Inside the Plastic Brain

Knowledge Valorization

This thesis presents research on fundamental processes underlying the neuroplastic nature of the human brain. Neuroplasticity is related to brain development and every day processing, storing and retrieval of information, but also to pathological malfunctions and degeneration of neuronal activity and communication. In the highlighted studies, the emphasis lies on the potential use of different non-invasive research techniques for the investigation and modulation of neuroplasticity in a clinical population and in healthy individuals. At first, we tested the applicability and behavioral relevance of measures of neuroplasticity as potential biomarkers for neurodegenerative processes in patients with diabetes type II. In addition, we probed the applied methods by exploring the reliability of neuroplasticity measures based on proven and novel non-invasive stimulation protocols and examined potential neurophysiological influences on the efficacy of these techniques. The conducted research allows us to reach a more fundamental understanding about the methodologies that can be used for non-invasive investigations of neuroplasticity mechanisms and it opens doors for future developments that can improve the applicability of these techniques and increase the specificity of expected effects.

In the guidelines to this chapter the term "knowledge valorization" is defined as "the process of 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". In other words this chapter is supposed to outline how new knowledge presented in this thesis can be applied and how it can be beneficial, not only for science, but also for non-science related purposes with the focus on social or economic use.

In my opinion, not all obtained knowledge needs to be suitable for direct valorization, i.e., not every research finding needs to undergo the process of creating direct value by making it available for social or economic use, and, most certainly, not all obtained knowledge needs to be directly suitable for translation into competitive products, services, processes and new commercial activities. In contrast, I believe that scientific research is primarily about the process of getting closer to a full understanding of a particular subject. Most often, knowledge needs to be broken down into its most fundamental pieces in order to reach a better understanding of single processes that make up a more complex story. Every scientific discovery is based on many previous scientific discoveries. Thus, all scientific knowledge is valuable for scientific progress. As a consequence, single research studies on very particular topics can create new knowledge, but most of the time these findings alone are not enough to be of direct value for social or economic use. Their main purpose is to serve the scientific progress, which at some point, as a result of a lot of different and separately conducted research, may produce knowledge that can become valuable for non-research related purposes. Therefore, scientific progress is composed of many discoveries that mostly do not offer new knowledge for immediate valorization, but that may become beneficial for social or economic use at an advanced stage of the research cascade. Nonetheless, many single studies belong to a more broad research inquiry and the value of the obtained knowledge can be described as part of a complex network of studies that may be available for social and economic use when the obtained knowledge is eventually translated into products, services, processes or industrial activity. Hence, most knowledge obtained from scientific research is first and foremost important for scientific progress and may become directly valorizable at a sophisticated state of the scientific journey. In this respect, the knowledge obtained from the studies presented here is important and meaningful for the scientific progress towards a better understanding of how neuroplasticity can be measured and modulated with non-invasive methods and it constitutes a crucial module for the development of novel applications of these techniques, which will prove to be of social and economic value in the future.

On a less stringently academic note, the main goal of science to understand and explain phenomena is in fact often accompanied by the aim to make use of new knowledge for social benefit. This may also include the generation of economic value. Therefore, I will briefly discuss the presented research findings in terms of how they may be implemented for social and economic benefits in non-purely science oriented environments. As mentioned above, this will only be plausible with the broader scientific framework of the separate studies in mind. The central focus lies on research based understanding of contemporarily applied methodologies for the assessment and modulation of neuroplasticity mechanisms. At first, it may not appear obvious how a better understanding and provided explanations about methodological procedures can produce direct social or economic value. However, the knowledge gained with these findings is a necessary and crucial piece of the puzzle for a general improvement of established application protocols and for the development of new techniques that will enable more specified clinical and non-clinical applications with the emphasis on the individualization of advanced non-invasive neuroplasticity assessment and modulation options.

The evaluation of obtained information based on these applications can provide personal benefit for individuals, as well as the whole procedure of measuring and modulating neuroplasticity has the potential to create economic value. For example, in chapter 2 we show that aberrant neuroplasticity mechanisms and their behavioral relevance can be measured with transcranial magnetic stimulation (TMS) in combination with neurodiagnostic recordings in patients with diabetes type II. This finding has relevant social and also economic value in that it presents a means to non-invasively measure and characterize neurophysiological change in diabetic patients. In the future, a fully developed application procedure based on research findings like those presented here could be applied during individual diagnosis and monitoring of diabetes type II and it may be transferable to other pathologies at risk for neurodegeneration. Thus, individuals could benefit directly from early detection of aberrant neuroplasticity, which may allow for a better therapeutic outcome. Furthermore, the presented findings can help to design an objective means to measure the efficacy of therapies, which would be of economic value by leading to a reduction of medical costs for patients or health care providers and allowing for more controlled, specified and successful therapeutic interventions at an earlier stage. At the same time, clinics can benefit from more advanced or novel therapies and clinical procedures as part of the range of services offered, which can create new business options, improve their reputation and ultimately generate extra income.

The remaining studies included in this thesis test the reliability of particular TMS protocols and the influence of neurophysiological factors on TMS effects. Our findings provide information for a better understanding of the mechanisms underlying general TMS application and of the possibility to assess and modulate neuroplasticity with non-invasive brain stimulation. This may create social and economic value by providing essential knowledge for the development of improved application protocols, which are more specified and more effective. Such an improvement of existing application procedures and protocol is of interest for clinical and non-clinical applications of TMS to measure or modulate neuroplasticity mechanisms or cortical and corticospinal excitability. In a clinical context, particular applications of non-invasive brain stimulation are already implemented in the treatment approaches of different pathologies. For example, the most prominent therapeutic application of this method is the treatment of medication resistant major depression disorder with TMS. Certain TMS protocols have proven to lead to long term amelioration of depression symptoms when applied almost daily for several weeks. Although this therapeutic application of non-invasive brain stimulation is well established for the treatment of depression in many countries today, it still constitutes a very young clinical application form with great potential to gain increased attention in the future. Still, more research is needed for a better understanding of how this technique interacts with and affects the brain. The presented studies provide crucial contributions towards the scientific progression necessary for the development of more advanced application possibilities with better specificity and stronger effects on the individual level. In the long term, individuals belonging to different patient groups will benefit directly from specified treatment opportunities tailored to their particular needs and clinics or businesses offering such applications for both clinical, but also non-clinical applications, e.g., cognitive enhancement or particular task related brain training, will emerge.

In summary, with regard to the matter of direct valorization of knowledge based on the presented findings, the therapeutic application of TMS for depression is a good example of how research on the mechanisms underlying general TMS application and the possibility to modulate neuroplasticity can be of social and economic value. Patients suffering from major depression directly benefit from the application of research based TMS procedures and protocols. In addition, clinics and companies can be founded to offer this particular treatment, which not only generates economic value, but also provides new places of employment. Through a better understanding of the mechanisms behind existing and new application procedures, the therapeutic application of these protocols can be enhanced and potentially be translated to other pathologies or applied for alternative purposes. Essentially, this will allow for more specified applications in clinical treatment settings, but also in other forms of individualized applications. Generally speaking, gaining conceptual knowledge about fundamental brain processes enables a broad spectrum of valorization opportunities for many different aspects of society or economy. New insights can be used for the development of neurophysiological biomarkers or therapeutic interventions. For the translation of obtained study results into reliable and meaningful application procedures a thorough understanding of the underlying mechanisms and of the individual specificity of observed effects is essential. Therefore, continuous enhancement of current paradigms through scientific progress based on fundamental research is a requirement for the advancement of application possibilities that eventually generates both social and economic value.