considerable challenges due to the relatively immature supporting ecosystem of data analysis tools and sparse information on best practices, underscoring the need for improving toolkits and documentation. In the long run, being able to capture nuanced differences between pleasure and arousal in subjective cycling experiences could provide insights for creating people-centric urban spaces and cities.

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