New Ideas in Psychology 50 (2018) 1–5

Contents lists available at ScienceDirect

New Ideas in Psychology

journal homepage: www.elsevier.com/locate/newideapsych

Is mediated embodiment the response to embodied cognition?

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A R T I C L E I N F O

Keywords:
Mediated embodiment
Embodied cognition
Embodiment
Avatar
Virtual reality
Robots

A B S T R A C T

Emerging technologies such as virtual reality and robots are evolving to increasingly integrate the user into the interface. During this temporary merge, users experience a digital or a robotic body of an avatar as their own. Embodied cognition sustains that the body and its interactions with the environment play an important role in cognition. I argue that the adoption of mediated embodiment technologies to explore cognitive development might substantially contribute to demonstrating the postulates of embodied cognition.

1. Mediated embodiment: a non-human body to be in the world

There is an increasing tendency in emerging technologies to progressively immerse and couple the human body to the interface (Biocca, 1997). Avatar embodiment in virtual reality and humanoid robot embodiment are the most representative forms of this phenomenon, which can be described as mediated embodiment. Similar concepts have been used to describe related phenomena (Biocca, 1997, 2002; Kilteni, Groten, & Slater, 2012; Lee, 2004; Ratan, 2010), but a more global definition is missing which includes all current and future embodiment technologies and conceptualizes these systems as a whole. As a working definition, mediated embodiment is introduced here as the technologically induced illusion of experiencing the body of an avatar as one's own, independently of the technology used to produce the illusion (Aymerich-Franch, 2017). Embodiment indicates the existence in the world through a body (Csordas, 1999, pp. 143–162), while the adjective mediated is related to the use of communication technologies. In mediated embodiment, users adopt an artificial body of a digital or a robot avatar from which they experience the virtual or physical environment in first person. The artificial body can be similar or drastically different from the human body (Aymerich-Franch, 2012) and it can even be non-physical (i.e., virtual).

The central claim of embodied cognition is that cognition is highly dependent on the characteristics of the physical body and its interactions with the world (Shapiro, 2004, 2007, 2010; Lakoff & Johnson, 1999; Seitz, 2000; Thelen & Smith, 1994; Thelen, 1995; Thelen, Schöner, Scheier, & Smith, 2001; Wilson & Foglia, 2011; Wilson, 2002). According to this view, the particular form of embodiment (i.e., the characteristics of the body) of an organism and its sensory-motor capacities determine the way the environment appears to that organism as well as the way in which the organism can interact in it (Lakoff & Johnson, 1999; Varela, Thompson, & Rosch, 1991; Wilson & Foglia, 2011). From these premises, it follows that, *if an organism of body structure type-A embodies a body with substantially different body properties (i.e., body structure type-B), significant differences should emerge both at the low and high cognitive levels compared to an original organism of body structure type-A*.

An important drawback to test this postulate is that, under normal circumstances, organisms cannot "abandon" their bodies to embody a different body. However, in a successful mediated embodiment experience, users feel their sense of self located within the boundaries of their avatar body and experience it as if it was their own (Ehrsson, 2007; Kilteni, Maselli, Kording, & Slater, 2015; Lenggenhager, Tadi, Metzinger, & Blanke, 2007; Petkova & Ehrsson, 2008; Slater, Spanlang, Sanchez-Vives, & Blanke, 2010). The transformations that take place during these experiences at the cognitive processing level (Ahn, Le, & Bailenson, 2013; Aymerich-Franch, Kizilcec, & Bailenson, 2014; Groom, Bailenson, & Nass, 2009; Hershfield et al., 2011; Kilteni, Bergstrom, & Slater, 2013; Maister, Slater, Sanchez-Vives, & Tsakiris, 2014; Rosenberg, Baughman, & Bailenson, 2013; Steptoe, Steed, & Slater, 2013; Won, Bailenson, Lee, & Lanier, 2015; Yee & Bailenson, 2007) could reveal to what extent the specific properties of the body determine cognition. Following this, *if a human being (i.e., organism of body structure type-A) embodies an avatar of substantially different body properties (i.e., body structure type-B) and interacts in the environment with that body, significant differences should emerge both at the low and high cognitive level compared to a regular human that interacts in the same environment.*

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https://doi.org/10.1016/j.newideapsych.2018.02.003
Received 17 February 2018; Accepted 23 February 2018

Fig. 1. Mediated embodiment process. Users wear a head-mounted display (A) which provides first-person audiovisual perspective from the avatar body and blocks vision from the physical world. Users embody an avatar in virtual reality (B) or in a physical environment (C) and experience its body and its surroundings in first person. Avatars can also be non-anthropomorphic living beings or objects (D).

