3 Using fMRI as an Investigation Tool in Hysteria Research

In the previous chapter, I have argued that the use of the fMRI technology has crucially contributed to re-establishing hysteria as an object of systematic scientific scrutiny by tentatively linking this disorder's elusive symptoms to functional brain pathologies. This linking relies on the production of functional brain maps that visualise the empirical findings of an fMRI study. Specifically, the resulting maps display the hysteria patients' experimentally isolated patterns of pathological brain activity deemed to underlie the symptom of interest. Thus visualised, these otherwise inaccessible patterns can be transported into "a site where they can be evaluated by peers,"[1] interpreted in terms of correlated cognitive processes, embedded into research articles, and disseminated in scientific journals. In this context, functional maps are instrumental in generating new scientific insights into hysteria. But how do researchers work with fMRI to produce new knowledge about the pathological functioning of hysteria patients' brains?

To an uninitiated observer, the answer to this question may appear deceivingly simple. This is because functional maps are commonly visualised in a clear-cut manner as patches of bright colours that are overlaid on grey-scale brain slices (see figs. 3.12 and 3.14).[2] As pointed out by Adina Roskies, due to such apparent visual accessibility, laypeople tend to mistakenly think that the thus visualised functional maps, akin to photographic snapshots, depict active brain areas 'lighting up.'[3] Even more problematically, such mistaken views are not limited to science-distant people. For example, in an article published in a popular science magazine the *Scientific American*, David Biello incorrectly suggested that, while investigating the symptom of hysterical anaesthesia with fMRI, researchers could immediately "see" the neural activity of interest.[4]

1 Latour, "More Manipulation," 347.

2 Later in this chapter, I will analyse various ways in which fMRI maps can be visualised. But, for the sake of simplicity, at this point, I refer only to the most frequently used type of visualisation.

3 Roskies, "Photographs of the Brain," 863.

4 "[T]he researchers could stimulate the body part and see what region of the brain 'lit up,' or benefited from increased blood flow as it dealt with new input." Biello, "Don't Get Hysterical," n.p.

However, there are two caveats to the assumption of fMRI's visual transparency, both of which have been discussed by humanities scholars. First, several authors have persuasively argued that fMRI maps have a distinctly non-mimetic character because they do not visually resemble the phenomena they display.[5] The brain processes to which these images refer are not only inaccessible to the unaided human vision but also decidedly nonvisual. Hence, various bright colours that indicate the anatomical locations of the essentially invisible, statistically significant brain activations are so-called false colours. Such colours are entirely arbitrarily chosen by researchers since the activation patterns do not have any intrinsic colour.[6] Second, contrary to the naïve assumptions cited above, after the subject has performed the designated experimental task inside the scanner, researchers cannot immediately observe her brain activity of interest.[7] This is because the scanner cannot directly generate a functional brain map. Instead, the measurement outputs are so-called raw fMRI imaging data (see fig. 3.3). As we will see in this chapter, researchers have to submit such imaging data to computerised but only partially automated procedures of preprocessing and statistical analysis to obtain functional maps that visualise the brain activity of interest.[8] Crucially, the numerous operations entailed in their time-consuming production are not visible in the resulting functional brain maps.

5 See, e.g., Roskies, "Photographs of the Brain," 861–63; and Alac, *Digital Brains*, 34–35.

6 Alac, *Digital Brains*, 34. Moreover, because the "choice of color is not standardized, the caption and legends [that accompany the maps] provide an explanations of what different colors stand for." Ibid. This, in turn, means that a particular choice of a false colour scale has no impact on the epistemic content of an fMRI map. For this reason, when discussing fMRI maps, I will disregard various colour choices used by different researchers.

