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.

the resulting fMRI data, researchers identify the brain regions that responded to the task. They do so by creating functional maps that display a potentially abnormal pattern of brain activity deemed to underlie the symptom. Since such experimental framing enables them to link the hysterical symptom to pathological brain activity, researchers invest considerable effort into planning it. Thus, the initial steps in the referential chain of a task-based fMRI study include:, first, choosing the type of experimental task; second, deciding how to structure the task throughout the measurement; and third, selecting the study participants. In the following three sections, I will analyse how researchers perform these operations by using the de Lange, Roelofs, and Toni article on conversion paralysis as my case study. I will argue that by designing their experimental setup, researchers gradually construct the measurability of hysterical symptoms through fMRI.

3.1.1 Negotiating the Adequacy of the Study's Experimental Task

When they decided to use fMRI to identify the neural basis underlying the loss of volitional movement in conversion paralysis, de Lange, Roelofs, and Toni drew on five previous task-based neuroimaging studies. The previous studies addressed the same question yet yielded mutually inconsistent findings.[37] The studies used different neuroimaging technologies (SPECT, PET, and fMRI) and employed diverse experimental tasks. The tasks ranged from attempting to move a paralysed limb, over being exposed to passive vibratory stimulation, to observing a projection of a moving hand.[38] In the introduction to their paper, de Lange, Roelofs, and Toni questioned the adequacy of the tasks previously used in the neuroimaging studies of conversion paralysis.[39] They argued that a different kind of experimental task called implicit motor imagery was better suited to investigating the neural basis of this symptom. But before we can unpack their argumentation, we first have to understand why researchers need to justify the adequacy of the task they had chosen to implement in their fMRI experiments and how they do it. With this purpose in mind, let us now examine the epistemic function of tasks in an fMRI study.

Generally speaking, a task serves to selectively induce a cognitive process of interest, such as attention, working memory, or impaired volitional movement.[40] It allows researchers to first isolate this process from many parallel operations in which an active brain is concurrently engaged and then to link the thus isolated cognitive process of interest to the task-induced pattern of brain activity. But far from being straightforward, such linking presupposes an entire chain of operations. To begin with, the task-based experimental manipulation rests on the assumption that any complex cognitive process encompasses mutually coordinated elementary components that are

37 Burgmer et al., "Movement Observation," 1341–42; Halligan et al., "Hypnotic Paralysis," 986–87; Marshall et al., "Hysterical Paralysis," B1–8; Spence et al., "Disorder of Movement," 1243–44; and Vuilleurmier et al., "Sensorimotor Loss," 1077–90.

38 Compare Halligan et al., "Hypnotic Paralysis"; Marshall et al., "Hysterical Paralysis"; Vuilleurmier et al., "Sensorimotor Loss"; and Burgmer et al., "Movement Observation."

39 De Lange, Roelofs, and Toni, "Self-Monitoring," 2051–52.

40 Huettel, Song, and McCarthy, *Imaging*, 302.

distributed across diverse brain regions.[41] For this reason, a task comprises a set of experimental conditions, each of which is designed to differentially manipulate one of the presumed cognitive components.[42] Next, by contrasting such conditions, researchers isolate the salient component from the accompanying cognitive operations of no interest. They then statistically analyse the collected fMRI data. The aim of the statistical analysis is to identify the brain regions that responded differentially to the experimental conditions researchers chose to contrast.[43] Finally, researchers visualise the resulting activations in the form of a functional brain map. In doing so, researchers map the cognitive component, which they had isolated by contrasting particular experimental conditions, onto the regional activity of the brain areas displayed in the functional map.

By repeating this procedure across different comparisons of experimental conditions entailed in the task, researchers break down the cognitive process of interest into its presumed functional components and localise each of these to a particular set of brain areas.[44] Having completed such functional decomposition, researchers proceed by making inferences about how the isolated components add up to produce either normal or pathological cognitive processes. In effect, by deploying fMRI, researchers aim to attribute the cognitive process of interest to a particular neural mechanism. Such a mechanism, in turn, is understood to comprise a set of interrelated, temporally and hierarchically organised functional components that are distributed across multiple brain regions.[45] This kind of search for the "objective neural correlates of functional mechanisms" underlying the loss of volitional movement informs the current fMRI research on conversion paralysis in task-based studies.[46] The same principle applies to fMRI task-based studies of all other hysterical symptoms.[47]

The description above already makes apparent the epistemic significance of defining an adequate task—one that correctly decomposes the phenomenon of interest into its elementary components and then disambiguates these from coinciding cognitive processes. However, to achieve this, researchers must make reliable a priori judgments about "how the task is performed" at the cognitive level.[48] Researchers are expected to derive such judgments from the current state of knowledge about the investigated phenomenon, which, ideally, is expressed in the form of a consistent cognitive model.[49] By embedding their choice of a particular task into a pre-existing theoretical framework, researchers can justify its adequacy and thus ensure that its use produces interpretable image-based findings. This precondition makes defining a task suitable

41 Posner et al., "Localization of Cognitive Operations," 1627.

42 Poldrack, "Subtraction and Beyond," 147.

43 In specialist terms, the task-induced local changes in brain activity detected by contrasting experimental conditions are called activations. Gusnard and Raichle, "Baseline," 685.

44 Poldrack, "Subtraction and Beyond," 147.

45 For a pertinent analysis of the role of neural mechanisms in cognitive neuroscience, see, e.g., Craver, "Beyond Reduction," 373–95.

46 De Lange, Roelofs, and Toni, "Self-Monitoring," 2051.

47 See, e.g., Ghaffar, Staines, and Feinstein, "Sensory Conversion Disorder."

48 Poldrack, "Subtraction and Beyond," 149.

49 Posner et al., "Localisation of Cognitive Operations," 1627.

for studying any complex cognitive process challenging.[50] Yet, in hysteria research, the situation is additionally aggravated by the lack of any undisputed neurocognitive model of this disorder that researchers could draw on to devise experimental tasks suited to studying hysterical symptoms.[51] The following analysis will show that to circumvent this problem, multiple neuroimaging studies of hysterical paralysis have instead relied—implicitly or explicitly—on the widespread neurocognitive model of healthy volitional movement.

In general neuroscience, volitional movement is understood to be underpinned by interrelated, temporally and hierarchically organised processes that occupy different neural regions.[52] According to this model, our intention to move triggers the brain centres responsible for the movement conceptualisation. In neurological terms, movement conceptualisation consists of the consecutive phases of motor planning and preparation. First, specialised brain areas create a motor plan "based on present perceptual information, past experience, and future goals."[53] In the phase of motor preparation, other brain areas then translate this abstract plan into concrete motor commands. During the subsequent stage of motor execution, the motor commands activate the muscles, thus initiating the movement. Finally, multiple brain regions responsible for controlling the process of execution use the bodily and environmental feedback to assess if the movement is made according to the initial plan. If necessary, these higher-order regions may intervene to modulate the ongoing movement by inhibiting inappropriate actions.[54]

From the perspective of this model, conversion paralysis could be attributed to a localised disturbance of any neural process that underlies the movement conceptualisation, initiation, or execution. Alternatively, conversion paralysis could also arise from a dysfunctional interaction among the different neural systems involved in the processes mentioned above.[55] The caveat is that, despite providing a useful general framework, the neurocognitive model of healthy volitional movement cannot predict which particular aspect of the interrelated processes that underpin volitional movement ceases to function appropriately in hysterical paralysis. This is because models of cognitive processes in healthy subjects provide information about the neural systems sufficient for proper functioning. But, since multiple brain areas can serve the same functional role, some of them may not be necessary for the normal execution of the

50 Posner et al., 1627.

51 In chapter 2, I have discussed this lack of a clear, uncontested theoretical model of hysteria and argued that, for this reason, current fMRI research into this disorder has a distinctly exploratory character. See section 2.4.1.

