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When Does Virtual Embodiment Change Our Minds?

Abstract

Can an avatar's body movements change a person's perception of good and bad? We discuss virtual embodiment according to theories of embodied cognition (EC), and afferent and sensorimotor correspondences. We present an example study using virtual reality (VR) to test EC theory, testing the effect of altered virtual embodiment on perception. Participants either controlled an avatar whose arm movements were similar to their own or reflected the mirror opposite of their arm movements. We measured their associations of "good" and "bad" with the left and right (i.e., space-valence associations). This study demonstrated how VR could be used to examine the possible ways that systems of the body (e.g., visual, motor) may interact to influence cognition. The implications of this research suggest that visual feedback alone is not enough to alter space-valence associations. Multiple sensory experiences of media (i.e., sensorimotor feedback) may be necessary to influence cognition, not simply visual feedback.

1 Introduction

From being swept away by characters in a book, or feeling heart palpitations while playing a first-person shooter videogame, users' minds and bodies connect with mediated environments. Media-technology provides users with dynamic interactive experiences. An embodied cognition (EC) framework may explain why humans get absorbed in mediated experiences in sensory (e.g., visual feedback on a screen) and nonsensory environments (e.g., text in a physical book). According to an EC approach, cognition is grounded in the body and in the body's relationship to the environment. Mental representations are stored through a multimodal system (various systems of the body) that integrates memory, perception (e.g., vision), action (e.g., movement), and introspection (e.g., emotion; Barsalou, 2008, 2010).

Humans spend substantial portions of their day navigating highly interactive media environments. The capabilities of new media-technology allow for greater mapping of interfaces to human body movements. For example, using a home video game console system is no longer a static experience involving abstract motions (i.e., a button press) that simulate movement in a virtual environment. Instead, game play can reflect the user's body movements in real time with controls that capture the player's body movements. Phone and tablet interfaces have become more user friendly by employing direct motions for control, such as a simple flick of the wrist, or the swipe of a few fingertips. Integrating interface

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control into the body not only provides ease, but also could have psychological effects on the user's experience. Research studies show that more natural mapping in video games can increase users' psychological presence in and enjoyment of the virtual game (Kim & Sundar, 2013; McGloin & Farrar, 2011; Schmierbach, Limperos, & Woolley, 2012; Skalski, Tamborini, Shelton, Buncher, & Lindmark, 2011; Tamborini & Bowman, 2010).

Leveraging virtual embodiment, immersive virtual reality technologies provide unique opportunities to empirically explore EC theory (Banakou, Groten, & Slater, 2013; Maister, Slater, Sanchez-Vives, & Tsakiris, 2015; Romano, Llobera, & Blanke, 2016; Schubert, Friedmann, & Regenbrecht, 1999). Users map their body schema onto the affordances of their virtual bodies and consider them to be extensions of the self, creating an embodiment illusion (Biocca, 1997; IJsselsteijn, de Kort, & Haans, 2006; Lenggenhager et al., 2007; Petkova & Ehrsson, 2008; Slater, Perez-Marcos, Ehrsson, & Sanchez-Vives, 2009; Slater, Spanlang, Sanchez-Vives, & Blanke, 2010). Through immersive virtual reality, users can interact with an environment in ways that are unusual or impossible in the physical world. Imagine, as a human, controlling an avatar with a tail (Steptoe, Steed, & Slater, 2013) or having the capability of three arms to complete a task (Won, Bailenson, Lee, & Lanier, 2015), and then imagine how these experiences could impact your perception and view of the outside world.

Given the development of interfaces with natural physical mapping, and the connections people form with their digital representations, how can the movements of an avatar alter how people think, feel, and act in their own bodies outside of the virtual environment? This article describes how mental representations of mediated interactions may be rooted in the body, and presents some of the psychophysiological effects of virtual embodiment on users' behaviors and attitudes. An example of experimental research with immersive virtual reality is presented to illustrate how to utilize VR to test EC theory. The study examines the influence of virtual embodiment on perception, specifically associations of "good" and "bad" with the left and right. Finally, we discuss what the study results could mean for virtual embodiment and interface design.

2 Embodied Cognition Framework

Embodied cognition defines cognition as an interaction between the mind and the body's systems. People generate mental representations through physical simulations, situated action, and bodily states (Barsalou, 2008, 2010). Grounded cognition and learning can occur at various levels of mental processing, taking into account abstract internal representations (Barsalou, 2008, 2010; Wilson, 2002).

