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How we may think
Imaging and writing technologies across the history of the neurosciences

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ABSTRACT

In the neurosciences, two alternative regimes of visualization can be differentiated: anatomical preparations for morphological images and physiological studies for functional representations. Adapting a distinction proposed by Peter Galison, this duality of visualization regimes is analyzed here as the contrast between an imaging and a writing approach: the imaging approach, focusing on mimetic representations, preserving material and spatial relations, and the writing approach as used in physiological studies, retaining functional relations. After a dominance of morphological images gathering iconic representations of brains and architectural brain theories, the advent of electroencephalography advanced writing approaches with their indexical signs. Addressing the brain allegedly at its mode of operation, electroencephalography was conceived as recording the brain's intrinsic language, extending the writing approach to include symbolic signs. The availability of functional neuroimaging signaled an opportunity to overcome the duality of imaging and writing, but revived initially a phrenological conflation of form and function, suppressing the writing approach in relation to imaging. More sophisticated visualization modes, however, converted this reductionism to the ontological productivity of social neuroscience and recuperated the theorizing from the writing approach. In light of the ongoing instrumental mediations between brains, data and theories, the question of how we may think, once proposed by Vannevar Bush as a prospect of enhanced human–machine interaction, has become the state of affairs in the entanglements of instruments and organic worlds.

The term "neurosciences" describes a fairly recent branch of research. It dates back to the 1960s when Frank Schmitt chose it for the name of a new interdisciplinary research program at MIT that quickly served as a role model for the emerging field. In 1969, the initiative had gained sufficient momentum to start the *Society for Neuroscience*, today one of the largest scientific societies (Doty, 1987; Adelman, 2010). Scientific interest in the brain can be traced back much further (Clarke & Dewhurst, 1968; Finger, 2001), but brain research proper really started with the *laboratory revolution in medicine* (Cunningham & Williams, 2002) at the beginning of the nineteenth century, when experiments under laboratory conditions started to complement (and dominate) clinical accounts and explanations. Experimental research used new tools and instruments for observing the phenomena of life and for investigating its characteristics. Renderings and recordings by scientific instruments increasingly shaped the understanding of organic structures and processes, as studies from the history of medicine and the life sciences have abundantly demonstrated (Rheinberger and Hagner, 1993; Schmidgen, Geimer, & Dierig, 2004). Brain research provides a particularly rich field for investigating these

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"entanglements of instruments and media in investigating organic worlds"[1] in at least two respects: compared to the mechanics of the musculoskeletal system, for example, or to the anatomical details of other organs, it soon became clear that the brain's gross anatomical structures were to reveal relatively little about its operations. In the course of its history, ever more sophisticated instruments and methods have been mobilized for research into the brain and for accessing its secrets. In addition, the brain was supposed to be the center of a range of complex, so-called higher activities, from language and speech to emotions and cognition, clearly exceeding the brain's observable macroscopic features. Since its beginnings, brain research investigated not just some bodily structures or organic processes, but explored this particular organ as the seat of specifically human activity and as the site of mind–body interactions (Hagner, 1997).

In history of science, great emphasis has been put on the investigation of scientific practices for analyzing the complex roles of instruments as part and parcel of experimental research and scientific communication (Lynch & Woolgar, 1990; Coopmans, Vertesi, Lynch, & Wologar, 2014). A slightly different approach to instruments and media has been propagated by the German and Canadian schools of media theory, shifting the analytical focus from the interaction with technology toward the epistemologically constitutive roles of scientific instruments as media of information, perception, and representation (Kroker, 1984; Kittler, 2010). In addition to approaching media as the means of communication, mediation here is conceptualized as the articulation of instruments, objects, and concepts (Rheinberger, 2010). In this regard, instruments serve as media in research methodologies and form parts of larger media infrastructures in epistemic regimes. This double role is particularly pertinent in visualization practices, also a core activity in brain research: instruments provide access to specific aspects of the brain and its functions in strictly technological relation to their mode of operation, mediating the information gathered. In addition to yielding data, instruments are research technologies that shape the materialization and conceptualization of the research object within the space opened and mediated by the technology employed. Along such a media-theory type of argument, this paper groups divergent investigative approaches to the brain into a historical epistemology of tool use and research technologies in brain research.