7 Strictly speaking, not all fMRI experiments use tasks. Since about 2000, an alternative fMRI paradigm, called resting-state fMRI, has been gaining increasing popularity in neuroimaging research. This paradigm focuses on measuring spontaneous brain activity while a subject is resting in the scanner without engaging in any external task. See, e.g., Raichle, "Brain's Dark Energy," 44–49. The first resting-state fMRI study of a hysterical symptom was published in 2011. See van der Kruijs et al., "Dissociation in Patients." Although the number of resting-state fMRI papers in hysteria research has continually grown in recent years, the majority of published studies to this date have used the task-based approach. Hence, this entire chapter will focus only on the task-based approach. In the following chapter (section 4.4.1), I will discuss in detail those fMRI studies of hysteria that have deployed the resting-state approach.

8 In recent years, real-time analysis of fMRI data has become possible due to technological advances. In real-time fMRI, the above-listed steps of data acquisition, preprocessing and statistical analysis still have to be performed sequentially. But they are optimised for speed so that a functional map can be obtained immediately following the data acquisition. This requirement, however, imposes significant limitations on the kinds of experimental designs and statistical analyses that can be used and on the quality of the resulting maps. Consequently, the application of real-time fMRI is not very common and has so far been limited to "intra-operative fMRI, brain-computer-interfaces, and neurofeedback." Kopel et al., "Real-Time fMRI," 421. See also Huettel, Song, and McCarthy, *Imaging*, 403–5. Therefore, in neuroscientific research in general and in hysteria research in particular, when fMRI is used as an investigation tool, the analysis of imaging data requires substantial time and, as we will see, typically involves collecting and comparing results from multiple subjects. At present, real-time fMRI is still not applicable in this context.

The extensive interventions that the creation of functional maps necessitates have given rise to different interpretations of their epistemic status. Alan Gross has declared fMRI maps to be indexical signs “insofar as the visible tracks” of the visualised brain events “point back to their cause.”[9] Yet, Gross has failed to explain how this ‘pointing back’ is achieved. Conversely, Anne Beaulieu and Sarah de Rijcke have influentially negated the fMRI maps’ reliance on “the physical truth chain” that underlies indexicality and have instead foregrounded the malleability inherent in the computer-based production of these images.[10] Expanding this argument, Beaulieu has ascribed the maps’ potential authoritativeness—which she calls “digital objectivity”—to procedures of standardisation and automation.[11] The aim of these procedures is to curtail the inherent malleability of fMRI maps. Moreover, Beaulieu has criticised researchers for attributing more relevance to the brain maps’ quantitative, measurement-based aspects than their visual features.[12] But at the same time, she has claimed that these two different aspects of brain maps are mutually irreconcilable. By contrast, although Morana Alac has not denied the maps’ indexicality, she declared it epistemically insignificant.[13] Consequently, in her analysis, she has mostly ignored the conditions of data acquisition. Rather, drawing on Charles Peirce’s theory of signs, Alac has suggested that fMRI maps are best understood as diagrams whose specificity lies in their use. To be more exact, Alac has argued that fMRI maps are iconic signs whose meaning is constructed through researchers’ embodied engagement with the digital and visual features of the imaging data.[14]

9 Gross, “Brains in Brain,” 381, 382.

10 De Rijcke and Beaulieu, “Networked Neuroscience,” 132.

11 Beaulieu, “Voxels,” 30–31. See also de Rijcke and Beaulieu, “Networked Neuroscience,” 136–37, 145. Similarly, Hannah Fitsch and Kathrin Friedrich have argued that the extensive mathematical modelling and algorithm-based processing entailed in the digital medical imaging technologies such as fMRI and CT result in the standardisation and normalisation of the thus visualised bodily processes. Fitsch and Friedrich have further claimed that, due to this inherent mathematically driven process of normalisation, both fMRI and CT “obfuscate the difference and agency of subjects” whose brains are visualised using these technologies. Fitsch and Friedrich, “Process of Normalization,” 25.

