Towards Neuroadaptive Technology: An outlook on the potential impact of Passive Brain-Computer Interfaces on Technology, Neuroscience and Society.

Dr. Thorsten O. Zander, TU Berlin, Germany / Zander Laboratories, Amsterdam, The Netherlands

Passive Brain-Computer Interfaces (pBCIs, [1]) can assess information about changes in cognitive and affective state in real time and convey an interpretation of these states as implicit commands [2] to a machine. The machine can then automatically adapt its own state to support a given task in the Human-Machine System [3]. Furthermore, by collating information about the user state with the task-specific context and using methods from machine learning and artificial intelligence a user model can be generated that even reflects correlates of higher cognition [4]. The resulting *Neuroadaptive Technology* leads to a convergence of human and machine intelligence and enables a fundamentally new way of interaction with technology [4, 5, 6].

In my talk I will provide an overview of recent developments in pBCI and Neuroadaptive Technology. Furthermore, I will discuss insights about how we can elaborate our understanding of human neuroscience by interpreting pBCI methods. By combining statistical machine learning with Independent Component Analysis, task-specific cortical sources and related single-trial activity can be identified directly from the used classification approach [7,8].

The approaches discussed have the potential to change the way we are affected by our interaction with technology [9] and to redefine privacy, as machines automatically gain access to private information potentially without our consent or even without our awareness [10]. I will discuss resulting ethical considerations in the conclusion of my talk.

References:

[1] Zander, T. O., & Kothe, C. (2011). Towards passive brain–computer interfaces: applying brain–computer interface technology to human–machine systems in general. *Journal of neural engineering*, *8*(2), 025005.

[2[Zander, T. O., Brönstrup, J., Lorenz, R., & Krol, L. R. (2014). Towards BCI-based implicit control in human–computer interaction. In *Advances in Physiological Computing* (pp. 67-90). Springer, London.

[3] Zander, T. O., Kothe, C., Jatzev, S., & Gaertner, M. (2010). Enhancing human-computer interaction with input from active and passive brain-computer interfaces. In *Brain-computer interfaces* (pp. 181-199). Springer, London.

[4] Zander, T. O., Krol, L. R., Birbaumer, N. P., & Gramann, K. (2016). Neuroadaptive technology enables implicit cursor control based on medial prefrontal cortex activity. *Proceedings of the National Academy of Sciences*, *113*(52), 14898-14903.

[5] Lorenz, R., Monti, R. P., Violante, I. R., Anagnostopoulos, C., Faisal, A. A., Montana, G., & Leech, R. (2016). The automatic neuroscientist: a framework for optimizing experimental design with closed-loop real-time fMRI. *NeuroImage*, *129*, 320-334.

[6] Iturrate, I., Chavarriaga, R., Montesano, L., Minguez, J., & Millán, J. D. R. (2015). Teaching brain-machine interfaces as an alternative paradigm to neuroprosthetics control. *Scientific reports*, *5*, 13893.

[7] Krol, L. R., Pawlitzki, J., Lotte, F., Gramann, K., & Zander, T. O. (2018). SEREEGA: Simulating Event-Related EEG Activity. *bioRxiv*, 326066.

[8] Krol, L. R., Mousavi, M., De Sa, V., Zander, T.O. (2018). Towards Classifier Visualisation in 3D Source Space. *IEEE International Conference on Systems, Man, and Cybernetics.*

[9] Ienca, M., & Haselager, P. (2016). Hacking the brain: brain–computer interfacing technology and the ethics of neurosecurity. *Ethics and Information Technology*, *18*(2), 117-129.

[10] Fairclough, S. (2014). Physiological data must remain confidential: electronic devices that track our emotions, heart rate or brain waves should be regulated to protect individual privacy. *Nature*, *505*(7483), 263-264.