52 For succinct overviews of this model, see Pacherie, "Action," 97–101; and Roskies, "Conception of Volition," 109–30. For more detailed descriptions, see Frith, Blakemore, and Wolpert, "Control of Action," 1771–88; and Gazzaniga, Ivry, and Mangun, *Cognitive Neuroscience*, 371–421.

53 Gazzaniga, Ivry, and Mangun, *Cognitive Neuroscience*, 378.

54 Roskies, "Conception of Volition," 121–22. Unsurprisingly, this model of volitional movement is considerably more complex than the one with which Charcot operated by drawing on Wundt, Bain, Spencer, and Ferrier. For details of Charcot's investigation of hysterical paralysis and his understanding of the neural processes underlying volitional movement, see section 1.3.2.

55 Vuilleumier et al., "Sensorimotor Loss," 1078.

process. If a dysfunction of an area gives rise to pathology, then this area is necessary for executing this process.[56] Thus, whether or not a brain area is necessary for a particular cognitive function, such as volitional movement, cannot be inferred from studies of healthy subjects. Instead, it requires studying patients within the framework provided by models of cognitive processes in healthy subjects.

Drawing on the cognitive model of healthy volitional movement, early neuroimaging studies of hysterical paralysis investigated the stages of motor preparation and execution through tasks that directly elicited patients to engage their affected limbs. In two influential and mutually related single-subject studies by Mashall et al. and Halligan et al., participants with one-sided leg paralysis were instructed to either prepare to move or attempt to move first their 'good' and then their 'bad' leg.[57] Both of the patients' legs were strapped during these experiments to prevent any actual movement. Based on the resulting PET scans, the researchers conjectured that the initiation of movement in hysterical paralysis remained intact but that higher brain centres inhibited its execution. By contrast, in another PET study, Spence et al. submitted their participants, who had one-sided arm paralysis, to an entirely different task. The task entailed moving a joystick in a paced, self-chosen sequence with the affected or the unaffected hand. As a result, Spence et al. obtained a different pattern of brain activations.[58] Based on the pattern obtained, Spence et al. attributed hysterical paralysis to a selective dysfunction in the movement initiation. Spence et al. thus contradicted the conclusions that the authors of the previous studies had reached.

However, authors of subsequent neuroimaging studies of hysterical paralysis have questioned the adequacy of using any type of active motor task to isolate this symptom's presumed neural basis.[59] For example, de Lange, Roelofs, and Toni have argued that due to their paralysis, patients were unable to perform such tasks correctly, which, in turn, induced confounding cognitive effects. These unwanted cognitive "effects [were] related to the consequences of a failed movement (like altered effort, motivation, or error processing)."[60] Therefore, the brain activities isolated through active motor tasks could not be unambiguously attributed to the hysterical symptom. This criticism appears to echo—and was probably influenced by—the consensus established in general

56 For details, see Price and Friston, "Neuropsychological Patients," 347–48. Interestingly, this criterion is called "double dissociation" and was initially established by Charcot and Pitres in their localisationist studies. See Jeannerod, *Brain Machine*, 58–59.

57 See Halligan et al., "Hypnotic Paralysis"; and Marshall et al., "Hysterical Paralysis." The Halligan et al. study was conducted on a single patient diagnosed with hysterical paralysis. The participant of the Marshall et al. study was a healthy subject in whom hysterical paralysis was modelled through hypnosis.

58 Spence et al., "Disorder of Movement." All the patients in this study could perform the limited movements required since they only had partial hysterical paralysis.

59 See, e.g., Vuilleumieur et al., "Sensorimotor Loss," 1078; and de Lange, Roelofs and Toni, "Self-Monitoring," 2052.

60 De Lange, Roelofs, and Toni, "Self-Monitoring," 2052.

neuroscience that in order to produce interpretable findings, "functional imaging studies of patients need to be designed around tasks the patient can perform."[61]

Accordingly, subsequent studies employed tasks that did not entail an active movement of the paralysed limb. Using a more indirect approach, researchers designed tasks to induce cognitive processes deemed to have at least a partially shared neural basis with volitional movement.[62] For example, Vuilleumier et al. exposed patients whose conversion/hysterical paralysis was accompanied by sensory disturbances to passive bilateral vibration of their limbs.[63] Conversely, Burgmer et al. instructed their patients to observe a hand movement shown on a screen.[64] Yet, de Lange, Roelofs, and Toni criticised the Vuilleumier et al. study for not providing sufficient evidence that the motor and sensory aspects of conversion paralysis relied on overlapping neural mechanisms. De Lange, Roelofs, and Toni also objected to the use of movement observation by Burgmer et al. because of its lack of "an active volitional motor simulation."[65] In effect, de Lange, Roelofs, and Toni argued that all these tasks failed to isolate cognitive processes specific to conversion paralysis, thus resulting in maps that were not unambiguously interpretable.

Aiming to avoid such limitations, de Lange, Roelofs, and Toni deployed a task called implicit motor imagery. They showed their patients a set of visual stimuli consisting of schematic drawings of the left and right hands at various degrees of rotation. The patients, who had one-sided hysterical hand paralysis, had to judge as fast and as accurately as possible if the image they saw represented a right or a left hand. To ensure that no actual hand movement took place, the patients responded by pressing one of the buttons attached to either their left or right toe. Referred to as the hand-laterality judgment, this task has been widely applied in behavioural and neuroimaging studies of volitional movement in both healthy subjects and patients diagnosed with neurological disorders.[66] The general consensus is that subjects judge the laterality of the rotated hand image by mentally moving their hand into the orientation depicted by the stimulus

61 Price and Friston, "Scanning Patients," 102.

62 Some researchers have entirely relinquished the use of active motor tasks. See, e.g., Vuilleumieur et al., "Sensorimotor Loss"; and de Lange, Roelofs, and Toni, "Self-Monitoring." Others opted for tasks in which movement execution was embedded into complex constellations that also included more indirect conditions, such as movement observations or imagined movement. See, e.g., van Beilen et al., "Conversion Paresis."

63 Vuilleumieur et al., "Sensorimotor Loss," 1078. Incidentally, this approach represents an interesting parallel to Charcot, who also imaged hysterical anaesthesia to draw inferences about the patients' concurrent paralysis. See section 1.3.2.

64 Burgmer et al., "Movement Observation," 1337–38. In fact, besides observing the projected movement, the participants were also asked to emulate it on cue. Yet, Burgmer et al. conceded that the activation patterns induced by movement simulation were difficult to interpret. They argued that "the actual execution might differ between subjects due to internal motivation, cooperation and particularly the degree of handicap." Ibid., 1341. For this reason, in their interpretation, Burgmer et al. focused only on the abnormal pattern of brain activations elicited in patients by movement observation and declared this to be the main finding of their study.

65 De Lange, Roelofs, and Toni, "Self-Monitoring," 2052.

66 For an overview, see de Lange, Roelofs, and Toni, "Motor Imagery," 495–97.

presented.[67] In other words, they mentally simulate a corresponding hand rotation without physically executing it. Significantly, while judging the hand laterality, subjects remain unaware that they imagine performing the movement. It is for this reason that the task is called implicit motor imagery.

De Lange, Roelofs, and Toni argued that the task that displaced an actual with an imagined movement allowed them to avoid confounding neural effects of "altered sensory feedback or enhanced monitoring," which are associated with impaired motor execution.[68] Put simply, they specifically chose the task they expected their patients could perform despite their hand paralysis. Yet, to be able to claim that the hand-laterality judgment task was indeed adequate for their aims, de Lange, Roelofs, and Toni also had to provide evidence that the covert movement simulation this task induced nevertheless allowed them to focus on volitional aspects of motor loss. With this purpose in mind, de Lange, Roelofs, and Toni quoted multiple neuroimaging and behavioural studies that had used implicit motor imagery to show a neural overlap between the imagined and actually executed movement.[69] Based on this literature review, de Lange, Roelofs, and Toni argued that the implicit imagery task was suited to isolating the neural mechanism underlying the voluntary motor loss specific to conversion paralysis.

