Understanding and improving neurofeedback-guided self-regulation

Knowledge Valorisation

In the last fifty years, a sharp rise in mental health issues has been observed (Kim, Coumar, Lober, & Kim, 2011; Whitaker, 2005), widely described as the „mental-health epidemic". During the same time, technical improvements like the development of functional magnetic resonance imaging and the exponential growth of processing speed and digital memory has put neuroscience, psychology and psychiatry into the state to create mental-health treatments based on excessively growing data related to human (*e.g.*, brain) functions.

While a research community contributing to such a massive increase of clinically relevant data has the ethical responsibility to support the utilization of its research in the clinical practice, developing treatments based on fast-changing and cost-intensive neuroimaging techniques remains a challenge under constant economic pressure. Increasing the efficacy of treatments and tailoring it to the patient population that will benefit the most from it will help to optimally translate findings from basic research in cognitive, affective and social neuroscience to the clinical domain.

In the process of this transition, neurofeedback has to compete or merge with other mental-health treatments that do not require such specialized technical equipment and are easier to access, as psychopharmacological treatments, psychotherapy or mindfulness-based approaches. Currently, research that observes such interactions between rtfMRI and other mental health treatments is emerging. A recent study could demonstrate that neurofeedback can support cognitive behavioural therapy by improving meta-cognitive abilities of participants (MacDuffie et al., 2018). An ongoing clinical trial is also evaluating whether brain activation during

neurofeedback can function as a biomarker for responsiveness to pharmacological treatments (Peciña, 2016). However, potential interaction with regard to the neural effects of such combinations are hard to predict, due to complexity of the involved neural mechanisms.

Acquiring and analyzing data of the neural processes that take place during neurofeedback is therefore crucial, in order to form valid hypothesis on how other available treatment approaches can contribute to the effects of neurofeedback and vice versa. Especially combinations between neurofeedback and brain stimulation techniques could constitute a first pathway beyond neurofeedback-only interventions, as both techniques provide flexible control over neural treatment effects. But while first closed-loop neurofeedback transcranial magnetic stimulation (NF-TMS) systems have already successfully been implemented (Koganemaru et al., 2018; Sokhadze et al., 2014), their applicability in the clinical domain is still in its infancy.

Another group of treatments that shows potential for being combined with neurofeedback are biofeedback trainings that do not feedback brain activation, but rather respiratory or cardiac activity. Such biofeedback approaches, as heart rate variability biofeedback, have also shown to constitute effective treatment options for major psychiatric disorders (see Siepmann, Aykac, Unterdörfer, Petrowski, and Mueck-Weymann (2008); Karavidas et al. (2007)), and could contribute to the training of self-regulation strategies, interoceptive abilities, as well as self-efficacy (Gevirtz, 2013).

In addition, meditation based treatments share several psychological core aspects with neurofeedback interventions, as training of self-regulation skills and

introspection (Baird, Mrazek, Phillips, & Schooler, 2014; Tang et al., 2007; Tang, Posner, & Rothbart, 2014). As these approaches are not as cost-intensive as fMRI-NF approaches, but potentially require more training sessions, combining such interventions with neurofeedback could provide a possibility to allow for continuous self-regulation training, while reducing treatment costs.

Another option for reducing treatment costs would be the application of cheaper and more easily accessible neuroimaging techniques for generating neurofeedback, as electroencephalography (EEG) or functional near-infrared spectroscopy (fNIRS). While these techniques lack the ability to provide reliable neurofeedback from subcortical areas, they are not associated with so many practical issues as MRI (e.g. related to safety) and can also be used without trained technical staff: Contemporary developments as BCI-EEG devices for home use (Sellers, Vaughan, & Wolpaw, 2010) could therefor help to integrate neurofeedback into the daily life of patients. Understanding how participants react to different types of neurofeedback will contribute to sensible decisions on which neuroimaging techniques are best to be applied for certain clinical conditions.

But before understanding the unique effects of a particular neurofeedback setting, as well as the effects emerging from combinations between neurofeedback with other therapies, research on the neural basis of neurofeedback is a first, necessary step. Neurofeedback can only develop its full potential as a clinical tool when we understand how it works.

To achieve this

i. …improvements of training designs as described in chapter 2 and 3 of this thesis will help to increase the cost efficacy of neurofeedback. At the same time they provide an example for transfer of self-regulation skills and thus give an optimistic outlook for more holistic training schemes, which not only implement different neurofeedback tasks, but in consecutive treatment phases apply neurofeedback and other mental health interventions.

ii. …research on the neural mechanisms of neurofeedback (as described in chapter 3 and 4), will allow to understand which properties of neurofeedback are unique in comparison to other types of treatment. Especially when considering that striatum activation (as described in chapter 4) could be modulated directly at reward sensitive time windows with neurofeedback-guided neurostimulation, neurofeedback contains powerful potential for reshaping dysfunctional brain circuits through reinforcement learning.

With its potential for integrating state of the art research from neuroscience, psychiatry and psychology into one comprehensive treatment approach, neurofeedback constitutes a modern treatment for psychiatric conditions that manifest themselves in the brain as well as in psychological experiences.