Striving for cognitive enhancement with RT-FMRI neurofeedback

KNOWLEDGE VALORISATION

Within academia, the importance of knowledge valorisation gains an increasingly important significance. According to the National Valorisation Committee (2011), knowledge valorisation aims at

"*creating value from knowledge, by making knowledge suitable and/or available for social (and/or economic) use and by making knowledge suitable for translation into competitive products, services, processes and new commercial activities*"
(Regulations governing the attainment of doctoral degree, UM, App. 4, §23).

On the one hand, engaging in knowledge valorisation is certainly an important aspect for the scientific community, as the experimental ideas themselves or the results of scientific endeavours often target societal, economic or governmental interests, whether directly or indirectly. In order to bridge the gap between academic work and these interests from outside academia, it is therefore necessary to translate the knowledge gained from science. However, and on the other hand, this is not an easy task and might not be directly applicable for all kinds of research, *e.g.* very fundamental research does not necessarily lead to any direct value for the economic market or societal wealth, but rather enriches the scientific community in order to increase our general understanding of the world, which might in itself again lead to benefits in social or economic matters, only on the long run. Therefore, writing a chapter about knowledge valorisation itself is a challenging and important task.
First of all, for the translation of knowledge, inter-disciplinary exchange is an important tool. Through this exchange, knowledge can propagate, creativity is facilitated and new research ideas can be sparked. The current thesis was part of a collaborative project called 'Human Enhancement and Learning" (HEaL), which focused on joining the fields of neuroscience and economics of education in order to combine their inherent expertise to gain new knowledge about human learning and improve education. To foster collaboration, as well as dialogue among these different fields, various meetings of the different research teams have been initiated throughout the different stages of the projects in this dissertation.

Through these meetings, mutual knowledge dissemination was encouraged and led to fruitful research ideas.

As for the current dissertation, the experimental results can be valorised in different terms, mainly providing suggestions and guidelines for future experimental research on cognitive enhancement with rt-fMRI neurofeedback, but also being relevant for the educational, as well as health-care sector.
The main goal of this thesis was to establish feasibility of employing rt-fMRI neurofeedback for cognitive enhancement purposes. Throughout the dissertation, different stages for potential cognitive enhancement applications were described which can be used as guidelines for future research on this topic, including methodological considerations about neurofeedback research, identifying brain states which can be enhanced and establishing feasibility to enhance these brain states (Fig. 1). However, these steps are only the first ones in a series of measures to take for applying rt-fMRI neurofeedback for cognitive enhancement. Fig. 1 emphasises a more complete view of the different stages along this way. After establishing replicated results about the steps addressed in this thesis, it needs to be clarified whether there is indeed a behavioural benefit from cognitive enhancement with rt-fMRI neurofeedback. Only once all of these steps have been proven to be replicable, a translation to educational and health-care settings is feasible. The coming years will thus show whether it is really feasible to enhance cognition on the basis of rt-fMRI neurofeedback.

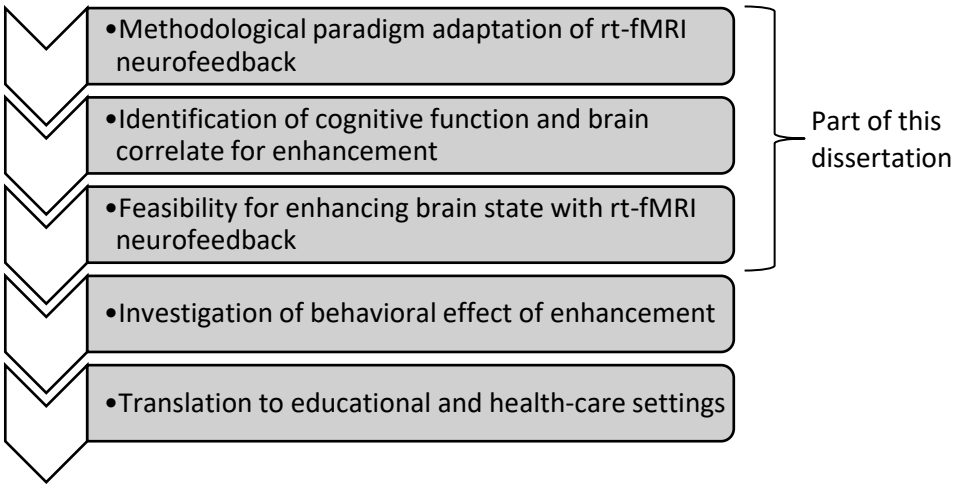

Fig. 1. Different stages in the process of studying cognitive enhancement with rt-fMRI neurofeedback.

One could argue that the work presented in this dissertation has a strong translational character, as it combines neuroscientific knowledge with applications for, *e.g.* the educational sector. However, all the subsequently mentioned aspects are only true once rt-fMRI neurofeedback fulfils all the criteria listed above. If so, neurofeedback could, in principle, be used in order to facilitate learning in schools or universities. In that sense, rt-fMRI neurofeedback could be used as an add-on learning medium in order to tailor every individual's learning strategies and maximise their efficiency or overcome pitfalls. Furthermore, health-care might benefit from the knowledge as rt-fMRI might constitute an alternative for pharmaceutical cognitive enhancers. However, the specific methods presented here are unlikely of any practical value for a broad application. Even if future studies on rt-fMRI neurofeedback for cognitive enhancement would result in robust, positive effects, it still remains highly questionable whether this method would find its way into practice for training or enhancing cognition over several scanning sessions, as the costs of employing an MRI scanner are high and machines are not readily and widely available. It is more conceivable to translate the findings into cheaper alternatives. It would, for example, be a possibility to tailor mental strategies based on research on cognitive enhancement to find robust strategies to alter specific brain states across people. With this knowledge, people could train

the mental strategies without the necessity of undergoing rt-fMRI neurofeedback training. Another possibility would be to translate the knowledge acquired with rt-fMRI neurofeedback into more portable solutions, as for example functional near-infrared spectroscopy (fNIRS) or electroencephalography (EEG), to make it more accessible and cheaper to use.

Despite all of the abovementioned possibilities, the ultimate realistic goal of the research on cognitive enhancement might be different than the direct application: It might constitute one small piece of the puzzle as to how the human brain works and how we can influence it. Thereby, the message of this research might also be to incorporate the results from cognitive enhancement studies into models of human information processing to pave a way to a different understanding of human functioning and learning. After all, it should not be forgotten that the purest idea behind research may lie beyond directly accessible worth, as Seneca (c. 4 BC-AD 65, Roman philosopher) already pointed out in Naturales quaestiones:

"*The time will come when diligent research over long periods will bring to light things which now lie hidden. A single lifetime, even though entirely devoted to the sky, would not be enough for the investigation of so vast a subject... And so this knowledge will be unfolded only through long successive ages. There will come a time when our descendants will be amazed that we did not know things that are so plain to them... Many discoveries are reserved for ages still to come, when memory of us will have been effaced.*"