But their choice of the experimental task was not without limitations. As de Lange, Roelofs, and Toni conceded in a later study on hysterical paralysis, current neuroimaging research suggests that the overlap in the neural mechanism underlying imagined and performed action is limited to the stage of motor initiation.[70] Consequently, this type of task allows no insights into the subsequent stages of movement execution. Moreover, despite its widespread use in neuroimaging, implicit motor imagery appears to induce complex and not yet fully understood cognitive processes, thus complicating the interpretation of the results obtained.[71] De Lange, Roelofs, and Toni also failed to mention that the ability to imagine movement varies significantly across individuals and that these differences may have confounding effects on fMRI findings.[72]

Taken together, these aspects raise the question of whether the implicit motor imagery task is indeed sufficiently suited to unambiguously isolating the core cognitive component underlying the loss of movement in hysterical paralysis. Hence, authors

67 De Lange, Roelofs, and Toni, "Self-Monitoring," 2052.

68 De Lange, Roelofs, and Toni, 2052.

69 De Lange, Roelofs, and Toni, 2052.

70 De Lange, Roelofs, and Toni, "Motor Imagery," 496.

71 There are currently two conflicting frameworks that attribute implicit motor imagery to different underlying cognitive processes. According to the first framework, the implicit motor imagery tasks induce "the generation of a complete motor plan that is prevented from operating on the body." De Lange, Roelofs, and Toni, 496. The competing interpretational framework states that these tasks elicit only general instead of concrete motor representations. The conflict remains unresolved since both frameworks have been supported by experimental findings. For an overview, see ibid.

72 Several neuroimaging studies have shown that individual differences in the ability to imagine movement are "associated with distinctive patterns of brain activation during imagery tasks." Van der Meulen et al., "Individual Motor Imagery," 456. See also Charlot et al., "Mental Imagery Abilities," 565–80.

of subsequent fMRI studies of this symptom have chosen to use other types of tasks. Some deployed explicit motor imagery tasks, which entail expressly asking subjects to imagine moving their limbs in a particular way.[73] Others opted for a passive movement task, which involved flexing and extending the wrists of a patient who was instructed not to interfere with the manipulation.[74] In each case, the authors provided a validation of the task they had decided to use in a manner similar to the one analysed above. Just like de Lange, Roelofs, and Toni, the authors of subsequent studies also justified their choices of the experimental tasks by grounding them in the findings generated by previous neuroimaging and behavioural studies.[75]

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In sum, the chain of references in an fMRI task-based experiment starts long before any actual measurement occurs. First, researchers must define an experimental task adequate for studying the hysterical symptom of interest using fMRI. As we have seen, their choice of the task needs to be justified in relation to previous fMRI studies of hysteria. But just as importantly, the choice also has to be embedded in the context of broader neuroscientific research into the cognitive processes whose presumed dysfunction underpins the symptom in question. My analysis has shown that such negotiation of the task's adequacy is not a mere rhetorical formality but a significant initial step in the meaning production and can, therefore, be designated as a semantic transcription.[76] Only by being able to claim—with reasonable certainty derived from the existing literature—which particular cognitive processes they believe their chosen task triggers can researchers curtail the potential ambiguity of their experimental intervention and, by extension, meaningfully interpret the task-elicited neural effects.

Since the discursive validation of the experimental task's adequacy is grounded in the construction of a consistent chain of references, it is inherently unstable. The examples above have demonstrated that the claims of the task's adequacy can always be questioned by other researchers or destabilised by new findings that are either directly related to hysteria or have arisen from ongoing conceptual shifts within general neuroscience. However, it appears to me that this epistemic instability is not a disadvantage. Instead, it enables researchers to build upon the current state of knowledge and test increasingly more refined ways of disentangling the cognitive components of hysterical symptoms' presumed functional mechanisms.

Finally, before we move on to analysing the next stage in an fMRI experiment, I would like to draw attention to one important aspect of the neuroimaging research on hysteria. When present-day researchers decide which particular type of task to

73 Van Beilen et al., "Conversion Paresis," 3–5.

74 Hassa et al., "Motor Inhibition," 719–20. Interestingly, as discussed previously, Charcot also deployed passive movements in his experiments with hysterical patients. See section 1.2.2.

75 For example, Hassa et al. justified their decision to use passive movement by quoting a previous study, which had shown that this type of task "typically elicits activity in the sensorimotor network that is also active when the movement is voluntarily executed." Hassa et al., "Motor Inhibition," 720.

76 I am using the term transcription in Jäger's sense. See Jäger, "Transcriptivity Matters," 49.

deploy for their fMRI study, they are still at the beginning of their experiment and have not even started recruiting hysteria patients. Yet, already at this point, the conceptual decisions the researchers are required to make and the methodological challenges they face have considerably exceeded the level of complexity we are familiar with from Charcot's image-based hysteria research. On the one hand, fMRI appears to facilitate closer access to neurophysiological processes underpinning hysterical symptoms than the images Charcot had used. But on the other hand, the experimental deployment of fMRI is epistemically far more demanding and intricate. As we are about to see, with each new step in the fMRI-based chain of references, the number of epistemic challenges with which researchers have to grapple will continue to rise.

3.1.2 Putting the Experimental Task into Operation

Having selected a task, researchers have to decide how to implement it within a particular experimental setup. As discussed above, the task aims to differentially manipulate the hysterical symptom's underlying cognitive components so that their neural correlates can be identified during the subsequent statistical analysis. The analysis, in turn, is based on the comparison of the brain activations elicited by different experimental conditions entailed in the task. Since much of the subsequent statistical analysis focuses on identifying task-induced changes in the brain activity over time, the data acquisition and the task manipulation must be synchronised.[77] To ensure that the temporal match between the data acquisition and the task manipulation is obtained, both processes are executed by respective computer programmes.[78] This means that, while her brain is being scanned, the experimental subject is shown a fully automated succession of stimuli and task instructions. However, my intention in this section is to go beyond such a finalised experimental setup and unpack both theoretical and practical assumptions that inform its construction. Thus, in what follows, on the example of the case study, I will first analyse how researchers structure the task by defining alternating experimental conditions. I will then discuss the researchers' decisions on how to organise such conditions temporally throughout the experiment. All these decisions, I will argue, partake in the constitution of the hysterical symptom's measurability through fMRI.

During the data acquisition that lasted twenty-three minutes on average, each subject in the de Lange, Roelofs, and Toni study judged the laterality of the presented visual stimuli altogether 160 times.[79] The stimuli comprised thirty-two different line drawings and were projected on a screen that the subjects could see in the mirror placed above their head. The drawings showed a left or a right hand from a dorsal or palmar view and at one of eight angles of rotation that ranged from 0 to 315 degrees with 45 degrees increments. The images were grouped in blocks of ten, with a rest period of ten seconds between the blocks. Shown in random order, the images stayed on the screen until the subject responded. Every two images within the block were separated

77 Huettel, Song, and McCarthy, *Imaging*, 43.

78 See, e.g., Burke at al., "Ancillary Activation," 334; and Voon et al., "Emotional Stimuli," 1528.

79 De Lange, Roelofs, and Toni, "Self-Monitoring," 2053.

by pauses—called intertrial intervals—that lasted 1.5 to 2.5 seconds. Both during the intertrial intervals and the rest periods between the blocks, the subjects were instructed to look at a fixation cross that appeared on the monitor.[80]

At a superficial glance, it may appear as if de Lange, Roelofs, and Toni deployed a basic though heavily criticised experimental setup that continues to be used in all areas of neuroimaging due to its simplicity.[81] Called categorical subtraction, this approach directly compares two conditions—task and control. The difference between the task and the control is supposed to consist of only a single cognitive component. Moreover, in many studies that employ categorical subtraction, the control condition is defined as a period of rest, during which the subjects either relax or passively view a fixation cross.[82] But the problem with such a setup is that its implementation relies on several assumptions whose validity has been questioned.