Simulation refers to the process in which the brain captures information across the body's modalities (e.g., sight, sound) and integrates all the representations to be stored in memory. When a person thinks about an experience or an idea, the brain reenacts all the perceptual motor and introspective states that were stored during the time the body and the mind interacted with the physical world (Barsalou, 2008, 2010). For example, an experience happens, such as petting a cat, and the brain captures it into a multimodal representation; how the cat looks and feels, the action of petting, and introspection of enjoyment or comfort. When information is remembered (i.e., petting a cat), the body simulates those same systems in the brain as if the body were enacting that experience.

Situated action, how that body interacts with the environment in specific ways, also shapes thinking. For example, how human bodies are situated in the environment (e.g., verticality) may influence the type of metaphors people create (e.g., happiness as "feeling up" and sad as "feeling down"; Anderson, 2003; Lakoff, 1993; Lakoff & Johnson, 1980). In addition, body position can contribute to thinking, suggesting that humans use their bodily states to interpret experiences. For instance, unconsciously smiling or frowning can influence how humorous a cartoon seems (Strack, Martin, & Stepper, 1988), or how holding a slumped posture can elicit feelings of helplessness (Riskind & Gotay, 1982).

3 Coordination in the Body Impacts Perception

Extending the EC framework, the body specificity hypothesis indicates that each person's body interacts with the world in a specific unique way. If mental representations are generated through the body, "people with different bodily characteristics, who interact with the physical environment in systematically different ways, should form correspondingly different mental representations" (Casasanto, 2009, p. 351). More specifically, handedness can influence how people feel about things they encounter on their left and right sides of space as being "good" or "bad." When given the choice between two similar items, such as job applicants, consumer products, or cartoon characters, right-handers tend to prefer the one on the right, and left-handers prefer the one on the left (Casasanto, 2009, 2011). Rather than being hardwired into the brain by the same mechanisms that control side dominance, Casasanto argues that this preference is driven by a person's sense of fluency with one side of the physical body.

Casasanto and Chrysikou (2011) demonstrated in two studies that this valence preference for one side in space is malleable and that it follows the direction of how fluently the body moves. The first study involved stroke patients who were initially right-handed but lost the ability to control the right side of their body after experiencing the stroke (making their left side more fluent). Results showed that this group of initially right-handed individuals attributed items on the left as positive and on the right as negative, just like naturally left-handed people. The second study examined healthy right-handed volunteers. The study manipulated the coordination of their hands during a dexterity task by placing a bulky ski glove onto either their left or right hand. Participants who wore the ski glove on their right hand (ostensibly making them left-handed) viewed the left side as good and the right side as bad at a significantly higher rate than participants who wore the ski glove on their left hand during the task (which preserved their right-hand fluency). These results demonstrate that temporarily changing a person's body fluency changes the way visual space (left or right) is designated as positive or negative. More broadly, these findings suggest that changing the way in which people physically interact with their environment may have effects on their cognition.

4 The Virtual Body as the Physical Body: Mapping Body Schema onto an Avatar

While experiencing altered bodies in virtual reality (VR), people map their body schema onto the virtual object by creating a mental model of their bodies based on the affordances of the virtual body (Biocca, 1997; Lenggenhager, Tadi, Metzinger, & Blanke, 2007; Petkova & Ehrsson, 2008; Slater, Spanlang, Sanchez-Vives, & Blanke, 2010). Furthermore, a person's virtual body can create different social meaning (which is situational and environmentally dependent) than the person's physical body, suggesting that virtual embodiment can alter personal identity and perception (e.g., Biocca, 1997; Peck, Seinfeld, Aglioti, & Slater, 2013). In one immersive VR study, participants changed their behaviors in the physical world based on the appearance of their virtual character. People assigned to inhabit a taller body in the virtual world subsequently behaved more assertively during negotiations in the real world compared to people assigned to a shorter body (Yee, Bailenson, & Ducheneaut, 2009).

Humans also have the unique ability to claim ownership over bodies drastically different than their own, or bodies that are impossible in the physical world (Ramachandran, Rogers-Ramachandran, & Cobb, 1995; Steptoe, Steed, & Slater, 2013; Yee & Bailenson, 2009). When an object is reasonably similar to the body or part of the body it is representing, its physical appearance is not the sole factor in creating the illusion of embodiment or body transfer to the physical or virtual objects (e.g., rubber hand illusion). Research by Steptoe, Steed, and Slater (2013) demonstrated that when participants embodied a human avatar with a long functional tail that was controlled by their hip movement, they reported that the tail felt as much a part of their body as their arms and legs.

