A wireless, wearable Brain-Computer Interface for in-home neurorehabilitation.

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TBH TRANSLATIONAL BRAIN HEALTH

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1. Introduction

- Clinical trials using Brain-Computer Interface (BCI) for stroke rehabilitation have shown promising results, yet clinical adoption is lacking [1]. Unsupervised at-home BCIs may increase clinical use by reducing the burden on healthcare providers and increasing patient agency.
- We adapted a mainstream BCI protocol (Graz-BCI) [2] to fit a realistic stroke rehabilitation scenario [3] to test the feasibility of such a system.

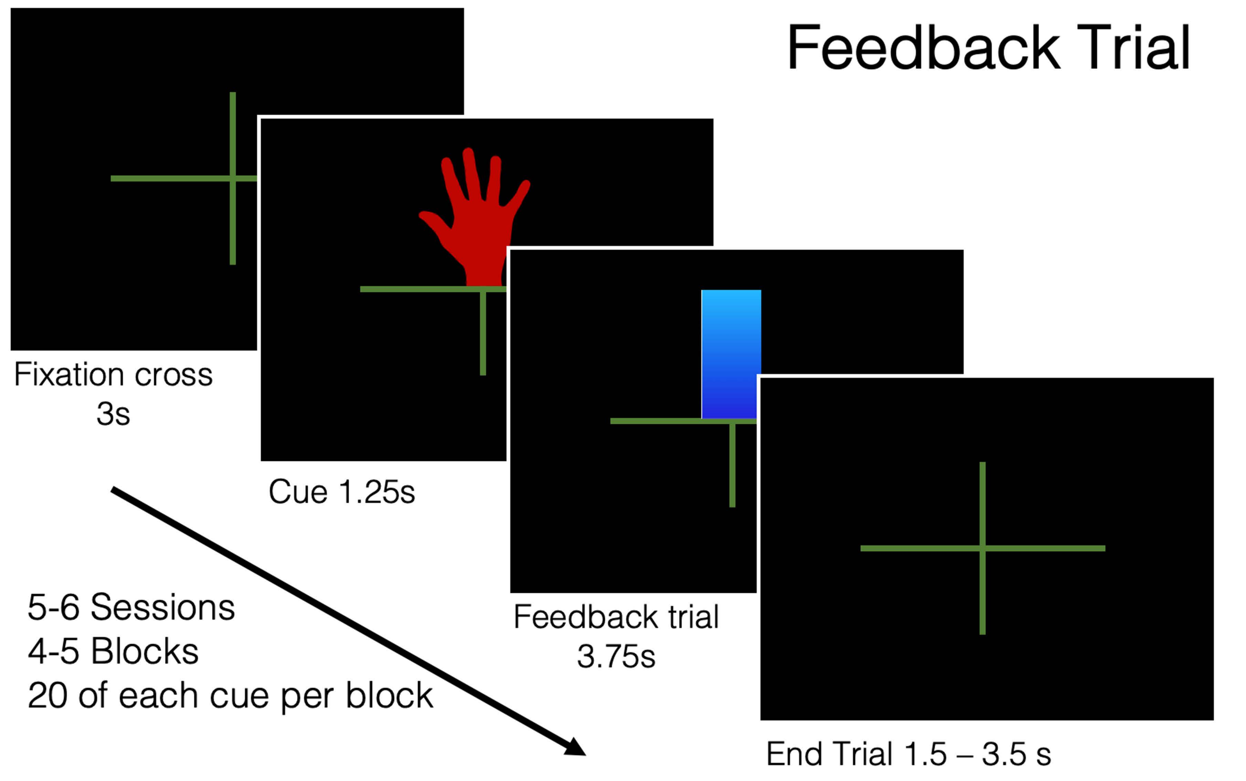
Research Questions

H1: Can participants control a BCI within six days, in their own homes with remote instruction?

H2: Will successful BCI control be associated with electrophysiological changes in alpha (8-14 Hz) and beta rhythm (15-30 Hz) frequency bands?