First, due to the absence of an active task, periods of rest were initially viewed as "something akin to a zero-activity condition."[83] Based on this assumption, researchers used the periods of rest as a baseline in relation to which they isolated the brain areas activated by the task. However, subsequent research demonstrated that, far from being inactive, the healthy human brain at rest is instead engaged in a significant amount of intrinsic processes.[84] Such intrinsic neural processes may, in turn, affect the brain activity during the task condition. In fact, several influential studies have identified a set of interconnected brain regions—jointly called the default-mode network—whose activity is high while the subject rests but decreases during the active performance of sensorimotor and cognitive tasks.[85] These findings suggest that functional maps generated by simply contrasting a cognitive task and rest fail to yield unambiguous insights into the brain's functioning. It is, therefore, no longer considered good practice to use rest periods as the only control condition.[86]

Second, a more general problem with categorical subtraction is that it entails an implicit assumption referred to as pure insertion.[87] Pure insertion states that it is possible to design a task that adds a cognitive component of interest into the cognitive processes elicited by a control condition without altering the pre-existing baseline processes. This assumption was refuted by multiple studies in general neuroscience, which showed that cognitive components across different task conditions mutually

80 De Lange, Roelofs, and Toni, 2053.

81 Poldrack, "Subtraction and Beyond," 147–48.

82 See, e.g., Marshall et al., "Hysterical Paralysis," B2–3.

83 Stark and Squire, "Zero Is Not Zero," 12760.

84 Biswal et al., "Functional Connectivity," 537–41.

85 See Gusnard and Raichle, "Baseline," 685–94; and Raichle et al., "Default Mode," 676–82. These findings have led to the development of a new functional imaging paradigm called resting-state fMRI that investigates the brain's spontaneous activity at rest. We will discuss the application of this paradigm in fMRI hysteria research in section 4.4.1.

86 Huettel, Song, and McCarthy, *Imaging*, 309.

87 Friston et al., "Cognitive Subtraction," 97. In experimental designs based on categorical subtraction, the assumption of pure insertion applies regardless of whether or not the control condition is defined as rest.

influence one another.[88] Even more significantly, pure insertion entails another implicit assumption. According to this corollary assumption, the inserted cognitive component should always translate into the same discrete neural process "irrespective of the cognitive or physiological context" of the experiment.[89] Contrary to this, empirical studies have demonstrated that the brain's neurophysiological implementation of cognitive processes is highly dynamic, nonlinear, and context-sensitive.[90] This means that functional maps created through categorical subtraction fail to establish an unambiguous link between the task-induced cognitive processes and their neural counterparts.

The criticism of pure insertion has positively affected neuroscience, as it has led to the development of more refined approaches aimed at circumventing the limitations of categorical subtraction.[91] In principle, all these new approaches still remain informed by the logic of subtraction. This is because to isolate the cognitive components of interest and then link these to regionally specific brain activity, even the new approaches deploy some form of comparison across experimental conditions. But unlike categorical subtraction, the new approaches entail multiple and multilevel comparisons of different combinations of experimental conditions. These types of comparisons were explicitly devised not to ignore but instead to explore how cognitive and physiological processes in the brain interact.[92] Thus, the new approaches are predicated on more nuanced assumptions about the relationship between task-induced effects at the cognitive and neurophysiological levels.[93] To see how these assumptions inform the actual practice, let us now return to our case study.

Since the experimental task—judging the laterality of the hand drawing—was the same throughout their study, it may appear as if de Lange, Roelofs, and Toni relied on a simple subtraction between this task and the rest condition. However, a closer examination will reveal that they instead combined two different experimental approaches that had been developed in the context of general neuroscience to avoid the limitations of categorical subtraction. Although the explicit task remained constant, the patients in our case study were induced to imagine a range of different movements owing to the changes in the stimuli's visual characteristics. As mentioned earlier, both the laterality and the orientation of the presented hand drawings kept varying throughout the experiment. Each such variation elicited different imagined

88 Friston et al., 98.

89 Friston et al., 97. Poldrack offers a detailed yet accessible account of how the pure insertion comprises both the assumption of the insertability of cognitive processes and the assumption of the insertability of neural processes. See Poldrack, "Subtraction and Beyond," 148–49.

90 "Even if, from a functionalist perspective, a cognitive component can be added without interacting with pre-existing components, the brain's implementation of these processes is almost certainly going to show profound interactions…[P]ure insertion discounts both functional and physiological interactions and therefore represents a very restrictive precondition for cognitive subtraction." Friston et al., "Cognitive Subtraction," 98.

91 See, e.g., Price, Moore, and Friston, "Experimental Design," 264–72.

92 For details about the types of comparisons entailed in these approaches, see Poldrack, "Subtraction and Beyond," 152–56.

93 For details about the assumptions that underlie these different approaches, see Poldrack, 152–56.

movements. These controlled variations in the stimulus-induced imagined movements constituted different experimental conditions. Moreover, the stimuli simultaneously manipulated several aspects of the imagined movements. Specifically, they either engaged the affected or the unaffected hand while also instigating the patient to mentally position the respective hand in different orientations relative to their body. The setup in which multiple experimental conditions—referred to as factors—are manipulated concurrently is called factorial design. Its main advantage is that it allows scientists to identify neural activities induced by each factor separately and to analyse the effects of the interactions among multiple factors.[94] As we will see by the end of this chapter, this complex setup enabled de Lange, Roelofs, and Toni to determine which functional aspects of the patients' volitional movement remained intact and which were impaired.

Additionally, de Lange, Roelofs, and Toni did not merely contrast the imagined movements to the condition of rest to identify the brain activity of interest. Instead, they opted for a more sophisticated approach. Called parametric design, this approach relies on the assumption that only those brain areas in which the increase in activity correlates with the increase in the task's complexity have been triggered by the task.[95] In line with this approach, de Lange, Roelofs, and Toni systematically modulated the level of their task's difficulty. To this end, they used hand drawings whose incrementally increasing angle of rotation relative to the body induced patients to imagine progressively more complex movements.[96] In the next step, de Lange, Roelofs, and Toni focused on demonstrating that different stimuli orientations correlated with the task's changing complexity at the cognitive and neural levels. With this aim in mind, they quoted multiple fMRI studies performed on healthy individuals.[97] Thus, not only the pertinence of the type of the experimental task they had chosen but also the details of its concrete implementation were grounded in the referential framework provided by previous studies. In short, to establish the validity of these two aspects of their experimental design, the researchers relied on operations of semantic transcription.[98]

So far, we have seen that de Lange, Roelofs, and Toni used a sophisticated experimental setup that combined elements of factorial and parametric designs. We can safely assume that their intention thereby was to attain greater precision in identifying the hypothesised neural mechanism underlying conversion paralysis. Yet, my analysis has shown that designing such a complex setup involves a spectrum of interpretational decisions that are informed by tacit and explicit assumptions of how the presumed task-induced cognitive processes are implemented at the level of brain activity. As we have seen, these include more general assumptions that cognitive processes can be decomposed into their functional components and that each of these components can be isolated through particular combinations and comparisons of

94 Poldrack, 153.

95 Henson, "Efficient Experimental Design," 194.

96 De Lange, Roelofs, and Toni, "Self-Monitoring," 2053.

97 For an overview of these studies, see de Lange, Roelofs, and Toni, 2054; and de Lange, Roelofs, and Toni, "Motor Imagery," 495.