12 Beaulieu has attributed what she calls researchers’ iconoclastic tendencies to, as she claims, the relatively low status of visual evidence in modern Western science. Images, which appeal primarily to the visual sense instead of the mind, she argues, are viewed as less apt at providing access to truth than words and numbers. According to Beaulieu, researchers foreground the numerical and analytic aspects of their practice, aiming to firmly place it in the domain of reasoning instead of sensory experience. See Beaulieu, “Not the (Only) Truth,” 53–86. My analysis in this chapter will challenge these views, both concerning the suggested discrepancy between the visual and quantitative aspects of fMRI data and concerning the purported dichotomy between image-based practices and reasoning.

13 Alac, “Fields for Interaction,” 66.

14 Alac, *Digital Brains*, 45. In her illuminating account, Alac has analysed how researchers interact with fMRI scans by placing their hands on the keyboards to perform digital actions, touching the screen displays, or making gestures to highlight what needs to be seen. She has introduced the term “a field for interaction” to refer to this embodied engagement with the images as the necessary condition for producing their meaning. Ibid. Significantly, her analysis has focused on teaching sessions during which experienced researchers instructed newcomers on how to work with scans.

These accounts provide insightful, although in part mutually contradictory, proposals of how fMRI maps semantically relate to actual brain activity. However, if we accept their point in common—that functional maps cannot be understood as visual copies of the reality of an individual's brain activity—we are left with a critical and so far unanswered question. On what basis can fMRI maps stand for active brains in the scientific context and thus, more specifically, be used to generate new epistemic insights into the neural basis of hysteria? To address this question, I draw on Latour's claim that the referential quality of scientific images does not hinge on their resemblance to the visualised object. Latour argues that because the gap between an object and an image is too wide to be closed in a single step, scientists narrow it down through a cascade of successive inscriptions, which are separated by smaller gaps.[15] Scientists then bridge these smaller gaps through a series of manipulations, which Latour calls a chain of transformations or a referential chain. According to Latour, an uninterrupted movement along such a chain guarantees the referential quality and knowledge-producing potential of scientific images.[16]

In this chapter, I will implement Latour's concept of the referential chain as an analytical tool with which I intend to unpack the epistemic functions of fMRI in the current hysteria research. I will thereby argue that to understand how researchers use fMRI maps to make judgments about the hysteria patients' active brains, we must go beyond the visual aspects of functional maps as finished products. Instead, we must focus on the process of their creation, use, and interpretation in the context of concrete experimental setups. Thus, in what follows, I will examine in detail how researchers work with a cascade of inscriptions with which they gradually bridge the otherwise insurmountable gap between the patients' brain activity and functional maps. The crucial questions are: What are the properties of incoming inscriptions at each step of the chain? Which operations and to what ends do researchers perform on these inscriptions? How are incoming inscriptions transformed into outgoing ones that enter the next step in the chain?

In addressing these questions, I will claim that although, as suggested by Beaulieu, automated algorithms provide a necessary framework, the active human judgment decisively shapes a particular referential chain in an fMRI study.[17] Apart from Alac's insightful analysis, little attention has been paid to this aspect of fMRI-based research in the current academic discourse.[18] But, unlike Alac's analysis of neuroscientists'

15 Latour, "More Manipulation," 348.

16 Latour, 348.

17 Admittedly, in her more recent contribution, which she co-authored with de Rijcke, Beaulieu has allowed for a more active role of the human user. But in this account, the researcher remains fundamentally constrained by standardised pipelines and the implicit conventions of the software used. See de Rijcke and Beaulieu, "Networked Neuroscience," 144–45. By contrast, my analysis will offer a considerably more dynamic view of the working process.