2. Method

- The Graz-BCI [4] – which detects real time differences in brain activity between two mental tasks – was adapted in OpenVibE [2].
- Participants collected data without feedback, to train a Common Spatial Pattern and a Linear Discriminant Analysis. Then they proceeded to train with feedback for 4-5 blocks.
- Participants imagined right-handed finger movement ( ) and a cold, dead, detached right hand ( ); tasks that have been shown to modulate excitability of stroke-affected limbs [3]
- Under careful instruction and remote supervision, the participants collected data in their own homes.



Participants were mailed a dry electrode, 16 channel, wireless EEG cap.
(Cumulus, Belfast, UK).

3. Analysis

- Lateralisation of brain activity was operationalised as the difference in power measured at FC3 and FC4.
- To investigate the influence of training on the EEG activity produced by participants, the averaged Riemannian distance – also called Distinctiveness [6] – of the EEG activity produced by the two tasks was analysed.
- A trained experimenter inspected the raw data and processed outputs to ensure the automatic processing was adequate.
- The EEG data was preprocessed using an automated pipeline:

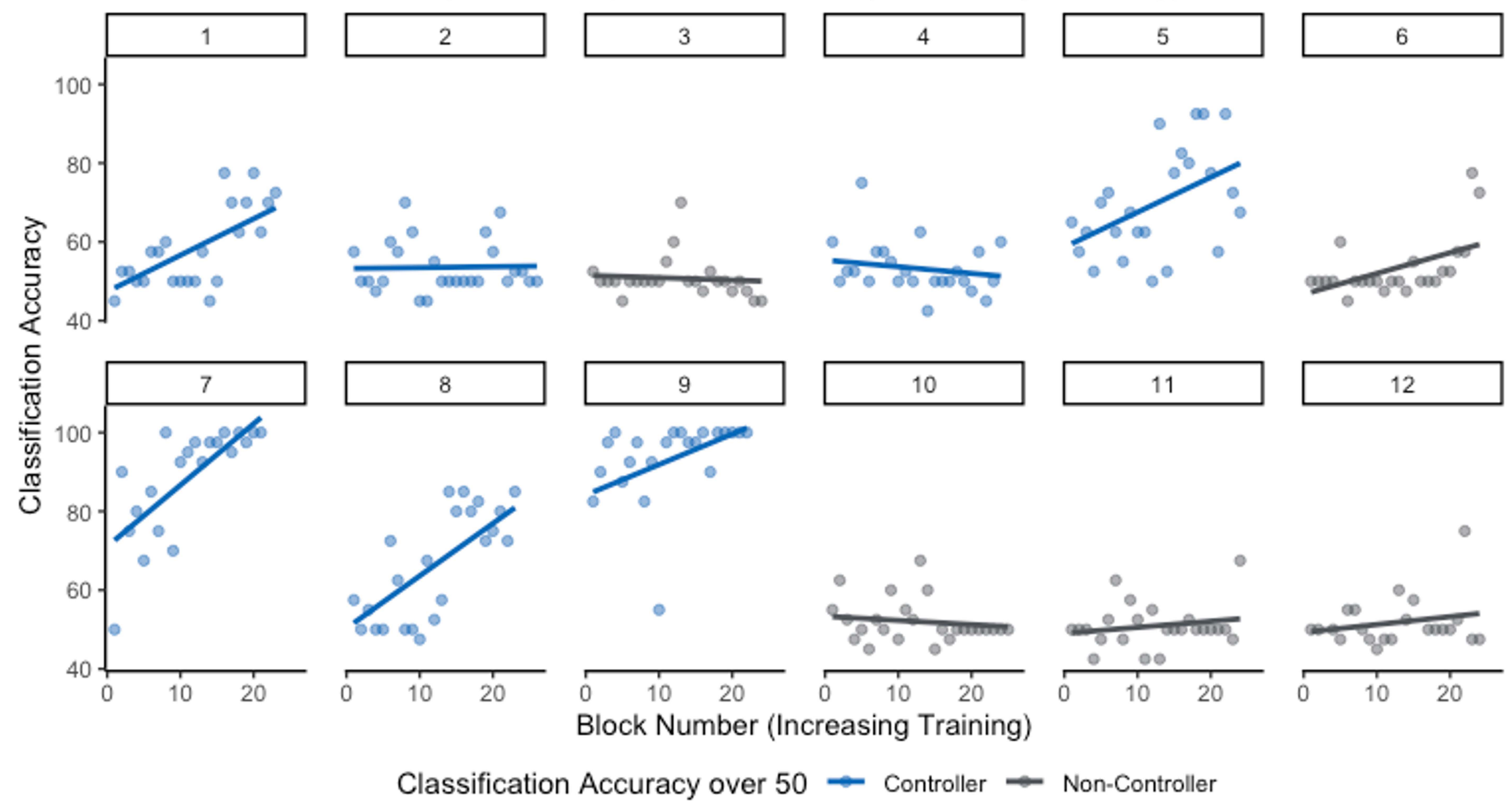
1. Lowpass Filter 45Hz
2. Highpass Filter 1Hz
3. Reference to Average
4. Artifact Subspace Reconstruction (ASR)
5. Interpolation of missing electrodes
6. Reference to Average
7. ICA, labelling and rejection
8. Epoching