98 See Jäger, "Transcriptivity Matters," 49.

multiple task conditions. Another implicit assumption is that the thus isolated cognitive components can be unambiguously mapped onto regionally specific task-induced brain activities. But we have also discussed that, additionally, researchers must make specific assumptions about the actual effects that different aspects of their task induce both at the cognitive and the neural level. All these assumptions are built into the imaging data and impose a particular view of the brain's functional organisation onto the hysterical symptom. The validity of the resulting fMRI findings on the neural basis of hysteria thus hinges on the correctness of all these underlying assumptions. Importantly, since these assumptions are derived from the current research community's consensus about how the human brain works, they remain subject to potential future revisions.

Having analysed how de Lange, Roelofs, and Toni structured their task into experimental conditions, let us now examine how they organised these conditions over time. By arranging ten different, randomly mixed hand images into distinct blocks that alternated with periods of rest, de Lange, Roelofs, and Toni deployed what is known as the mixed experimental design.[99] The mixed design merges elements of two basic approaches to temporally structuring the experimental setup. In the older approach, called the blocked design, experimental conditions are ordered into discrete, mutually alternating groups, each containing a single stimulus type.[100] The newer approach, known as the event-related design, entails short-duration presentations of separate stimuli, called trials, whose timing and sequencing are randomised.[101]

It should be noted that these different experimental designs produce different neurophysiological effects on the brain.[102] This is highly significant because fMRI does not measure neural responses directly but only their accompanying physiological changes.[103] Referred to as the haemodynamic responses, such physiological changes lag behind the correlated neural response and last much longer. When the brain is exposed to blocked stimuli, separate stimulus-induced haemodynamic responses add up to produce a cumulative effect.[104] This cumulative effect is easy to detect but provides no information about the separate responses contained in it. Conversely, event-related designs permit a good estimation of the relative timing of the haemodynamic responses to individual stimuli at the expense of a lower efficiency for detecting them.[105] The mixed design that de Lange, Roelofs, and Toni used combined the benefits of the blocked and event-related approaches. This combination enabled the researchers to identify in the fMRI data the individual effects induced by different aspects of the hand drawings while also increasing the chances of detecting them.[106] Yet, the implementation of

99 For details on this experimental design, see Huettel, Song, and McCarthy, *Imaging*, 325–26.

100 This approach was already used for PET scanning. See Huettel, Song, and McCarthy, 303–13.

101 This approach was developed specifically for fMRI. See, e.g., Dale and Buckner, "Selective Averaging," 329–40.

102 See Henson, "Efficient Experimental Design," 196–97.

103 See, e.g., Huettel, Song, and McCarthy, *Imaging*, 208–10. We will discuss this in more detail later in this chapter.

104 Huettel, Song, and McCarthy, 310–13.

105 Henson, "Efficient Experimental Design," 196.

106 This will become apparent in section 3.4.2 during my discussion of statistical analysis.

this complex design relied on multiple assumptions about how the brain reacts to the stimuli, which de Lange, Roelofs, and Toni had to take into account.

First, de Lange, Roelofs, and Toni had to decide how to organise the individual stimuli both within and across the blocks. This aspect was crucial because research into the efficiency of experimental design in fMRI has shown that a predictable ordering of stimuli elicits confounding psychological effects in subjects, such as habituation, boredom, stimulus anticipation or tiredness.[107] All these effects could introduce noise into the imaging data and thus blur the intended task-induced cognitive processes. To alleviate such unwanted effects, de Lange, Roelofs, and Toni followed the recommendations in the neuroimaging literature and presented the stimuli in random order.[108] Importantly, what counts as the optimal level of randomness remains an open question since there is no straightforward method to verify if and to what extent a particular sequence of stimuli induces the confounding effects listed above.[109]

Furthermore, not only the sequencing of the stimuli but also their number, relative timing and the duration of intervals between successive stimuli had a precisely defined role in inducing unambiguously measurable neural and neurophysiological responses. For instance, de Lange, Roelofs, and Toni kept the intertrial intervals short so as to increase the number of individual stimulus presentations without making the experiment last longer. In doing so, they aimed to generate a sufficiently large amount of individual stimulus-induced responses and thus increase the detection power during statistical data analysis while also trying not to tire the patient.[110] Yet, short intertrial intervals are known to cause a potential overlap between the haemodynamic responses to individual stimuli, thus making the responses mutually indistinguishable.[111] To offset this problem, de Lange, Roelofs, and Toni randomly varied the intervals' durations between 1.5 and 2.5 seconds. They thus acted in accordance with findings of studies into fMRI task optimisation. Such studies concluded that randomising the duration of intervals between successive stimuli enabled the subsequent reconstruction of individual haemodynamic responses from the fMRI data.[112] Since such meta-research provides only general guidelines, the temporal parameters are not standardised.[113] De Lange, Roelofs, and Toni thus had to decide how to best apply these guidelines to their concrete study.

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107 See Huettel, Song, and McCarthy, *Imaging*, 301–2.

108 Liu et al., "Detection, Estimation, and Predictability," 770.

109 Some authors suggest that to determine the optimal level of randomisation, researchers should participate in their study as pilot subjects. See Huettel, Song, and McCarthy, *Imaging*, 301–2. Others recommend using quantitative methods that rely on computer programmes to estimate the probability with which a subject can correctly guess the next stimulus in the sequence. See Liu et al., "Detection, Estimation, and Predictability," 766–70.

110 Henson, "Efficient Experimental Design," 199.

111 Dale and Buckner, "Selective Averaging," 330.

112 This strategy is called jittering. For details, see Dale, "Experimental Design," 109–114.

113 See, e.g., Dale, "Experimental Design," 109–114; Liu, "Part 2: Design," 401–413; and Liu and Frank, "Part 1: Theory," 387–400.

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In summary, when setting up their experiment, researchers make interpretational choices by structuring the chosen task into a temporal sequence of changing experimental conditions. We have seen that, if chosen poorly, each aspect of this structure can introduce noise into the fMRI imaging data, either by eliciting psychological confounds or by producing neural and haemodynamic effects that are not unambiguously extractable through subsequent statistical analysis. However, my detailed discussion has also underscored that if chosen according to the research community's guidelines, a particular structure of the task contributes to making the neural correlates of hysterical symptoms identifiable and visualisable through fMRI. Therefore, I argue that in task-based fMRI studies, the measurability of the hysterical symptom is constituted by organising and quantifying various aspects of the task manipulation. In effect, the quantified framework that research thus construct serves to discipline the elusive hysterical symptom.[114] But this disciplining relies on a set of assumptions about how each aspect of the task manipulation affects the patients' brains at the levels of induced cognitive processes, neural activities, and haemodynamic responses. For it to be successful, the experimental setup must clearly isolate the impaired cognitive processes underlying the symptom and facilitate the unambiguous translation of the thus isolated cognitive processes into extractable neural and haemodynamic effects.

There is an additional aspect of disciplining in the context of fMRI experiments that deserves to be pointed out. Apart from the fMRI data, most task-based studies also generate a supplementary set of behavioural data by measuring various details of the subjects' task performance, such as their response times and error rates.[115] In doing so, researchers aim to control and quantify both the subjects' compliance with and their ability to perform the task. Hence, it can be said that such supplementary machine-generated data serve to 'objectively' validate the experimental manipulation, proving that the measured neural activity was indeed induced by the subject's active fulfilment of the task. Moreover, as we will see later, such behavioural measurements also play a role in the subsequent analysis of the fMRI data. In short, based on my analysis in this section, it is apparent that all aspects of hysteria patients' behaviour during an fMRI experiment are thoroughly quantified. Interestingly, multiple parallels to this present-day quantitative framing—although far less strict and thoroughgoing—can be found in various examples from Charcot's image-based research on hysteria that we discussed in chapter 1.[116]

3.1.3 Transforming Hysteria Patients Into Experimental Subjects

Apart from choosing the task and defining the details of its implementation, another crucial step that researchers must complete before acquiring the fMRI data is selecting

114 My analysis here draws on Lynch, "Material Form of Images," 37–66.

115 See Cojan et al., "Inhibition," 1028–29; and de Lange, Roelofs, and Toni, "Self-Monitoring," 2053.

116 See, e.g., Charcot's research on hysterical ischuria in section 1.1.1. See also sections 1.1.2, 1.3.1, and 1.3.2.

experimental subjects. Simple as it may appear, we will see that this process is fraught with methodological challenges arising both from the use of fMRI technology and the nature of hysteria. In what follows, I will examine the ways in which the decisions on how many and which patients to recruit influence the creation of functional brain maps that, in turn, impose a particular epistemic perspective on hysteria while foreclosing its alternatives.