Users are able to map their body schemas onto their avatars through two possible pathways: (1) afferent or sensory signal correspondences (e.g., visuo-tactile technique) or (2) sensorimotor correspondences between the physical body and the virtual body. Visuo-tactile techniques have been used to create corresponding afferent signals between the person and the artificial or virtual representation. An embodiment illusion occurs through the use of outside tactile stimulation. In the rubber hand illusion, when a person views a fake or virtual hand being touched in synchrony with his or her occluded hand, that person develops ownership over the fake hand and a sense of being touched (e.g., Blanke, 2012; Lenggenhager, Tadi, Metzinger, & Blanke, 2007; Petkova & Ehrsson, 2008). However, the illusion of ownership is removed or mitigated when the touch is asynchronous.

The pathway to the illusion of embodiment and ownership of an avatar can also occur through sensorimotor correspondences. This embodiment illusion happens when the artificial or virtual representation's movements are synchronous with the participant's own physical movements (e.g., seeing your avatar's hand/arm movements correspond with your hand/arm movements in real time; Banakou, Groten, & Slater, 2013; Banakou & Slater, 2014; Sanchez-Vives, Spanlang, Frisoli, Bergamasco, & Slater, 2010). Participants see their virtual or artificial representation move synchronously with the sensation of their own physical body movements. The effect of sensorimotor correspondences also fosters a sense of agency over an avatar (different than feeling ownership). A study by Kalckert and Ehrsson (2012) found that when participants experienced the rubber hand illusion but had passive control over movement, they felt ownership of the hand but did not feel agency. In comparison, when they had active control during the rubber hand illusion, they felt both ownership and agency.

Virtual embodiment has psychological (e.g., reducing implicit race bias; Peck, Seinfeld, Aglioti, & Slater, 2013) and physiological effects (e.g., reduction in skin or body temperature; Moseley et al., 2008; Salomon, Lim, Pfeiffer, Gassert, & Blanke, 2013). Through these two different pathways, people's brains process artificial or virtual bodies as if they were their own bodies. Researchers have used embodiment in virtual reality for stroke rehabilitation (You et al., 2005), and to reduce pain perception in burn patients (Hoffman, Patterson, & Carrougher, 2000; Hoffman et al., 2008).

Approaches to virtual embodiment through afferent or sensorimotor correspondences are not mutually exclusive but have been found to be effective when the approaches are merged. A study by Hara and colleagues (2015) demonstrated that the combination of self-administered touch created stronger body ownership over a virtual hand compared to a passive form of self-touch (i.e., participant's hand guided by researcher). These two approaches illustrate that to create embodiment illusion, it is important to include active sensorimotor and synchronous movement.

EC theory contends that mental representations are developed through embodied experiences. The VR literature has demonstrated that users can map onto virtual bodies as if they were their own bodies. Given these areas of research, how might perception of the physical world change when virtual embodiment pushes the boundaries of what is felt and seen in the virtual world? How might VR be used to test EC theory and its relationship to virtual embodiment?

5 Study Example: Virtual Bodies' Coordination and Perception

Immersive VR provides a fertile testing ground for examining EC theory, and how humans may create mental representations based on their experiences in the physical and virtual worlds. VR provides unique embodiment opportunities not found in other media, and could push the development of EC theory. Utilizing Casasanto's theory (2009, 2011) and Casasanto and Chrysikou's (2011) experimental work, we investigated the use of immersive virtual reality to examine embodied cognition theory as it relates to sensory media technology.

Using the body specificity hypothesis, we examined the impact of virtual embodiment on people's implicit associations of "good" and "bad" with the left and right sides of space. In all previous tests of the link between hand fluency and the attribution of valence, the visual space in which the more fluent hand acted was confounded with the side in which the more fluent action occurred or was felt. This makes it impossible to dissociate *space-valence* associations from *hand-valence* associations, and to distinguish the contributions of motor action on perception (Casasanto & Chrysikou, 2011; de la Vega, Dudschig, De Filippis, Lachmair, & Kaup, 2013). VR allowed us to dissolve this confound: we dissociated participants' hand movement (e.g., right hand) from the space in which the movement occurred (e.g., having it appear on the left instead of the right side of space). We separated the visual appearance of hand movement from the proprioceptive or sensorimotor feedback they felt in their physical body. For example, when using their physical right arm (proprioceptive feedback, feeling the motion), participants saw their avatar's left arm move on the left side of space (visual feedback, seeing the movement).

