Submillimeter T2 weighted BOLD fMRI of human visual cortex

DOI:
10.26481/dis.20160421vk

Knowledge Valorization

According to the "National Valorization Committee", the term knowledge valorization refers to "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" (Regulations governing the attainment of doctoral degree, UM, App. 4, §23), and the doctoral candidate is requested to write "an approximately five-page addendum" on the topic, which, however, shall not be a part of the dissertation itself.

So, how can the insights of the present thesis be "valorized"? The present thesis is mostly methodological in nature, that is, for the most part it deals with the question of how T2 weighted high resolution BOLD fMRI in visual cortex can be performed better for cognitive neuroscientific applications. Since these applications lie within the field of fundamental natural sciences, the thesis can also be allocated in this domain. Fundamental sciences and the concept of "valorization" are considered diametrically opposed to one another by many, and this conflict has been pointed out in the valorization addendums appended to recent dissertations in the department for cognitive neuroscience (see e.g. R. L. Rademaker, "Internal representations of the brain" (2015); G. Lange, "Psychophysical investigations of perceptual learning and attention" (2016)). However, the results of fundamental research may yield immeasurable value to society in the future via complex and unforeseeable paths. In this light, the answer to the question posed above can impossibly be answered exhaustively. It is clear to see that the degree to which the knowledge is straight-forwardly applicable scales inversely with the "distance" of the specific application to the centers of attention of the present work. In an attempt to illustrate this view, Figure 1 displays a classification of various applications of magnetic resonance imaging. It is needless to say that this binary hierarchical classification is extremely simplified for the purpose of clarity and underestimates the variety and complexity of applications. Some levels may as well be swapped, e.g. the distinctions in species and purposes (otherwise e.g. neuroscientific research on rodents or a diffusion scan for the diagnosis of a brain tumor in a race horse could not be accommodated). Further, the branches which do not lead to the BOLD technique are kept very general and are not detailed further.

To the first order, the considerations with regard to "valorization" may be limited to the displayed realm of applications of MRI. The core claim of this chapter will be that the concepts presented in this thesis are applicable in other side branches at *all* hierarchical levels in figure 1. In other words, any information provided in this thesis may influence decision-making with regard to the techniques for any applications in magnetic resonance imaging. As stated above, the direct applicability to different nodes of the graph then scales inversely with the "distance" (i.e. shortest path in the graph). In the following, we will provide some examples of this.

The most direct application of the findings of this thesis is in other modalities or other functional domains. 3D-GRASE has been used for arterial spin labeling fMRI, and the variable flip angle technique (Chapter 3) can improve the data quality in this application, as has also recently been shown by other authors. The thesis discusses advantages and disadvantages of T2- and T2*-weighted BOLD fMRI at length (e.g. Chapter 5), and these apply to other functional domains, e.g, any sensory domains, memory, emotions, decision-making etc. just like in the visual domain. The suitability of 2D SE-EPI or 3D-GRASE for these applications may be guided by the findings in Chapter 2.

The application of the variable flip angle technique proposed for the 3D-GRASE imaging pulse sequence in Chapter 3 is most beneficial at long spin-echo train duration compared to T2 and long T1. These conditions are not only given in brain imaging (functional and structural (anatomical), for which 3D-GRASE is also employed), but may occur in various applications, in various materials and organic, human or non-human tissue types. Examples range from human lung imaging and musculoskeletal imaging to non-hydrogen ("X-Nuclei") imaging in soft tissue, e.g. sodium imaging in knee cartilage, or imaging in solid inorganic materials. The additional degrees of freedom enabled by the variable flip angles may be exploited in larger spatial coverage, reduced image blurring, or higher nominal spatial resolution. Further, the significantly reduced power deposition may enable new applications, especially when SAR is a delicate issue.