This paper can obviously not provide (and does not intend) a full review of the rich and manifold interplay of media and instruments during more than two hundred years of brain research. Instead, it addresses the rather abstract question of how specific types of investigative tools and the resulting research methodologies interacted in their respective socio-cultural settings with the theorizing about the brain. It thus aims to explore the shaping of brain theories by instrumental and methodological approaches, material constraints, and socio-cultural research agendas. This approach bears a resemblance to Gerd Gigerenzer's (1999) "tools-to-theories" heuristic. Gigerenzer has shown how alternative theories in cognitive psychology related to different research cultures as they emerged during the nineteenth century. The direction of my argument, however, is different, as I am less interested in questions of scientific creativity or discovery (Gigerenzer, 2003), and focus rather strictly on the epistemological effects of mobilizing particular tools, instruments and research technologies. Instead of offering a historical contextualization of heterogeneous research activities by exploring the interactions between actors and networks, this paper focuses on the interplay of methods, media, technologies and theories for developing a systematic perspective on the epistemological and ontological dynamics of representational practices in this highly active field of research.

In particular, I will differentiate between two clusters of research, here labeled the "imaging" and the "writing" approaches.[2] While imaging preserves and assumes the relevance of a mimetic resemblance between the object of investigation and its scientific representation, the writing mode depicts measured, recorded or otherwise encoded relations. With "imaging" and "writing," the paper builds on Peter Galison's (1997) seminal distinction of image and logic in the research cultures of particle physics (as will be discussed in more detail later in this paper). Adapting Galison's typology to brain research, however, implies an important transformation of his argument. In contrast to microphysics' material culture, both lines of neuroscientific research rely on visualization at their methodological core. Imaging and writing thus allow a comparison of the epistemological and ontological dynamics of different modes of visualization. The difference between imaging and writing roughly matches the contrast between morphological and functional investigations. The distinction of imaging and writing builds on the disciplinary differences between anatomy and physiology as they emerged together with the institutionalization of experimental research in the life sciences. Anatomy and physiology are typically regarded as complementary branches of research, both contributing to a richer understanding, if not the full picture. This is not the perspective of my argument. Instead of questioning research technologies in relation to a supposedly "real" entity behind its representations, I am interested in how research tools, instruments and methodologies participated divergently in shaping the brain as a scientific object; how instruments, technologies and media directed further research, guided the interpretation of observations and shaped theorizing about the brain.

Although this essay starts with a dichotomizing of research in the neurosciences into the imaging approach (primarily the morphological or anatomical tradition), and the writing approach (predominantly the functional or physiological tradition), the very purpose of this classification is to prepare for an analysis cutting across such disciplinary landscapes and thus allowing the identification of similarities or analogies between institutionally distant branches of research. Korbinian Brodmann's morphological cytology (Brodmann, 1909) and Karl Kleist's clinical pathology (Kleist, 1934), for example, shared scientific practices from the imaging approach such as slicing, staining and microscopic investigation, regardless of the fact that the former was obsessed with the brain's microarchitecture while the latter searched for clinical manifestations of localization. I use the differentiation between imaging and writing not as an exclusive distinction but as characterization in the sense of Max Weber's ideal types. The morphological tradition differs from the functional in the form of information derived from a set of methods which all aim to identify and characterize the shapes and structures of the brain's various parts—and thus this field fosters localizationism, the theory that specific human faculties such as listening or speaking or mental arithmetic are localized brain functions. The writing tradition, by contrast, focuses on processes and brain activity. Visualizations in the form of charts with traces generated by the graphical method are the paradigmatic example for this approach as an ideal type.

[1] This was the title of the Research Seminar Series in Science & Technology Studies hosted by the Science and Technology Studies Program at York University, Canada, germinating this paper.

[2] From a series of inspiring but all too brief joint discussions, Frank Stahnisch (2014) has recently suggested somewhat similar perspectives. Focusing on a different series of examples, my aim here is to advance this analysis further toward an exchange about recent research, without losing the larger historical background.

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