

Consciousness as the Emergent Property of the Interaction Between Brain, Body, and Environment

Implications for Robot-Enhanced Neuromotor Rehabilitation

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Abstract. Neuromotor rehabilitation, typically seen with stroke patients, is usually mistakenly focused on the recovery of movements while disregarding the insufficient or missing awareness of the affected part of the body. Thus, the functional recovery of sensorimotor abilities is fundamentally a problem of consciousness. The paper addresses the implications of this concept in the design of optimal robot-assistance in the training of patients, according to the assumption that consciousness is the emergent property of the interaction between brain, body, and environment. Optimal assistance is formulated as a process that follows three basic guidelines: (1) limitation of the assistance level to the minimum value capable of allowing patients to initiate the movements; (2) trial-to-trial reduction of assistance in order to promote the emergence of voluntary control; (3) nonmonotonic modulation from session to session in order to promote memory consolidation.

Keywords: consciousness, stroke, rehabilitation, robotics

Consciousness as an Emergent Property of Action

That consciousness cannot be a purely mental phenomenon has become the common wisdom in recent years among roboticists, neuroscientists, and a new wave of philosophers. The idea, concisely and effectively formulated by Chiel and Beer (1997), is that “the brain has a body.” Moreover, the “body” interacts continuously with the “environment” in a bidirectional manner, which means that even the most abstract cognitive processes are formed and informed by the physical processes going on in the real world (Figure 1).

The intimate relationship between the brain and the body and the importance of this relationship for the maintenance of the sense of self is evident in different pathological conditions, such as the phantom limb syndrome, in which the brain is *orphan* to a part of the body. There is an elaborate folklore surrounding it. For example, Admiral Nelson, who

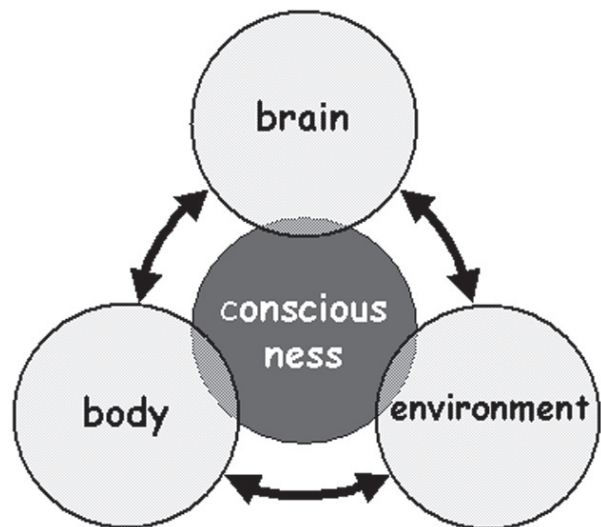


Figure 1. Consciousness as the emergent property of the bidirectional interaction of brain, body, and environment.