

An Enactive Approach to Artificial Hand

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Abstract—Neuroprosthetics aims at restoring two essential components of the hand: both active manipulation and sensory feedback. In the last decade, several studies investigated the frontiers of neural elicitation of tactile sensation as a potentially helpful way to control the prosthesis. This finding is significant for the understanding of how biomedical engineering is impacting on/reshaping the concepts the concepts of experience and sensation. This contribution proposes an enactivist approach to elaborate a new pathway of understanding the experience mediated by neuroprosthesis.

Keywords—Enactivism, Technology of sensitivity, Hand Prosthesis.

I. INTRODUCTION

The introduction of sensory feedback in upper limb prostheses is one of the primary goals achieved, in recent years, in the manufacturing of artificial hand [e.g.,1]. On the one hand, the achievement highlights the close connection between neuroscience and robotics; on the other hand, it brings out the tendency to implement sensation, understood as a phenomenological dimension of experience, within technological devices. In this sense, in line with Montani [2], it seems reasonable to hypothesize the future as increasingly centered on the “technologies of sensitivity”. The concept of “technologies of sensitivity” implies an explicit paradoxical clash between technology, allegedly based on a neuroscientific reductionist inspiration, and sensitivity (aisthesis), as a subjective sphere identifiable as a prerogative of the human being. The present contribution aims at considering such oxymoron moving from the assumption that qualitative states have a phenomenological dimension that is difficult to reduce entirely to neurophysiological states [3,4,5]. Assuming that it is impossible to ultimately reduce sensation to neuroscientific principles, yet acknowledging a neuronal basis for sensation, it emerges the need to build an integrated vision capable of taking into account the irreducible duality of feeling, understood both as based on neural elicitation and as a phenomenological dimension of experience. To solve this issue, this contribution proposes enactivism as a fruitful conceptual tool to define new perspectives on bio-inspired robotics.

I will organize the paper as follows: in section 2, I will describe the close connection between neuroscience and robotics, highlighting the issues related to a reductionist paradigm in the case of sensation. In section 3, I will introduce the principles of the enactivist theory. Finally, section 4 will highlight the theoretical and practical benefits of introducing enactivism [6] for the case of upper limb prostheses.

II. THE NEUROSCIENTIFIC APPROACH TO ROBOTICS

As [7] affirms, there is a strong connection between robotics and neuroscience because roboticists “have looked at neuroscience for more than half a century as source of

inspiration” [7]. Specifically, this is a consequence of the assumption that both mind and body are machines [8] explicable according to a single quantitative paradigm [9]. In this view, all the qualitative states, such as tactile sensation, are entirely reducible to electrical stimuli [10].

In particular, in the case of current active upper limb prostheses, tactile feedback is re-created via two different approaches: vibrotactile substitution and neural interface [11,12]. The vibrotactile substitution is a less invasive method, which consists in applying a series of vibrotactile motors on the skin in proximity of the stump. On the contrary, a neural interface is an invasive approach that involves implanted electrodes in the muscles and nerves as insertion point for an external electrical stimulus.

Although it is indisputable a brain base for sensation, many researchers doubt the possibility of a complete scientific explanation of the qualitative dimension of experience [4,13,14, 15]. In line with [4] and partially with [3,5], I will argue that the physicalist model of description of the experience that reduces the complexity of perception into brain activity is unable to take into account essential aspects, such as

- the interaction with the environment which substantially modifies not only our experience but also our brain,
- The problem of the first-person experience that the scientific perspective does not fully address.

III. THE ENACTIVISM

In line with Fuchs [3], I consider enactivism to be an opposing but complementary position to neuroscience. It is a new theoretical framework that overcomes the classical view of cognitive science by introducing the phenomenological perspective. Varela, Thompson and Rosch argue in favor of a new understanding of cognition which is “is not the representation of a pregiven world by a pregiven mind but is rather the enactment of a world and a mind.” [6]

The enactivism also underlines the bodily root of cognition, emphasizing that “sensory and motor processes, perception and action, are fundamentally inseparable in lived cognition.” [6]

IV. AN ENACTIVE APPROACH TO NEUROPROSTHESIS

Enactivism sheds new light mainly on two issues concerning active prostheses:

1. the role of sensation;
2. the difference between sensations obtained through sensory substitution and neural implants.

In particular, the new perspective is produced from two theoretical innovations: an active characterization of perception, which, contrary to what neuroscientific theories

claim, becomes "something we do" [16] and the conceptualization of sensation as an "enactment" that occurs between the subject and the world.

Concerning the first issue, sensation represents, from the phenomenological point of view, a qualitative structure that needs to be rigorously analyzed. Despite the neural derivation, the enactive perspective emphasizes the active dimension of sensation, which develops in relation to the world.

This conception does not mean to relegate sensation to something external from the body but rather to conceive a relational structure of co-dependence between the body and the world. This provides a new theoretical background for experimental results, which prove that sensation is paramount for action [17].

In addition, enactivism is also able to take into account the difference between qualities, subjectively experiences, and between the sensation elicited through sensory substitution and the feedback recreated through neural implants.

Indeed, enactive theories are able to fully account the difference between kinds of touch, as, for example, softness versus hardness or between squeezing a sponge and squeezing a tennis ball [18,19]. According to [18], the difference cannot be traced back to a brain mechanism, but it is analyzable from the enactive point of view.

In a specular way, according to enactivism, it is possible to address the difference between sensory substitution and neural implant. Literature [e.g., 12] refers that the neural implant provides a more natural feedback. This difference can be investigated through the concept of embodiment. The prosthetic body assumes the technological device [20,21,22], implanted in close contact with the body, to mediate perception from a proximal point of view.

The different feedbacks are related to the body mediation and the sensors' different positioning, on the body or in the nerve, because the physical positioning produces a different kind of embodiment. For example, as Helena De Preester points out, prostheses with sensory feedback can be viewed as an extension of sensibility according to the category of incorporation of an object into the user's body [23].

Therefore, introducing the enactive perspective determines a reversal in the guiding principle of neurorobotic research that should: 1. focus on sensation as a principal element and dexterity as a trait derived from the feeling dimension; 2. consider the prosthesis as an incorporated object, which becomes part of the living body.

V. CONCLUSION

This study set out to gain a better understanding of artificial sensations recreated by the neuroprosthesis. In particular, the findings have shown the importance of a new theoretical framework, the enactivism, in order to encompass the problem of neuroscientific explanation.

This study's theoretical evidence suggests the possibility to develop an enactivist approach able to address a fine-grained analysis of the neuroprosthetic experience, which can deepen the first-person account of sensation and the

difference between vibrotactile substitution and neural implant.

The question raised by this study is limited to the theoretical aspects of a new paradigm; further research should explore the feasibility of this approach in real experimental settings. In particular, it is necessary to deepen the complementarity, in the analysis of technological-mediated experience, of a quantitative third-person neuroscientific approach and the qualitative first-person phenomenological point of view.

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