The study utilized VR to provide greater insight on the mechanisms behind the body specificity hypothesis on body fluency and space-valence associations. The study separated the side on which the dominant hand acts *visually* from where the dominant hand *feels* in a proprioceptive way, looking at how certain systems (i.e., visual versus proprioception) may contribute to space-valence associations. In addition, the study explored whether altered virtual body movements influenced users' experience of their avatar and the virtual environment (i.e., self- and spatial presence).

5.1 Method

5.1.1 Participants. A convenience sample of participants from the student population of a medium-sized west coast university in the United States received course credit for their involvement. The sample consisted of 155 right-handed students, 55.48% female ($n = 86$) and 44.52% male ($n = 69$).

5.1.2 Apparatus. Participants viewed the virtual environment through a head-mounted display (HMD), a fully immersive virtual reality helmet that provided three-dimensional stereoscopic views (see Figure 1). The HMD was an nVisor SX111 head-mounted display (NVIS, Reston, VA) with a resolution of 2056 x 1024 and a refresh rate of 60 frames per second (in each eye). An orientation sensor (Intersense3 Cube accelerometer) tracked physical head orientation (pitch, roll, and yaw), and rendered the virtual world accordingly, operating at 180 Hz with a four-millisecond latency rate. In addition, participants' head and arm movements (on the *x*-, *y*-, *z*-axis) were tracked using an optical infrared camera system (Worldviz PPT-H) operating at 180 Hz with a 20-millisecond latency rate and a precision of 0.25 millimeters. LED sensors tracked participants' head and arm movements: one sensor on the top of the HMD and one sensor strapped around each wrist.

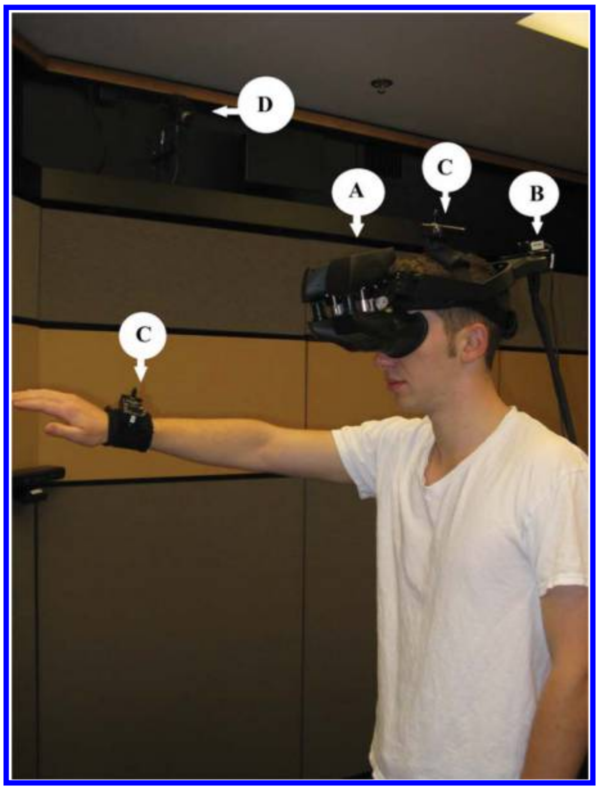

Figure 1. *A participant reaching for the virtual blocks. The figure depicts: (A) a head-mounted display (HMD); (B) the orientation sensor; (C) the optical tracking sensors; and (D) one of the eight motion capture cameras that track the optical tracking sensors.*

5.1.3 Design and Procedure. A between-participants design was used to investigate how altering body movements in virtual spaces impacted cognition related to space-valence associations. Participants embodied an avatar with a first-person perspective, and were randomly assigned to either a normal arm movement or a switched arm movement condition. In the normal condition, when participants moved their arms in the physical world, their virtual arms moved about the same, such that when they moved their physical right arm, they saw their avatar's right arm move. For those

