Decoding mindfulness vs. wandering thoughts from magnetoencephalography using machine learning

Alexander Zhigalov[1, 2], Erkka Heinilä[4], Lauri Parkkonen[2], Tiina Parviainen[4], Aapo Hyvärinen[1, 3]

[1]*Dept of Computer Science. University of Helsinki, Helsinki, Finland*
[2]*Dept of Neuroscience and Biomedical Engineering, Aalto University, Espoo, Finland*
[3]*Gatsby Computational Neuroscience Unit, University College London, London, United Kingdom*
[4]*Dept of Psychology, University of Jyväskylä, Jyväskylä, Finland*

Machine learning methods have recently become popular for analysing brain imaging data. In particular, "decoding" means training a machine learning classifier to tell, for each short epoch, which experimental condition it belongs to. Such methods can potentially be directly applied in neurofeedback, by providing information on whether the subject is in a wanted state or an unwanted state. In the context of mindfulness, we could improve mindfulness training by neurofeedback where an alarm signal is given to the subject when there are wandering thoughts. Here, we investigate the potential of machine learning to decode whether the subject is in a mindfulness state or has wandering thoughts. As a proxy for wandering thoughts, we use two further experimental conditions (in addition to mindfulness) where the subject is instructed to either plan future actions, or reflect on emotionally charged photographs. We recorded magnetoencephalography (MEG) from 24 subjects with zero to moderate meditation experience. Two sessions of 26 minutes were recorded for each subject, one for training the classifier and the other for testing its performance. We used features based both on spectral energies and connectivities, and epochs of length 4 seconds. The classification accuracies in pairwise classification were typically around 60%, reaching 62% for the best method, for decoding mindfulness from the other two conditions. Both spectral energies and connectivity provided similar results, with alpha band features the most important. A major difficulty in a neurofeedback application would be the strong individual variability of the brain correlates of the conditions. While the decoding accuracy is rather modest, the results indicate that machine learning methods methods could potentially be used to generate neurofeedback to help maintain a state of mindfulness, but further development is needed.