Chapter 79
Can We Induce a Cognitive Representation of a Prosthetic Arm by Means of Crossmodal Stimuli?

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ABSTRACT

The ownership feeling of our body occurs mainly due to feedback responses in real-time from environment stimuli to our own body. These constant feedbacks induce a neuronal arrangement, generating a representative map and, consequently, an ownership and unity feeling, named as a body schema. Although there is a relative well knowing of the sensorial mapping about each part of our body, there are still several gaps about how the integration of all this representation is indeed accomplished. Many researchers have shown high rates of prosthesis non-acceptance due to different reasons. Here, the authors discuss an experimental protocol to induce optimally the ownership feeling associated with upper limb prosthesis, by means of a crossmodal vibro-tactile stimulation over the individual's body. The main hypothesis is that through this procedure the participant will extend their proprioception and achieve an ownership feeling of the prosthesis.

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INTRODUCTION

The development of prosthetics and orthotics are directly related to advances of micro-electronics, materials and automation engineering. All new devices have been using different technologies in order to expand functionality and improve the integration with the human body. However, some studies show that, despite of all these efforts, the actual prosthesis present high rates of non-acceptance. Statistical data indicate that this ratio may reach 70% of users. These users leave or use their prosthesis only sporadically along day life (Ostlie et al., 2012; Biddis & Chau, 2007). Among the main factors that justify these high rate of non-acceptance are: economic, because of the high costs; biological, due to uncomfort; function, due to the restrictions of movements and degree of freedom, when compared with the original limbs and; finally, psychological factors (Lisa et al., 2007; Ostlie et al., 2011). One of the most important psychological factors is the perception that the user has on the appearance of the prosthetic and also the lack of ownership feeling. That is, the user does not feel the prosthesis belonging to its own body, but as something which needs to be carried out, as burden. Despite the neural plasticity introduced by physiotherapy, training and by the natural adaptation, the subjects cannot cognitively represent the prosthesis in its totality; most probably because a new representation[1] depends on an adequate body interaction to its new object (Stephen, 1985; Ehrsson et al., 2008; Graziano & Botvinick, 2002).

The ownership feeling occurs mainly because of the real-time sensory responses from our own body – by external tactile and visual stimulus, especially. These constant feedbacks induce not only an effective neuronal arrangement, but also a representative mapping and, consequently, an ownership and unity feeling, say a body schema (Dhillon & Horch, 2005; Maravita & Iriki, 2004). Although these premises are necessary, the exact process under the neural-cognitive integration under the ownership feelings, regarding an external object, like some tool, is far to be totally understood. In spite of the relative well knowing about the sensorial mapping considering each part of our body and its correspondent senses, there are still several gaps in the way the integration of all these representations is accomplished. One of these gaps concerns how the brain maps spatial occupation and planning of our body movements (Vignemont, 2013; Kwok, 2013). Under these key aspects relies our prospective notion, or our predictive ability of future events. And, in a similar way of our memory working, our future prediction capacity, or prospective inference, is fundamentally relevant to construct our body schema (Luinge & Veltink, 2005; Hoffman et al., 2010).

Recently, different researches proposed tactile protocols to induce or optimize the sensation of ownership of a prosthetic arm. Most of these protocols are based on the classical Rubber Hand Illusion concept. In this illusion it is made a crossing tactile and visual stimulus, at the same time, on the artificial rubber hand and on the hidden real volunteer's hand, that promotes a sort of ownership feeling of the artificial rubber limb. With a correct tactile and visual stimulus the individual starts to consider the fake rubber hand as part of his/her body, and may even report pain (or some discomfort) when the rubber hand suffers some injuries (Luinge & Veltink, 2005; Hoffman et al., 2010; Kuiken et al., 2004; Marasco et al., 2011; Beeker et al., 1967).

Based on these experiments, here, the authors discuss a new multi-task protocol designed to improve the ownership feeling of an artificial limb. They propose a cross modal mapping which intends to transduce a set of predefined movements into a pattern of vibro-tactile stimuli, on different parts of the subject's body. In this context, this experimental procedure seeks to evaluate how strong and effective might be a cognitive representation of an artificial robotic arm induced by a simultaneous vibro-tactile stimulation with a predefined arm movement (Kim et al., 2010; Gohil et al., 2013; Tsakiris et al., 2007;