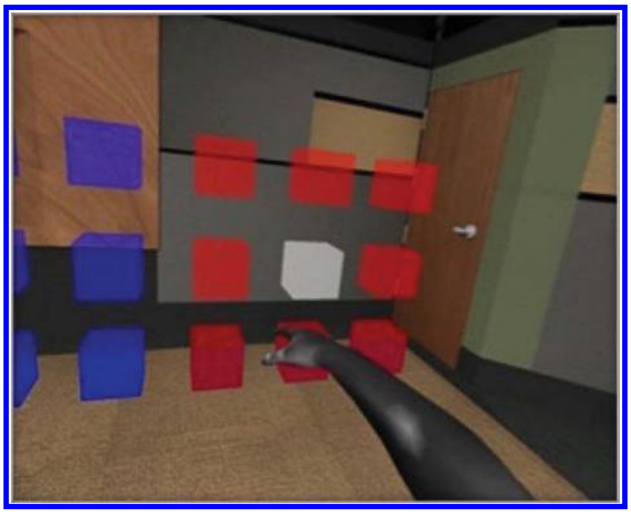

Figure 2. *The viewpoint of participants during the virtual reality task. The participants' goal was to touch the white block with their virtual hand. After they initiated the white block, the white block would randomly appear in a new location.*

assigned to the switched arm condition, their arm movements in the virtual world mirrored their physical arm movements. Specifically, when participants moved their physical right arm, their avatar's left arm moved, and when they moved their left arm, their avatars' right arm moved. The switched condition dissociated the movement of the participants' physical arms and the space in which they saw their avatar's arms move (participants never crossed their arms in the physical or virtual environments).

Before entering the virtual environment, a researcher described to participants how their avatar would appear and move. Participants embodied an avatar that matched their sex, was silver, and undetailed. Their virtual arms were in a stiff extended position (i.e., the wrists and elbows did not bend). After entering the virtual environment, participants went through a brief orientation phase, moving their avatars' arms up and down and to the side. Participants completed a task in which they used their avatars' hands to touch stationary virtual blocks (see Figure 2). Their specific goal was to touch the white block wherever it appeared (they were also allowed to touch the other blocks). Once they held one of their virtual hands on the white block, another white block would appear in a new random location. Participants used only one arm and hand at a time, and a researcher told them which arm to use and when. They completed this task for ten rounds lasting for 30 seconds each. Participants alternated between their right and left arm, totaling five rounds per arm (they were randomly assigned to start with either the left or right arm). A sign appeared in their line of sight accompanied by a brief jingle to indicate the beginning of each round.

After the virtual reality treatment, participants were taken into a separate room where a researcher measured their space-valence association (i.e., right or left side preference) using the materials and procedures implemented in studies by Casasanto (2009; Experiment 3) and Casasanto and Chrysikou (2011; Experiment 2), with the following exception: the same researcher was used throughout the entire procedure and therefore was not blind to condition. Space-valence associations were measured by participants placing a "good" and a "bad" animal into boxes on the left or right: participants verbally indicated which side they would put the "good" or "bad" animal verbally to avoid using their hands. The order of the animal, the valence assigned to each animal, and the order in which they were asked about the "good" and "bad" animals were counterbalanced. Finally, participants completed a self-report questionnaire measuring self- and spatial presence regarding the virtual reality treatment.

5.2 Measures

5.2.1 Presence (Self- and Spatial).

Self-presence was measured with a five-item scale (adapted from Ahn & Bailenson, 2011; Nowak & Biocca, 2003; see Appendix) used to measure the extent that participants felt their avatars were an extension of the self ($\alpha = 0.84$, $M = 2.68$, and $SD = 0.70$). Each question was given a score from one to five. Spatial presence was a five-item scale used to measure the extent that the virtual room as a whole felt real to participants ($\alpha = 0.83$, $M = 3.60$, and $SD = 0.78$), and was adapted from presence measures in previous research studies (Ahn & Bailenson; Nowak & Biocca; see Appendix).

Both self- and spatial presence was used to determine if participants' view of their avatars and/or the virtual environment as real (based on condition) would impact their perception of space as positive or negative. This analysis was exploratory and completed to help rule out the possibility that participants' subjective experience of the virtual environment and their feelings of connection to or ownership of their avatar (as opposed to the affordances of their virtual body) impacted their space-valence associations in the physical world. Some virtual embodiment research suggests that avatar body type can influence the perception of an environment (i.e., overestimation of objects after embodying a child avatar; Banakou, Groten, & Slater, 2013).