One key issue that researchers have to address when selecting participants is how many subjects to include in their study. Early neuroimaging research on hysteria comprised single-case studies.[117] Since the beginning of the twenty-first century, the focus has shifted towards generating group-level brain maps computed from fMRI data that stem from multiple subjects.[118] The reason for the shift is that the results of single-case studies apply only to the examined individual, whereas findings from group studies can be generalised.[119] In the latter case, the generalisability of findings is the outcome of statistical models researchers use to calculate group-level functional maps from imaging data.[120] The caveat, however, is that small sizes of participant samples negatively affect the potential validity of the resulting group-level fMRI maps.[121]

The implication seems straightforward—to obtain statistically valid fMRI results, researchers must use a sufficiently large sample of subjects. Admittedly, what counts as a sufficient sample size remains a topic of contentious debate in general neuroimaging literature.[122] For our discussion, it suffices to say that several accounts converge on the view that the very minimum of sixteen to twenty subjects is required, whereas more recent accounts recommend recruiting more than a hundred patients.[123] This means that much of the neuroimaging research on hysteria published within the first two decades of the twenty-first century was severely under-sized. For example, when it appeared in 2007, the de Lange, Roelofs, and Toni study, which included eight patients, was the largest fMRI study of hysteria up to that point.[124] Only since the

117 See, e.g., Halligan et al., "Hypnotic Paralysis"; and Marshall et al., "Hysterical Paralysis."

118 Single-case studies still sporadically appear. See, e.g., Cojan et al., "Inhibition"; Kanaan et al., "Repressed Memories"; and Saj et al., "Mental Imagery."

119 Poldrack et al.,"Scanning the Horizon," 118.

120 This will be discussed in detail in section 3.4.2.

121 At this point, it is important to note that fMRI brain maps do not display actual brain activity but merely the statistical probability that the activity was induced by a given experimental task. See, e.g., Huettel, Song, and McCarthy, *Imaging*, 332. This probability is calculated by using various statistical tests. In mathematical terms, statistical power is the chance these tests have of discovering the task-induced activity in very noisy fMRI data. Since the statistical power of an fMRI study depends on its sample size, small-sized studies have very low statistical power. This means that small-sized studies have a very low chance of discovering task-induced brain activity in their participants and that, from the statistical point of view, their results are neither reliable nor reproducible. For details, see Button et al., "Power Failure," 365–76. We will return to this important epistemic question when discussing the details of statistical analysis in section 3.4.3.

122 See, e.g., Friston, "Ten Ironic Rules," 1300–10; and Thirion et al., "Large fMRI Cohort," 105–20.

123 Compare Friston, "Ten Ironic Rules," 1300–10; Poldrack et al.,"Scanning the Horizon," 116; and Thirion et al., "Large fMRI Cohort," 105–20. See also Perez et al., "State of the Field," 2, 102623.

124 The sample size of previous fMRI-based studies of hysteria varied between three and five patients. For an overview, see Stone et al., "Simulated Weakness," 962.

mid-2010s have studies with samples that include more than twenty patients started to appear.[125] Yet, in parallel, under-sampled studies with ten or fewer subjects continue to be published.[126] To understand why fMRI-based hysteria research in the first two decades of the twenty-first century has struggled with recruiting sufficiently large samples, we must analyse the underlying participant selection criteria, for which our case study provides a pertinent example.

In the published article, de Lange, Roelofs, and Toni duly listed both the inclusion and exclusion criteria that guided their selection of study participants. These criteria disclose that the researchers chose to focus on conversion disorder patients with one-sided paralysis restricted to the arm. Instead of merely relying on patients' self-reports, the researchers quantified each subject's maximum voluntary contractions for both hands using a dynamometer. In doing so, de Lange, Roelofs and Toni provided empirical evidence for the symptom's lateralisation.[127] However, the resulting numerical data also clearly demonstrate that the severity of paralysis varied considerably across the eight patients, ranging from partial to almost complete loss of voluntary hand movement. These data thus make evident that the differences in the symptom severity did not represent an exclusion criterion in this study. Similarly, de Lange, Roelofs, and Toni chose to tolerate the differences in the symptom's laterality and duration. As a result, half of the patients in the sample had left-hand and the other half had right-hand paralysis, with the symptom duration ranging from three months to over three years.[128] By contrast, the authors decided to exclude patients who exhibited additional conversion symptoms such as "pseudo-epileptic insults, tremors, sudden movements and deteriorated speech or vision."[129] They also excluded patients with an accompanying neurological illness and those receiving medications that could alter cerebral blood flow.

Clearly, some of these criteria were tailored to the requirements of the study's experimental setup. For example, it is safe to assume that the symptom's strict lateralisation was required to facilitate the intended comparison of the task-induced effects between the affected and healthy hands. Similarly, the patients' legs had to be unaffected by paralysis so that they could respond to the task by pressing the buttons attached to their toes. But taken as a whole, the criteria implemented in our case study are illustrative of a targeted sampling strategy that has characterised fMRI-based hysteria research in the first two decades of the twenty-first century. In an analogy to the example above, most studies used the patient selection to clearly delineate either a single symptom (e.g., paralysis) or a subtype of symptoms (e.g., various forms of excessive involuntary movements, such as tremors, contractures, and gait abnormalities).[130]

125 See Baek et al., "Motor Intention"; Espay et al., "Functional Tremor"; and Morris et al., "Avoidance".

126 See Bègue et al., "Visuomotor Cognition"; Blakemore et al., "Aversive Stimuli"; and Burke et al., "Ancilliary Activation."

127 De Lange, Roelofs, and Toni, "Self-Monitoring," 2052–53.

128 De Lange, Roelofs, and Toni, 2053.

129 De Lange, Roelofs, and Toni, 2052.

130 See, e.g., Aybek et al., "Life Events," 59; Burgmer et al., "Movement Observation," 1337; Espay et al., "Functional Tremor," 181, 183; Voon et al., "Emotional Stimuli," 1535.

Although no standardised criteria concerning patient selection have ever been established, the shared tendency across the studies published until the end of 2019 has been to construct a homogeneous patient sample by controlling multiple variables. With this purpose in mind, researchers typically excluded patients who simultaneously exhibited different types of hysterical symptoms, used medication or had accompanying neurological and psychiatric comorbidities.[131] At the same time, most researchers have endeavoured to strike a balance between achieving a sufficiently strict delineation of the symptom of interest, on the one hand, and avoiding having too small a sample, on the other. It is probably for the latter reason that Lange, Roelofs, and Toni decided to include in their study two patients with comorbid psychiatric conditions, one of whom used antidepressants.[132] Their approach thus contradicted other fMRI studies that explicitly excluded hysteria patients diagnosed with any form of comorbid psychiatric disorders.[133]

The major caveat is that, on the whole, such homogenising focus on a hysterical symptom of interest contradicts the typical clinical characteristics of conversion disorder/hysteria. Notably, most hysteria patients simultaneously suffer from several highly heterogeneous symptoms. There are considerable variations across patients concerning the particular combination of such concurrent hysterical symptoms, as well as the severity, duration, and extent to which the individual symptoms affect different body parts.[134] Additionally, hysteria frequently overlaps with a host of accompanying psychiatric disorders and neurological diseases. Taking all this into account, it becomes clear that by focusing on symptom specificity, fMRI studies selected atypical patients. This, in turn, explains why they persistently struggled with problematically small sample sizes. By contrast, epidemiological studies of hysteria/conversion disorder tend to use more inclusive criteria and, as a result, appear to have no problem with recruiting samples that exceed a hundred patients.[135] But, it is also interesting to note that the choice of atypical hysteria patients as experimental subjects in the fMRI research within the first two decades of the twenty-first century represents another parallel to Charcot. As discussed in chapter 1, Charcot also conducted his image-based experiments on those rare patients in whom a particular symptom of interest was most fully and clearly developed.