2. The technologically created experience of "becoming someone else"

First-person perspective is a fundamental requirement to induce sense of embodiment in an avatar (González-Franco, Pérez-Marcos, Spanlang, & Slater, 2010, pp. 111–114; Maselli & Slater, 2013; Slater et al., 2010). Head-mounted displays (HMDs) are used to provide visual feedback from the avatar's eyes and occlude participant's vision from the real world (Fig. 1A). In virtual reality, HMDs display the virtual environment whereas in robot embodiment the HMD displays real time video feedback from the robot's eyes. Head movements of the embodied user are tracked and synchronized to those of the avatar to offer real time visual feedback of the avatar surroundings in accordance to those movements. Control of the avatar body movement can be achieved in multiple ways (Fig. 2), such as body motion tracking and synchronization, brain-computer interface, eye-tracking, or a joystick (Aymerich-Franch, Petit, Ganesh, & Kheddar, 2016, 2017a,b; Alimardani, Nishio, & Ishiguro, 2013; Cohen et al., 2014, 2012; Kishore et al., 2014; Nishio, Watanabe, Ogawa, & Ishiguro, 2012). Auditory feedback is implemented with the use of headsets or speakers and haptic feedback can be implemented with the aid of different sort of haptic devices that facilitate grasping and moving objects, experiencing a texture, or receiving force feedback (Fox, Arena, & Bailenson, 2009; Stone, 2001).

Avatars can be digital (virtual reality) or physical (robots). They can present human-looking appearances (Fig. 1B), non-human looking appearances (Fig. 1C), or even have non-anthropomorphic shapes (Fig. 1D). In order to create identification with the avatar's body, users are able to see its limbs (if they have any) and part of its body when they look down. Full-body identification is obtained with the use of reflecting surfaces such as mirrors (Aymerich-Franch et al., 2016; Aymerich-Franch et al., 2014; González-Franco et al., 2010, pp. 111–114). Table 1 synthetizes the technical commonalities used by mediated embodiment systems to create the sense of embodiment.

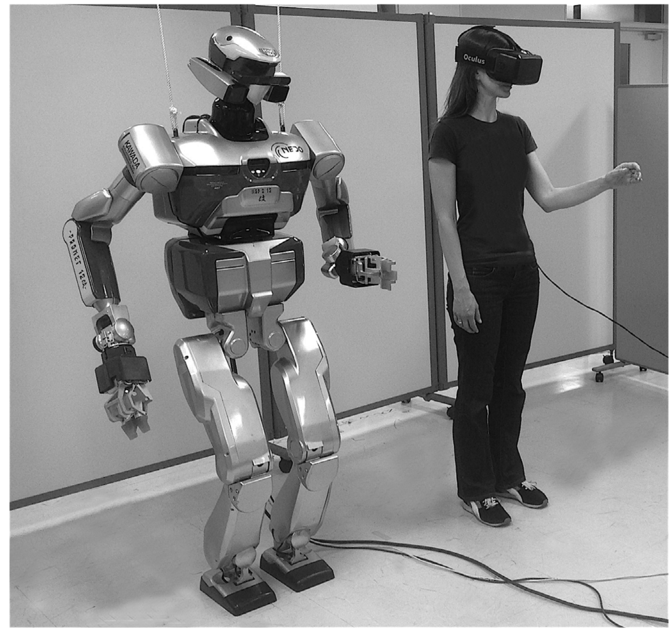

Fig. 2. Example of embodiment setup. An embodied user (right) wears a head-mounted display that provides visual feedback from the avatar (left) perspective and blocks vision from the physical environment. The user's head and body movements are synchronized to those of the avatar. The user can interact in the environment through the body of the avatar.

Table 1
Technical commonalities used by mediated embodiment systems to create the sense of embodiment.

Sensory feedback
•**Visual**: First-person perspective is the most fundamental requirement to induce the illusion of embodiment. Head-mounted displays (HMDs) provide visual feedback from the avatar's eyes in real time and occlude participant's vision from the real world. •**Auditory**: Audio feedback is implemented with the use of headsets or speakers. •**Haptics**: Haptic feedback can be implemented with haptic devices to grasp and move objects, experience a texture, or receive force feedback.
Agency
•**Head movement**: Head movements are synchronized to those of the avatar. •**Body control**: Control of the avatar body can be achieved in multiple ways (i.e., body movement tracking and sycnhornization, brain-computer interface, fMRI, eye-tracking, joystick…).

3. Empirical evidence of full-body ownership transfer in artificial embodiment

The rubber-hand illusion experiment (Botvinick & Cohen, 1998) has been largely used to demonstrate that humans are able to experience body ownership of an artificial limb. As an extension of this paradigm, full-body ownership illusions involving virtual and fake bodies have been used to show that sense of body ownership may also be transferred towards a full body (Maselli & Slater, 2014; Petkova & Ehrsson, 2008; Slater et al., 2010). Beyond that, full-body ownership illusions have recently been proposed as a paradigm to study self-consciousness and, specifically, as a way to demonstrate that the spatial unity between self and body can be disrupted (Ehrsson, 2007; Guterstam & Ehrsson, 2012; Lenggenhager et al., 2007). Studies following this paradigm suggest that multisensory correlations altogether with a manipulated visual perspective are enough to transfer the perceived sense of self-location to an illusory body (Ehrsson, 2007; Guterstam & Ehrsson, 2012; Lenggenhager et al., 2007).

During mediated embodiment experiences, users feel present in the