4. Results

Classification Accuracy (CA)

- 7 of 12 participants (1, 2, 4, 5, 7, 8, 9) achieved CAs above 50 and were classified as “controllers”.

Classification Accuracy of Participants Over time (Increasing Training)

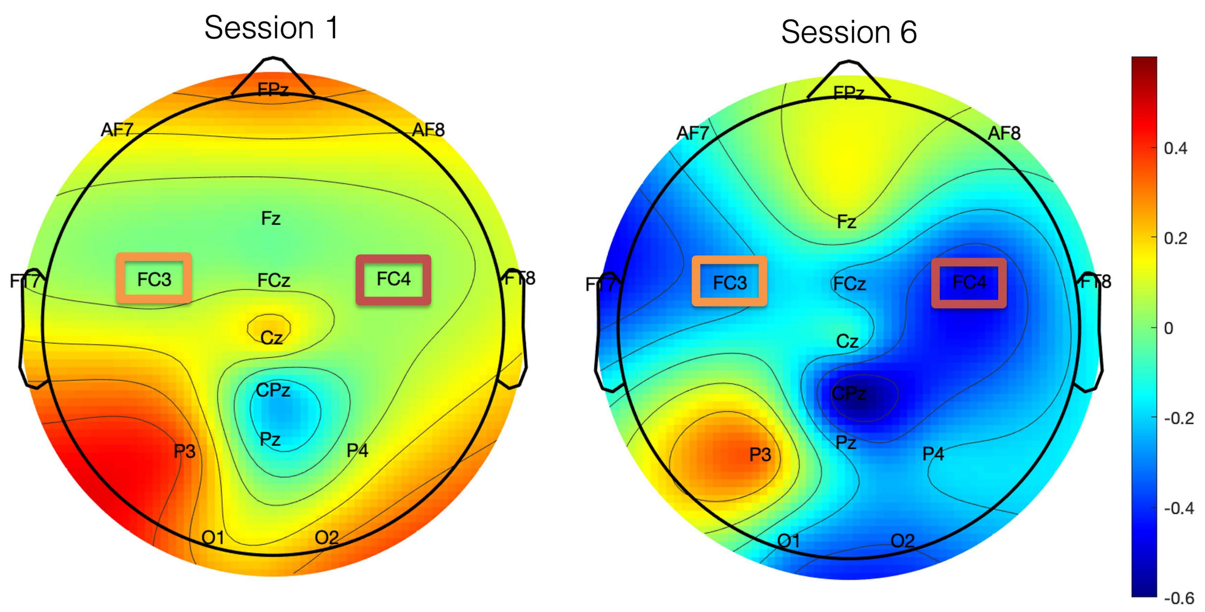


A mixed effects linear model was used to predict CA, using block number (represents the effect of training) and a random intercept and slope per participant. The training effect was significant ($b = 0.42$, $t = 2.31$, $p = 0.044$). These data support H1.

