On the ubiquity of movement

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Movement is ubiquitous in life, and the results presented in chapter 2, 3, 4 & 5 suggest that movement-related neural activity is ubiquitous in the brain as well. Identifying the extent, understanding the neural basis, and decoding these global motor dynamics may lead to both scientific and societal impact.

Most immediate, we strengthen the scientific support to look beyond the motor cortex [1]. A broader perspective of motor decodable information may lead to a more comprehensive understanding of the full motor system. In the context of BCIs, this may uncover new implantation targets, increasing the available information for motor decoders. Moreover, motor-related activity can be decoded outside of the motor-cortex, making motor-BCIs available for users who have a damaged motor cortex. In an ideal future, neuroprostheses integrate seamlessly, perform real-time and decode (near) perfectly. To achieve this, all brain areas that contain motor-related information essential for decoding need to be captured. This set of areas is currently unknown, but given the narrow focus on the motor cortex, there might be unidentified (networks of) regions that improve motor decoders. A broader focus and decoding endeavors may uncover these areas.

A potential application of decoding non-motor areas is that global motor dynamics (chapter 4) may be beneficial for stabilizing decoders. One of the current problems experienced in motor decoders based on microelectrode arrays (MEA) is a decrease in performance over time, requiring regular calibration sessions. Stabilizing the decoder would reduce calibration sessions, increasing the potential for long-term at home use. From a manifold perspective, the reduction in performance can be viewed as a degradation of the underlying manifold due to changing signal in the electrodes [2]. Given the stability of the global motor dynamics to loss of signal (stable up to 50% of lost channels, as demonstrated in chapter 4, Figure 4.3), they might act like a stable anchor to retain more performance. Increasing long-term stability by decreasing (re)calibration of decoders would increase the likelihood of clinical deployment of at home use of BCIs

That same stability may contribute to calibrationless decoders via a different pathway as well. We demonstrated a proof-of-concept of transfer learning with non-overlapping electrodes, which may be beneficial to improve or reduce calibration of training of decoders. If we are able to extract neural structures that are similar between users, then we may be able to pre-train models based on earlier recorded data. This way, a decoder may be used as a plug-and-play device. Given that the decoding performance was more reliant on the data or electrode locations of the target participant, no pre-selection or optimization is required for initializing a decoder for a new user.

So far, motor BCIs in this thesis have been discussed in the context of controlling some kind of assistive device. However, the same motor decoding methods might prove useful for other purposes. For example, changes in global motor dynamics may relate to symptom severity or disease progression in motor neuron diseases. Particularly in treatments where electrodes are implanted already for another clinical goal, like deep brain stimulation (DBS) in Parkinson's disease (PD), research to relate changes in global motor dynamics to clinical measures can be performed directly. Additionally, if changes in dynamics are related to symptom severity, then this change might be used as control signal to adaptive DBS.

Given the number of DBS implantations, 30.000 between 2002 and 2011 in the United States [3], the possible impact of new potential clinical measures like global motor dynamics can be widespread. Moreover, DBS treatments are expanding from PD to more neurological disorders and syndromes, including Tourette syndrome, pain, major depression and obsessive compulsive disorder [4], expanding the potential research potential and clinical impact even further.

References

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