However, although such a narrowly targeted patient selection in contemporary studies may appear misplaced, it was a direct consequence of the specific demands stemming from the use of fMRI in hysteria research. For an fMRI study, especially in the early days of the research, the major epistemic problem arose from the lack of the research community's consensus on whether different hysterical symptoms (e.g., paralysis, tremor, anaesthesia, seizures, pain, and blindness) share the same putative neural mechanism, or if, conversely, each symptom might have a distinct neurocognitive basis. Some authors hypothesised the existence of a single mechanism

131 See, e.g., Aybek et al., "Life Events," 59; and Voon et al., "Emotional Stimuli," 1535.

132 De Lange, Roelofs, and Toni, "Self-Monitoring," 2053.

133 See, e.g., Voon et al., "Emotional Stimuli," 1528; and Morris et al., "Avoidance," 287.

134 See, e.g., Stone, Warlow, and Sharpe, "Controlled Study," 1537–51.

135 Stone, Warlow, and Sharpe, 1537–51.

across diverse symptoms, whereas others contradicted such conjectures.[136] Moreover, it was equally unclear whether and to what extent various psychiatric comorbidities (e.g., depression, anxiety, and panic disorder) might interfere with the patterns of brain activity attributed to the hysterical symptom under study.[137]

Hence, the authors of most fMRI studies operated under the premise that the simultaneous presence of heterogeneous hysterical symptoms and co-occurring psychiatric and neurological disturbances could introduce ambiguity into the experimental setup at the cognitive and neural levels. Since the epistemic efficacy of functional maps hinges on their ability to isolate pertinent neural correlates from the ongoing brain activity, targeted participant selection served to minimise potentially confounding patient characteristics. Therefore, the choice of atypical patients as study participants was epistemically justified because there was no prior knowledge about the potential neural basis of hysteria on which fMRI-based research could have drawn.

Nevertheless, apart from small sample sizes, the focus on symptom specificity during the recruitment of participants had another drawback. Functional brain maps obtained through such studies have a limited epistemic scope since they cannot be generalised to other types of hysterical symptoms or to mixed manifestations of hysteria.[138] For example, to this day, it "remains unclear whether the neurobiology of isolated functional deficits (e.g. limb weakness) differs significantly from mixed presentations."[139] It can thus be argued that this sampling strategy has effectively compartmentalised the hysterical body into individual symptoms and led to the production of brain maps that failed to offer an overarching insight into the disorder's multisymptomatic character.

Interestingly, as of the mid-2010s, the authors of several studies have addressed this shortcoming by applying a different sampling strategy. The underlying principle of this alternative sampling strategy is to group patients with multiple and mutually heterogeneous hysterical symptoms, such as paralysis, tremor, anaesthesia, pain, and seizures.[140] As a result, researchers using this approach could recruit samples of over twenty patients whose varied clinical characteristics were representative of hysteria's heterogeneous manifestations. Even more importantly, the major aim of this novel approach has been to explore shared neural deficits across different types of hysterical symptoms "assuming homogeneity in behavioural, cognitive and neural dysfunction" across the symptoms.[141] However, since this approach relies on an empirically unproven assumption that different symptoms at least partly rely on shared neural mechanisms, the authors of these studies stated that the heterogeneity of their patient samples

136 For accounts that hypothesise the existence of a single mechanism across diverse symptoms, see, e.g., Edwards et al., "Bayesian Account of 'Hysteria,'" 3507. For an opposing stance, see, e.g., Perez et al., "Conversion Disorder," 148.

137 Baek et al., "Motor Intention," 1633.

138 Aybek et al., "Life Events," 59.

139 Bègue et al., "Structural Alterations," 14–15, article 101798.

140 Baek et al. "Motor Intention," 1627–28; and Morris et al., "Avoidance," 290.

141 Morris et al., "Avoidance," 293.

might be a potential limitation concerning the validity of their findings.[142] Despite this limitation, there are indications in the neuroimaging literature that this new, more inclusive approach to selecting patients as experimental subjects in fMRI studies of hysteria is gaining increasing acceptance and might become dominant in the third decade of the twenty-first century.[143]

So far, we have discussed how hysteria patients' characteristics are framed by the explicit criteria that underpin the selection of patients as study participants in an fMRI experiment. Let us now turn to those of patients' characteristics that are not explicitly controlled through the selection criteria but which, as I intend to show, nevertheless have important epistemic implications for the resulting functional maps. Apart from listing the patient selection criteria, published fMRI studies typically also list the demographic information on the study participants. The purported aim of such lists is to give "a full description" of the subject sample.[144] Interestingly, in group studies, these descriptions are mostly devoid of information on the patients' ethnicity, social background, education, family status, occupation, or income.[145] Although it remains an open question if and to what extent broader socio-economic factors might influence the symptoms,[146] fMRI research on hysteria has so far entirely neglected such factors.

By contrast, the subjects' age and gender are duly noted in the demographic descriptions. These data show that almost all studies published within the first two decades of the twenty-first century were mixed-gender and recruited adult patients whose age ranged considerably—from the early 20s to the late 70s.[147] Since the variations in age and gender were not controlled through the selection of participants, we can presume that these two factors were viewed as not having a potentially confounding effect on hysterical symptoms at the neural level. In other words, the tacit assumption that has informed functional neuroimaging research on hysteria within the first two decades is that shared neuropathological mechanisms underpin hysterical symptoms in patients across genders and across different age groups. Although this assumption has not been explicitly stated in any published study, it appears to have an axiomatic character since its validity has not been empirically tested. As a result of this implicit assumption, all fMRI studies discussed in this book neglected potential differences between male and female patients at the neural level, focusing instead on identifying the neuropathology shared by the genders. Interestingly, as discussed earlier, a comparable assumption of the shared underlying neuropathology across genders also informed Charcot's hysteria research.

The only segment of fMRI hysteria research in which the participant's age and gender were explicitly considered as potential nuisance factors during participant

142 "Since the group included both positive and negative motor symptoms, with about half experiencing non-epileptic seizures, it is likely that the disorder etiology differs between subjects." Morris et al., 293.

143 See, e.g., Perez et al., "State of the Field," 3–4, 102623.

144 Poldrack et al., "Guidelines for Reporting," 409.

145 See, e.g., Blakemore et al., "Aversive Stimuli," 231; de Lange, Roelofs, and Toni, "Self-Monitoring," 2053; and Espay et al., "Functional Tremor," 183.

146 See, e.g., Escobar et al., "Concurrent Somatic Symptoms," 2.

147 See, e.g., Espay et al., "Functional Tremor," 183; and Hassa et al., "Motor Control," 144.

selection are so-called between-subjects studies. In such studies, researchers recruit two distinct groups of participants—hysteria patients and healthy volunteers referred to as control subjects. In this type of study, researchers compute functional brain maps by contrasting the task-induced neural responses between these different groups of experimental subjects.[148] The inclusion criteria for control subjects are the lack of any serious medical, neurological or psychiatric illness. Control subjects are also specifically recruited to match the patients' number, age, and gender.[149] Thus, gender- and age-related differences between patients and controls are viewed as having potentially confounding effects on the comparison of neural responses between the groups and, therefore, explicitly controlled.

