Intuition, deduction, and the art of picking up the pieces

VALORIZATION

Opinions differ on the question whether scientific knowledge is of instrumental or final value; that is, whether it is a means to an end or an end in and of itself. Supporters of the former view might hold that science being publicly funded ought to directly and tangibly benefit society. Opponents, on the other hand, deplore the degradation of scientific knowledge to the status of a mere resource and fear the rise of conflicts of interest. Between these diametrically opposed views exists a third according to which scientific knowledge is of contributory value. According to this view scientific knowledge is not a means to any specific end nor is it an end in itself, rather it contributes indirectly to an enlightened and free society.

I shall not discuss which view holds the most merit in my opinion nor will I discuss the work presented in the present thesis in terms of any of these three. Instead, I will argue that the work presented in this thesis is of importance to the neuroscientific community. If I am successful in that, my work will inherit its value from that of neuroscientific knowledge, irrespective of whether that knowledge turns out to be instrumental, final, or contributory. First, I will focus on the two parts of my thesis and discuss the functional value of my methodological considerations regarding theory testing and theory building. Following this, I will discuss the functional value of the results of each research chapter for the neuroscientific community.

The first part of my thesis was dedicated to demonstrating that functional magnetic resonance imaging (fMRI) can be used to compare competing theories instantiated as computational models. This is of importance to the neuroscientific community as it adds a vastly available, seminal, and non-invasive neuroimaging tool to pre-extisting methods for evaluating computational models. Since crucial findings necessary to resolve long-standing conflicts between competing theories often come with the transition to novel methods, fMRI might tip the scale on a number of theoretical controversies among computational neuroscientists. The resolution of these controversies might come in the form of outright refutations of some theories in the light of others or, as in the present thesis, by revealing how competing theories can be integrated. In both cases neuroscience would benefit from the resulting insights as they lead to a deeper understanding of the brain and open new research avenues to pursue.

The second part of my thesis was dedicated to demonstrating that the integration of fMRI with computational modeling can be used to develop theories in neuroscience. In this case the value for the neuroscientific community directly stems from the complementary nature of the two fields. Theoretical considerations can inform empirical research as well as supplement analysis tools. In turn, new insights stemming from fMRI research can immediately be integrated into existing theoretical scaffolds and hence drive, evaluate, and constrain theory development. The latter is especially important as it prevents researchers in the field of computational neuroscience from getting carried away by abstractions of the brain which eventually bear little resemblance to the original target system.

A

The research on population receptive fields (pRFs) presented in the second chapter of my thesis is relevant for computational neuroimaging, a field which is becoming increasingly important in vision neuroscience. Since pRFs are at the heart of computational neuroimaging it was essential to evaluate their estimation procedures as well as establish their temporal consistency. Furthermore, knowledge of receptive fields is crucial for a number of neuroscientific applications: a) they provide a source of information for the reconstruction of stimuli from the blood oxygenation level dependent signal, b) they can serve as target for transcranial magnetic stimulation, c) they may assist function based alignment, d) they provide a spatial forward model for computational models, and e) they might give important insights with respect to theories of attention as well as into pathologies of visual cortex and brain development. In order for these applications to fully benefit from pRF estimation, it was essential to validate the estimation framework.

In line with the possibility that population receptive fields can be utilized as a spatial forward model for computational models, chapter 3 of this thesis presents new developments with regard to a common brain space. The common brain space is an idealized, retinotopically organized, surface representation of visual cortex which allows for the integration of empirical and simulated data in the same anatomical frame of reference. Such integration allows for the evaluation of computational models in terms of predictions they make with respect to the detailed spatial activation profiles in visual cortex. This is of importance for the neuroimaging community as it supplements existing techniques able to evaluate the information content of visually responsive brain regions predicted by computational models. That is, it enables neuroscientists to investigate not only what information is encoded in a region but also how that information is represented.

Another topic of great interest to the (neuro)scientific community pertains to the role of the rich club phenomenon present in the human connectome. This phenomenon is prominent in many network topologies from the internet to transportation networks and understanding its implications for the brain will aid us in understanding it in other topologies and vice versa. With regard to the brain, the fact that the rich club forms a central core in the connectome has lead researchers to suggest that it is important for the integration of information processing within specialized brain regions, and hence for cognition. However, studying the architecture of the connectome is insufficient to establish and further elaborate this hypothesis. It is necessary to study the functional implications of this architecture and contrast it with others. Chapter 4 presents simulation research addressing this issue by studying the implications different architectures, including those possessing a rich club, have for the capacity to functionally integrate distinct brain regions. As such the work I present there functions as a theoretical framework from which interesting empirical studies on the relationship between rich club organization and cognitive capabilities can be derived. Chapter 5 builds on this framework by introducing empirical findings and combining whole-brain simulations with fMRI. Of interest to the neuroscientific community is here especially that the work presented in chapter 5 provides further evidence for the thesis that the rich club is essential for functional integration as well as that it extends this thesis by suggesting a local mechanism through which rich club regions might help to organize and coordinate this integration. In accordance with what I set out to show here, the present work is thus relevant to the neuroscientific community in a number of respects.