18 See also Hoel and Lindseth, "Differential Interventions." In line with the argument that informs my analysis, Hoel and Lindseth have stated that "[f]ar from being passive reflections of pre-given realities, medical images rely on active interventions." Ibid., 179. However, Hoel and Lindseth do not analyse the use of fMRI in the research context but focus instead on the use of structural MRI as navigational tools in neurosurgery.

embodied actions, I will examine what kinds of judgments and decisions researchers make while working on and with the imaging data. I intend to show that while the fMRI data's visual and numerical aspects are mutually intertwined, they nevertheless fulfil distinctly different functional roles during various stages of the working process. Additionally, my analysis will foreground that across different stages of the working process, which starts with the acquisition of raw imaging data (see figs. 3.2 and 3.3) and ends with the interpretation and publication of fMRI maps (see figs. 3.14 and 3.15), researchers deploy a variety of intermediary visualisations. Just as importantly, it will become evident in the course of my analysis that to be able to meaningfully use such intermediary images as research tools, researchers must possess particular visual skills.

Specifically, I will demonstrate that when working with different types of visualisations of their data, researchers do not see in them the visual content that is apparently visible to an uninitiated observer. Instead, researchers submit these images to a process of targeted "reading."[19] Further, I will argue that the process of reading is informed by the researchers' background assumptions and often implicit visual conventions. Their goal is to access the information of interest about the brain activity they had previously encoded into the data through the measurement. We will see that, to fulfil this goal, researchers have to learn how to recognise as relevant particular visual configurations and patterns when viewing various visualisations of their data. At the same time, they also have to learn to disregard all those individual elements in these visualisations that are unimportant for their epistemic purposes.

Yet, crucially, my analysis will highlight that at multiple stages of an fMRI study, some of the intermediary visualisations with which researchers work are what I will designate as 'illegible.' By this, I mean that such images are impossible to read even for an expert. For reasons we will discuss in this chapter, in 'illegible' images, the information of interest is not encoded in visually recognisable ways and thus remains indiscernible and inaccessible to visual inspection.[20] In fact, we will see that such images must undergo mathematical transformations that gradually translate them into different types of images that are 'legible.' It is through this protracted multi-stage process that the information of interest about the presence and location of brain activity is finally made accessible to visual inspection of a trained expert and thus becomes 'readable.' Thus, in this context, the 'legibility' of an image is a necessary precondition for its potential 'readability,' when used by an expert.

Moreover, I will also draw attention to the fact that, at various stages of the working process, choosing which types of visualisations to use when visually inspecting their data has a decisive impact on how easily, comprehensively, and accurately

19 I am using the term 'reading' here in the sense introduced by Sybille Krämer in her discussion of operative iconicity. See Krämer, "Operative Bildlichkeit," 102.

20 Importantly, in my use, the term 'illegible' is not synonymous with 'unreadable.' An illegible inscription is impossible to read because its visual content is unclear and can, therefore, not be made out. By contrast, although essentially legible, an unreadable inscription is nevertheless incomprehensible to those who lack the visual skills required to read it. Hence, strictly speaking, the term 'illegibility' denotes a property of an image, whereas the term 'readability' foregrounds the interaction between an image and its informed user. For a comparable differentiation of these two terms regarding written texts, see University of Chicago Press, *Chicago Manual of Style*, 335.

researchers can identify the information of interest. To emphasise their ability to provide researchers with varying levels of visual accessibility to the information of interest encoded in the data, I will designate different types of visualisations as more or less 'graspable.' I will insist that the potential 'graspability' of a particular visualisation will often depend on the type of information that a researcher is interested in obtaining from the data.

In short, I will use the terms 'reading,' 'legibility,' 'readability,' and 'graspability' to refer to various aspects of visually scrutinising fMRI images to access the information of interest regarding the potential presence and location of the brain activity of interest. But as mentioned previously, once they have identified the experimentally isolated patterns of brain activity, researchers then make inferences about the potentially correlated cognitive processes. I will refer to this final stage of researchers' engagement with images as 'interpretation.' I thereby do not mean to imply that the process of 'reading' the images in which researchers engage is semantically neutral. Instead, the purpose of my differentiation in terms between 'reading' and 'interpreting' is to emphasise that only in this final stage of working with images researchers attribute to them explicit symbolic meanings.[21] Hence, I will designate fMRI maps as 'interpretable' or 'uninterpretable' depending on whether or not researchers can attribute sufficiently unambiguous meanings to them in terms of associated cognitive processes.