Although fMRI hysteria research has so far curiously circumvented addressing the role of the patients' gender, in most studies published by the end of 2019, the number of female patients was significantly higher than male patients.[150] This may seem irrelevant, given that the gender of experimental subjects is invisible in the visualisations of the resulting brain maps. Nevertheless, gender is implicitly inscribed into these images,[151] since most studies produced group-averaged brain maps that were predominantly female from a statistical point of view. This apparently unintentional inscription of gender can be viewed as problematic due to hysteria's long and often troubled history, during which it was conceived as a purely female disorder.[152] For this reason, the question that must be asked is if the current implicit linking of hysteria to the female gender is indeed purely accidental.

We could assume that the predominance of female patients in fMRI studies of hysteria within the first two decades of the twenty-first century merely reflected a higher incidence of this disorder among women. According to the current version of the *DSM*, conversion disorder "is two to three times more common in females."[153] The predominance of female patients in general medical settings may be taken to indicate that in some currently still unknown ways, women might be either biologically more predisposed or, perhaps, socio-culturally more conditioned than men to develop hysterical symptoms.[154] However, the predominance of female study participants in the neuroimaging research might also point to the medical community's tacit diagnostic bias or an implicit patient selection bias in the current fMRI research. Alternatively, it

148 Conversely, our case study is an example of the within-subject approach since de Lange, Roelofs, and Toni used a single group of patients and generated fMRI maps through comparisons within this group.

149 See, e.g., Aybek et al., "Life Events," 53.

150 See, e.g., Aybek et al., 54; Hassa et al., "Motor Control," 144; and Morris et al., "Avoidance," 290.

151 For incisive analyses of how gendered norms and the concepts of femininity and masculinity inform neuroimaging and neuroscientific research on the whole, see, e.g., Fine, *Testosterone Rex*; Rippon et al., "Sex/Gender Neuroimaging Research"; and Schmitz and Höppner, *Gendered Neurocultures*.

152 For a discussion of hysteria's troubled history as a female disorder, see, e.g., Showalter, "Hysteria, Feminism, and Gender," 286–336.

153 APA, *DSM-5*, 320.

154 Should this be the case, it is all the more reason why future fMRI studies should start exploring the role of such potential gender-related differences across hysteria patients.

is possible that female patients are more accepting of their diagnosis and thus more willing to participate in medical research.

All such considerations will remain purely speculative as long as fMRI studies of hysteria continue to avoid explicitly addressing the potential role of the patients' gender in the pathophysiology of hysterical symptoms. However, there are indications that this situation might change in the near future. Two perspective articles published in 2020 and 2021 have recommended that future fMRI studies should go beyond the presumably shared neural mechanism across genders that has so far been the focus of research and empirically explore the potential existence of gender-based neurophysiological differences between male and female hysteria patients.[155] Once such studies start appearing, it will be necessary to critically evaluate how they use image-based findings to differentially frame the role of the patients' gender in the development of hysterical symptoms.

One final aspect of participant selection that we need to examine is its relation to traumatic life events, which Freud had famously declared to be the cause of hysteria. Until the revision of the *DSM* in 2013, psychological factors, even if no longer causally linked to hysteria, were nevertheless seen as having a potential contributing role and thus included in the official diagnostic criteria.[156] Therefore, like most fMRI studies published before 2013, de Lange, Roelofs, and Toni duly listed the traumatic events that had been diagnosed in each of their patients. Even a mere glance at this list reveals how diverse the individual events were, ranging from a school exam, over a family conflict, to the death of a partner.[157] Yet, the researchers disregarded the possibility that such diverse psychological factors could have introduced unwanted variability into their experiment. Instead, their selection strategy placed a strict focus on the patients' physical symptom of arm paralysis. Hence, de Lange, Roelofs, and Toni apparently did not consider the individual traumatic events experienced by their patients to have any epistemic relevance for the particular research questions they chose to address in the study. The list of adverse life events they included in their study thus seems to have been a mere formal nod to the diagnostic criteria valid at the time.

But, perhaps more surprisingly, even in the rare fMRI studies that have explicitly addressed the potentially causative role of traumatic life events in conversion disorder, the patient selection was informed by criteria comparable to those used by de Lange, Roelofs, and Toni.[158] Specifically, even in such studies, patients were not selected for the similarity of their stressful experiences. Instead, the selection of patients was based on the compatibility of their physical symptoms. Moreover, following the deletion of psychological factors as diagnostic criteria from the current version of the *DSM*, the information regarding personal traumatic events stopped being listed in the patients'

155 See Drane et al., "Framework," 6; and Perez et al., "State of the Field," 11, article102623.

156 See chapter 2 for a detailed discussion of this topic.

157 De Lange, Roelofs, and Toni, "Self-Monitoring," 2053.

158 Only two studies have focused explicitly on examining neuro-cognitive effects induced through hysteria patients' recall of specific adverse life events. See Aybek et al., "Life Events"; and Kanaan et al., "Repressed Memories." I will analyse these studies in detail in section 4.3.1.

demographic characteristics.[159] As a result, it can be said that fMRI studies within the first two decades of the twenty-first century have placed the hysteria patient into a decidedly somatic framework. Not only have these studies aimed to determine a neurophysiological basis of hysteria, but they have also judged the patients' adequacy as a potential study participant by focusing exclusively on their quantifiable physical symptoms. Notably, both aspects of this purely somatic framing of the present-day hysteria patient as an experimental subject are curiously reminiscent of how Charcot had approached his patients more than a century earlier.[160]

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To summarise, my analysis has shown that, on the whole, the inclusion in an fMRI study has tended to strip hysteria patients of the messy multisymptomatic materiality of their disease while also detaching them from individual life events that might have given rise to their symptoms. To speak with Latour,[161] the transformation of hysteria patients into experimental subjects in the first two decades of the twenty-first century has entailed the amplification of those aspects of their disorder that were judged to have a shared neural basis and could thus be addressed adequately by the fMRI measurement. At the same time, the patient selection has also involved the reduction of the idiosyncratic features that might have had the potential to skew the results by introducing unwanted variability into the imaging data. I thus argue that from the perspective of an fMRI experimental setup, hysteria patients are viewed as contingent variables. In other words, hysteria patients are treated as products of chance that need to be disciplined through sampling to meet the technological requirements of fMRI. Through such disciplining that underpins the inclusion into an fMRI study, each hysteria patient becomes part of the chain of transformations on whose consistency the meaning of the resulting functional brain maps hinges. Hence, we have seen that the participant selection, together with the choice of the experimental task and the conditions of its implementation, play crucial roles in making the hysterical symptom measurable through fMRI.

3.2 Measurement: Translating the Active Brain into Imaging Data

Having recruited the experimental subjects and programmed the task implementation, researchers can finally start to collect imaging data by scanning each subject's brain separately. For this purpose, the subject enters the scanner room and lays face upwards on the machine's moveable table.[162] Here, she receives earplugs and headphones to

159 See, e.g., Espay et al., "Functional Tremor," 183; and Hassa et al., "Motor Control," 144.

160 For a discussion of Charcot's somatic framing of his patients' emotional states and memories of traumatic experiences, see, in particular, sections 1.1.3, 1.2.2, and 1.3.2.

161 Latour, *Pandora's Hope*, 70–71.

162 The following description is based on my experience of participating as a healthy control subject in 2012 in two fMRI studies conducted at the Charité Campus Mitte Berlin. Moreover, on multiple occasions in 2014 and 2015, I sat with researchers in a control room of the fMRI scanning facility at the Department of Psychiatry and Psychotherapy, Charité Campus Mitte Berlin, while they were