

CHAPTER THREE

SENSORY-MOTOR REPRESENTATIONS OF TIME, THE OUTPUTS OF THE CLOCKS AND THE TWO CONSTRAINTS ON MOTOR TIME COORDINATION

In the previous chapter, I categorized timing mechanisms into periodic and interval clocks. I explained why the circadian clock is a reliable periodic clock and why the stopwatch is a reliable interval clock. In this chapter, I address questions concerning the representational outputs of these clocks, e.g., what criteria they must satisfy to be considered representations, what kind of representations are they and what kind of information they contain? I answer these questions with a philosophical proposal concerning temporal sensory-motor representation, paying close attention to the experimental evidence.

I explained how the evidence on the anticipatory behavior of bees and hummingbirds for specific odors and flower replenishing rates satisfies the criterion that, according to Burge (2010), any legitimate mental representation must satisfy: representations produced by the clocks must attribute temporal sensitivities to environmental particulars at the organism level. These are not linguistic or conceptual representations. How, then, should we characterize the representations that are the outputs of the clocks?

A very important property of the outputs of the clocks is that they are representations with *metric* structure. In this chapter, I define metric structure and explain how such structure allows for the cognitive integration of the outputs of the clocks with other metrically structured representations. Understanding how this type of metrically structured cognitive integration occurs is fundamental to appreciate the important role that the clocks play within the sensory-motor system. I argue that circadian and stopwatch clocks are two independent systems for temporal representation whose outputs are crucial for motor coordination and action.

The structure of this chapter is as follows. Section 3.1. is an assessment of issues of representation and isomorphism. I explain why the temporal representations of the circadian clock and the stopwatch need to be understood in terms of isomorphism, and describe the different properties of the isomorphic representations of periods and intervals. This isomorphism allows animals and humans to rely upon the two constraints

for accurate time measurements, based on the reliability of the clocks, as constraints on successful and precise motor coordination.

In section 3.2., I focus on considerations concerning the structure of these outputs, and I argue that the structure that frames these representations is metric, i.e., it preserves information about magnitudes. I review the relevant experimental evidence on the metric structure of the outputs of the clocks and discuss it in two subsections, one of them devoted to the circadian clock and the other to the stopwatch. I then explain the importance of the metric features of these representations, such as their relation to Weber's law.

Finally, in section 3.3., I argue that the best way to account for the metric structure of the outputs of the clocks and their isomorphism with respect to periods and intervals is by characterizing these outputs as *analog* representations. I present five criteria for defining analog representation and demonstrate that the outputs of the clocks satisfy all these criteria. Indeed, this section shows that the outputs of the clocks are *paradigmatic* cases of analog representation.

3.1. REPRESENTATION AND ISOMORPHISM

John Heil (2005) says that 'disposition' "is a term of art: you can define dispositions as you please."¹ I believe that the same is true about the term 'representation.' Heil also says, however, that some ways of defining a term are more felicitous than others. Felicitousness depends ultimately on capturing the specifics of a particular case. Defining artistic or scientific representations poses specific challenges that are very different from the challenges one faces in defining mental representations. But even if one focuses exclusively on mental representations, there are different types of representations that generate their own definitional challenges.

The best way to capture the specific characteristics of the representations that I analyze in this chapter, namely the representations of time produced by the circadian clock and the stopwatch, is by taking what J. L. Bermúdez (2003) calls a *minimalist approach* to nonlinguistic thought. Taking a minimalist approach is important because the sensory-motor representations of time produced by these clocks are best described as measurements, or representations with metric structure. It would be inappropriate to characterize these representations in terms of language

¹ J. Heil (2005), p. 343.