Finally, from the methodological point of view, my analysis is informed by Ludwig Jäger's claim that the indexicality of a sign is constructed through the process of its discursive articulation.[22] Specifically, according to Jäger, the indexicality is not simply a direct consequence of a physical contact between an object and its sign. Instead, to be instituted as an indexical sign, a trace of a causal, physical contact with an object must undergo a medium-specific process of interpretation, which embeds this trace into a network of references to other signs and inscriptions. Drawing on Jäger, I will argue that although each fMRI brain map creates its referent—which does not exist independently of the chain of operations underlying the maps' production—this very chain also establishes an indexical link between the referent and the map. I will claim that, in the research context, the thus constructed indexicality of fMRI maps is a precondition for the ability of these images to produce insights into a potential neurocognitive basis of hysteria.

This chapter will reference multiple fMRI-based research articles on hysteria but focus in particular on two closely related studies conducted by Floris de Lange, Karin Roelofs, and Ivan Toni. In the first study published in 2007, de Lange, Roelofs, and Toni set out to isolate the pattern of brain activity underlying hysterical arm paralysis.[23] With this aim in mind, they used a specifically designed experimental task and, following the data acquisition, computed the so-called activation fMRI maps (see fig. 3.14). This approach is known as functional segregation and has so far dominated not only functional neuroimaging in general but also fMRI-based hysteria research.[24] In

21 That this is indeed the case will become apparent by the end of this chapter.

22 Jäger, "Indexikalität und Evidenz," 289–315.

23 De Lange, Roelofs, and Toni, "Self-Monitoring."

24 Büchel and Friston, "Extracting Brain Connectivity," 295.

2010, the same research team returned to their original fMRI dataset and submitted it to a newer processing approach called functional connectivity analysis.[25] The use of the subsequent data analysis enabled the researchers to compute the so-called connectivity fMRI maps. In their second study, de Lange, Roelofs, and Toni thus shifted the focus from delineating discrete locations of the task-induced neural activity to identifying how patterns of interactions across distant brain regions changed in response to their experimental manipulation.[26] In doing so, de Lange, Roelofs, and Toni authored the first full-length fMRI study of a hysterical symptom that used the functional connectivity approach.[27] Although the functional segregation approach continues to dominate current hysteria research, the number of studies that use functional connectivity has steadily risen in recent years.[28] Hence, it can be said that the de Lange, Toni, and Roelofs paper from 2010 exemplifies a growing trend in fMRI-based hysteria research of adopting novel analytical approaches.

My decision to focus on these two particular case studies is not arbitrary but instead motivated by the following reasons. First, paralysis has been the most systematically studied symptom of conversion disorder/hysteria through functional neuroimaging.[29] Thus, fMRI studies of conversion paralysis are representative of contemporary image-based hysteria research in general. Second, drawing on the two de Lange, Roelofs, and Toni studies, I intend to show that by the early 2010s, fMRI has become an increasingly sophisticated investigation tool in hysteria research. Based on the detailed analysis of the two case studies and their comparison to previous neuroimaging research, I will argue that the investigation of hysterical paralysis has undergone a gradual refinement. This refinement, I will claim, is evident in the increasing specificity of the experimental designs and the growing sophistication of the analytical and interpretational approaches scientists utilise while working with fMRI. Finally, since the image-based investigation of hysterical paralysis occupied a crucial role in Charcot's theorising of this disorder,[30] analysing how this particular symptom is framed in the current fMRI studies will allow me to compare the historical and the contemporary hysteria research.