Power differences between mental imagery conditions show changes in motor region activity for controllers

- Power changes of alpha and beta power band at the FC3 and FC4 electrode (orange/red square, nearest to motor cortex) were significant: between groups, and within controllers – but not within non-controllers. These data support H2.
- Controllers had significantly stronger lateralisation of brain activity in the alpha and beta power band compared to non-controllers.

Alpha band power difference in controllers between trials



Distinctiveness between the mental imagery conditions increases with training and predicts CA.

- The Distinctiveness of brain activity between the two mental imagery conditions increases with training.
- The Distinctiveness is a better predictor of CA than is training time alone.

Variable	Beta Coefficient	t-Value	p-Value
Increase of Distinctiveness predicted by training	0.0106	3.04	0.0131*
Increase of CA predicted by training†	0.354	1.76	0.112
Increase of CA predicted by Distinctiveness†	7.598	2.07	0.0402*

† Predicted using the same model.

5. Conclusion

- It is possible to obtain control (improving CA) over an in-home BCI using a 16-electrode, wireless, EEG system
- Over time controllers produced more distinct and lateralized patterns of activity.
- Spectral analysis showed that the power of alpha and beta oscillations in the brain measured at FC3 and FC4 of power was significantly different between controllers and non-controllers, and within controllers, replicating similar results in literature [5].
- Future development of this work will aim to improve upon the extent and speed of learning to control the BCI and thus facilitates the development of new neurorehabilitation technologies.

Sources

[1] Simon, C., Bolton, D. A. E., Kennedy, N. C., Soekadar, S. R., & Ruddy, K. L. (2021). Challenges and Opportunities for the Future of Brain-Computer Interface in Neurorehabilitation. Frontiers in Neuroscience, 0. https://doi.org/10.3389/fnins.2021.699428

[2] Renard, Y., Lotte, F., Gibert, G., Congedo, M., Maby, E., Delannoy, V., Bertrand, O., & Lécuyer, A. (2010). OpenViBE: An Open-Source Software Platform to Design, Test, and Use Brain–Computer Interfaces in Real and Virtual Environments. Presence: Teleoperators and Virtual Environments, 19(1), 35–53. https://doi.org/10.1162/pres.19.1.35

[3] Liang, W., Xu, Y., Schmidt, J., Zhang, L., & Ruddy, K. L. (2020). Upregulating excitability of corticospinal pathways in stroke patients using TMS neurofeedback; A pilot study. NeuroImage : Clinical, 28. https://doi.org/10.1016/j.nicl.2020.102465

[4] Pfurtscheller, G., & Neuper, C. (2018). Motor imagery based EEG features visualization for BCI applications. Procedia Computer Science, 126, 1936–1944. https://doi.org/10.1016/j.procs.2018.08.057

[5] Ruddy, K., Balsters, J., Mantini, D., Liu, Q., Kassraian-Fard, P., Enz, N., ... & Wenderoth, N. (2018). Neural activity related to volitional regulation of cortical excitability. Elife, 7, e40843. https://doi.org/10.7554/eLife.40843

[6] Lotte, F., & Jeunet, C. (2017, September). Online classification accuracy is a poor metric to study mental imagery-based bci user learning: An experimental demonstration and new metrics. 7th International BCI Conference. https://hal.archives-ouvertes.fr/hal-01519478

QR code or link lead to short video of the Setup and experiment. https://1drv.ms/v/s!Aoo1_Keltny2ke0RfSYdKzVr76i2Jg?e=lyjuyt