

# Functional Anatomy of the Sense of Agency: Past Evidence and Future Directions

## 4

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### 4.1

#### Introduction

Until the past decade, the sense of agency received very little attention in the field of cognitive neuroscience, despite its relevance to a variety of psychiatric and neurological syndromes associated with abnormalities in the awareness of actions [1]. Yet, compared to other areas of interest in the fields of cognitive and social cognitive neuroscience, the number of studies that have recently investigated or are currently investigating the brain basis of agency can still be considered as minor to moderate. One reason may be that the sense of agency is a topic often left to philosophers and clinicians rather than empiricists; another reason may lie in the complex, multifaceted, and often ill-defined nature of the sense of agency. Nonetheless, advancing methodologies in cognitive neuroscience and conceptual refinements of the sense of agency along with the emergence of interdisciplinary fields such as neurophilosophy have opened up new, intriguing possibilities for investigating the brain basis of agency experience.

The cognitive neuroscience approach to the sense of agency understands agency as an operationalizable construct that can be broken down into paradigms amenable to neuroscience techniques, such as functional magnetic resonance imaging (fMRI), positron emission tomography (PET), electro- or magnetoencephalography (EEG or MEG), and transcranial magnetic stimulation (TMS). On a general note, research strategies in cognitive neuroscience may be manifold. First, a researcher may focus on a given brain region X and investigate whether it subserves a process Y. Compared to this more *a priori* approach, a researcher may instead focus on a process Y and, in a more exploratory manner, investigate the network of brain regions associated with

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it. In addition, a researcher may look for “loci,” that is, brain regions activated during a given cognitive process (e.g., the medial temporal lobe is implicated in memory encoding), or mechanisms (e.g., how do medial temporal neurons encode new information?). However, the afore-mentioned cognitive neuroscience techniques are not equally suitable to meet the research needs posed by these different strategies; for example, fMRI is particularly—but certainly not exclusively—advantageous for addressing questions about loci, unlike EEG, which is valuable for the examination of neural mechanisms.

This chapter reviews present neuroimaging studies in the field of agency, focusing on functional anatomy. In what follows, it will become clear that the picture of the sense of agency compiled by cognitive neuroscience studies remains heterogeneous and inconclusive. The multifaceted and multilevel nature of the sense of agency may explain this heterogeneity, but it may also be due to the theoretical conceptions of the sense of agency offered by the researchers who designed these studies. It should be kept in mind that theories determine hypotheses, which determine paradigms or operationalizations, which in turn influence results. Thus, operationalizations of agency can be very diverse (Table 4.1): from manipulating the sensory feedback to a subject’s movement, abolishing the sensation of self-agency and often leading to attribution of the action to another agent, to judging the onset of voluntary and involuntary movements and their sensory consequences [2].

## 4.2

### A Functional Anatomy of the Sense of Agency: Past Evidence

Functional MRI or, in the earlier days, PET studies have associated a list of brain regions with the sense of agency, namely, the inferior parietal lobe (IPL) or posterior parietal cortex (PPC) [3–8], the cerebellum [9, 10], the posterior superior temporal sulcus (pSTS) [11, 12], the insula [3, 5], dorsolateral and ventrolateral prefrontal cortex [8, 13], as well as the supplementary motor area (SMA) [14, 15] (Fig. 4.1a).

Critical voices may consider this a rather long list of brain regions compared to the more circumscribed neural networks associated with other cognitive processes, such as episodic memory (which mainly involves medial temporal structures). However, the complex phenomenon of agency is likely to rely on lower-level sensorimotor as well as higher-level phenomenal processes [16]. To elucidate the exact functions and the specificity of each implicated region for the sense of agency, a closer inspection of the present data, especially in the context of employed tasks, seems helpful (Table 4.1) as it reveals that some brain regions have more consistently been associated with the sense of agency than others, for example, the parietal cortex and the cerebellum (Table 4.1, Fig. 4.1b). In the following, the specific contributions and possible groupings of agency-associated brain regions, displayed in Fig. 4.1, are discussed.