Each of the five sections of this chapter discusses a distinct stage in the referential chain that underlies the production of functional brain maps in hysteria research. These

25 See de Lange, Toni, and Roelofs, "Altered Connectivity."

26 De Lange, Toni, and Roelofs, 1782. Different functional connectivity analyses can be applied to task-based and resting-state fMRI data. See, e.g., Poldrack, Mumford, and Nichols, *Handbook*, 130–44. In this chapter, I will only discuss connectivity analysis in task-based studies. The functional connectivity analyses used in resting-state fMRI studies of hysterical symptoms will be discussed in section 4.4.1.

27 Strictly speaking, the first fMRI connectivity map of a hysterical symptom was published a year earlier in Cojan et al., "Motor Inhibition." However, the major part of the Cojan et al. study focused on the imaging results obtained through the functional segregation approach. By contrast, the de Lange, Toni, and Roelofs study from 2010 placed an exclusive focus on functional connectivity.

28 See, e.g., Aybek et al., "Life Events"; Bryant and Das, "Neural Circuitry"; Dogonowskie et al., "Recovery"; and Voon et al., "Emotional Stimuli."

29 Vuilleumier et al., "Brain Circuits," 325.

30 See section 1.3.2.

stages include the experimental setup, acquisition of imaging data, preprocessing, statistical image analysis, and the interpretation of the resulting functional brain maps. In the course of my analysis, I will address multiple issues that are not specific to hysteria research but are equally valid for other research areas using fMRI. Nevertheless, these technological aspects are relevant for this enquiry because they are constitutive of the kinds of questions that can be asked and the kinds of insights into hysteria that can be produced using fMRI.

3.1 Experimental Setup: Creating the Measurability of Hysterical Symptoms

Much of fMRI-based hysteria research in the first two decades of the twenty-first century has focused on limb paralysis, which as one of the most prevalent symptoms of conversion disorder/hysteria is referred to as the paradigmatic manifestation of this disorder.[31] According to recent studies, full or partial paralysis frequently occurs in current clinical settings and is characterised by physical signs that appear to have remained constant since Charcot's time.[32] Interestingly, diagnosing this symptom is no longer considered a particular challenge.[33] However, despite diagnostic advances, prior to the emergence of the fMRI-based research, not much progress had been made in understanding the symptom's nature.[34]

The most perplexing feature of this symptom is the impairment of voluntary movement that cannot be attributed to any apparent organic damage. In essence, patients try to move the affected limb but fail for no apparent reason. Yet, when distracted, their ability to move returns temporarily.[35] Why this happens remains unclear. The use of fMRI seems to offer a way out of this conundrum by allowing researchers to go beyond the apparently non-existent anatomical brain damage and instead search for a functional neurological defect as the potential underlying cause of the symptom. But, as we are about to see, this promise of new insight comes at a price since the use of fMRI entails an array of considerable methodological challenges. To begin with, in order to pinpoint the presumed neurological dysfunction, researchers first have to make multiple decisions about how to construct an experimental setup within which they can meaningfully implement fMRI for their aims.

Most fMRI experiments deploy what is referred to as the task-based approach.[36] In such an experiment, researchers collect fMRI data while preselected subjects lie in the scanner performing a temporally cued set of activities referred to as a task. By analysing

31 Vuilleumier, "Brain Circuits," 325.

32 Population-based studies have estimated the symptom's incidence at about 5 in 100,000 patients. For details, see, e.g., Nowak and Fink, "Psychogenic Movement Disorders," 1016. For a detailed description of the symptom's clinical signs, see Stone and Aybek, "Limb Weakness," 221–25.

33 See, e.g., Stone, Warlow, and Sharpe, "Controlled Study," 1538–42; and Stone, Zeman, and Sharpe, "Functional Weakness and Sensory Disturbance," 241–43.

34 See Nicholson, Stone, and Kanaan, "Conversion Disorder," 1268.

35 This is one of the symptom's diagnostic features. See Stone and Aybek, "Limb Weakness," 223.

36 See Ashby, *Statistical Analysis*, 6; and Aybek and Vuilleumier, "Imaging Studies," 73–84.