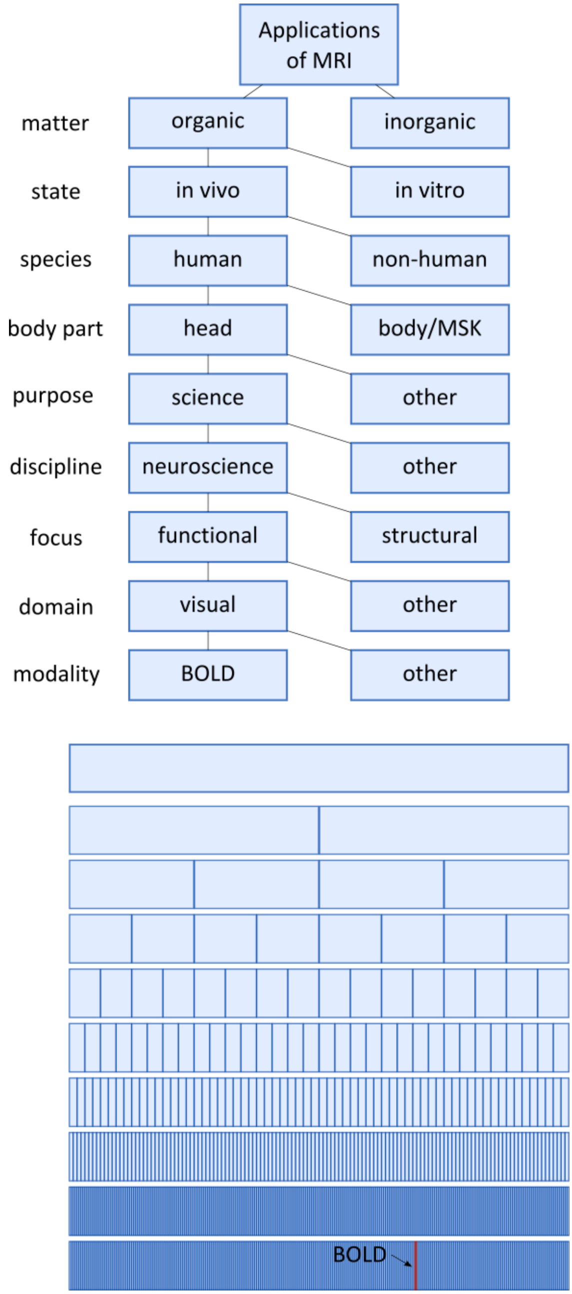

Figure 1: Classification of various applications of magnetic resonance imaging (strongly simplified). Top: Hierarchical binary tree, bottom: Same structure displayed to scale under the assumption of equal binary composition and a random placement of BOLD imaging among other applications.

The work presented in this thesis relies on ultra-high field imaging. By the methodological advancements in it, it makes ultra-high field imaging more accessible to the various applications mentioned above. The improved signal-to-noise ratio at higher field strength is unquestioned and may be translated to stronger contrast-to-noise ratio, shorter imaging time, and/or higher spatial resolution, all of which may be helpful in clinical routines. These factors would facilitate the diagnosis of known pathologies, but moreover enable diagnosis of previously elusive diseases. Ultimately, these factors will help, e.g. to start patient treatment earlier, and improve its monitoring throughout the process, thereby improving quality of life and life expectancy. Economically, this potential is showcased by the introduction of the first commercially available 7T scanner with CE and FDA approval, the "Terra" manufactured by Siemens Healthcare about fifteen years after the world's first human 7 Tesla MRI scanner was installed at University of Minnesota in 1999. In this context we may also refer to the development of novel RF transmission and receive coil designs. A close link between manufacturers (e.g. Life Services, Minneapolis, MN, USA) and the scientific research institute enabled the customized design for the RF coils used in the studies reported here. Based on this experience (e.g. with regard to the spatial distribution of coil sensitivities and coupling) additional RF coils have been and will be designed for advanced imaging applications, which pushes research forward worldwide. Finally it is worth mentioning that innovations from the ultra-high field domain have previously also translated to improvements at lower field strength, and this process is likely to continue. Given that 1.5 T and 3.0 T machines are the mainstay of clinical MRI, methodological improvements at ultra-high field already enhance clinical routine to the benefit of patient care.

Currently, there are merely a handful of operational human MRI systems worldwide which exceed 7T field strength, and our anatomical and functional study at 9.4 T (Chapter 4) is still one of the first of its kind. Whether this even higher field strength will eventually also find its way into clinical routine remains to be seen. However, our study is a door opener in the sense that it demonstrated the feasibility of 9.4 T scanning in the human brain without the requirement of complicated parallel transmission pulses. This circumstance facilitates the access to 9.4 T for application in different fields and possibly without the close monitoring by MR physicists after appropriate training of non-expert users.

It was stated above that the limitation of the “valorization” considerations may be limited to the organization according to Figure 1 *to the first order*. What was meant by this is that the “valorization” is most direct in this framework. As though this would not already present a (perhaps infinitely) large amount of improved techniques and new possibilities, they themselves open up new paths for improved techniques and new possibilities in other domains – *second order* – and so on. This cascade describes the sum of marginal utility and leads eventually to an infinite “valorization” potential, as held by all scientific projects.