5.2.2 Space-Valence Association. A space-valence association measure assessed participants' right or left side preference. Participants provided a verbal response indicating on which side they would put the "good" or "bad" animal. The same stimulus was used from Casasanto's 2009 and 2011 studies.

5.3 Results

One participant determined the purpose of the study during debriefing and was removed from the analyses, leaving a final sample of 154 participants.

5.3.1 Presence. Analysis of the self-presence scores revealed no significant difference in mean scores according to condition, $t(147) = 0.70$, $p = 0.48$, 95% CI $[-0.13, 0.32]$. Participants in the normal condition had a mean score of 2.73 with a standard deviation of 0.76, and the switched condition had a mean score of 2.63 with a standard deviation of 0.66. For spatial presence, there was no significant difference between group means, $t(149) = -0.50$, $p = 0.62$, 95% CI $[-0.31, 0.19]$. Participants in the normal condition reported a mean score of 3.33 with a standard deviation of 0.82, and participants in the switched condition reported a mean score of 3.39 with a standard deviation of 0.74.

5.3.2 Space-Valence Associations. Data analysis of the space-valence associations examined the association between condition and side preference (left versus right) using a two by two contingency table. We first tested the direct relationship between condition and space-valence association (i.e., side preference) using Pearson's Chi-square. Next, using the same data, we conducted a secondary analysis following the procedure of Casasanto (2009), Casasanto and Chrysikou (2011), and Kominsky and Casasanto (2013), Experiment 2. In this analysis we conducted a sign test for each condition, comparing it to the 50% chance that the left and right sides had of being selected.

Table 1. *Space-Valence Associations by Condition*

	Placement of Good Animal	
Condition	*Left*	*Right*
Normal	25	51
Switched	34	44

Table 1 contains the frequencies of the side in which participants placed the "good" animal according to condition (either in the left or the right box). The rates at which participants in the normal condition indicated the right side as "good" and the left side as "bad" were comparable to rates in previous experiments (Casasanto, 2009; Kominsky & Casasanto, 2013). The results of the Pearson's Chi-squared test revealed that placement of the good animal on the left versus the right did not differ by condition, $\chi^2(1, N = 154) = 1.86$, $p = 0.17$. Because there was a weak association found according to the previous Pearson's Chi-square test, we did not find it necessary to calculate the odds ratio found in the analysis by Casasanto and Chrysikou (2011), Experiment 2.

The secondary analysis tested the individual rates of side preference according to condition (Casasanto, 2009; Casasanto & Chrysikou, 2011; Kominsky & Casasanto, 2013). Each box had a 50% chance of selection. The majority of participants in the normal condition, 67.11% (95% CI = 55.37, 77.46), indicated that the "good" animal should go in the right box, showing a "good-is-right" bias that was statistically different from a 50-50 chance (i.e., 50%; *Sign Test*, 25 versus 51; *z-score* = 2.98). By contrast, only 56.41% of the switched condition (95% CI = 44.70, 67.61) placed the "good" animal in the right box, a bias that was not statistically different from chance (i.e., 50%, *Sign Test*, 34 versus 44; *z-score* = 1.13).

6 Discussion

Media-technology continues toward greater integration with the human body. Immersive VR can be utilized to understand and test EC theory and to examine how cognition may relate to the affordances of immersive virtual technology. The presented example study leveraged the body specificity hypothesis to test how visual location/appearance of arm movements in a virtual world (switched versus normal) related to side preference in the physical world. While participants in the normal condition selected the right side significantly above a 50% chance (67%) and those in the switched condition did not differ from a 50% chance (56%), there was no overall interaction between condition and side preference.

The null results of this study suggest that space-valence associations do not change by simply altering the visual experience while maintaining the same proprioceptive experience (i.e., maintaining greater motor fluency felt on the right side). Instead, the results implicate that proprioception is an important factor that drives the experience of motor fluency, which influences space-valence mapping (see de la Fuente, Casasanto, & Santiago, 2015; de la Fuente, Casasanto, Martínez-Cascales, & Santiago, 2016 for additional examples of manipulating fluency). The example study presented here only manipulated visual feedback, not motor fluency itself, which contributes further evidence that people generate mental representations through a multisensory integrated system (i.e., proprioception of fluency, not a visual change alone).

The results of our study coupled with previous EC and VR research suggest that it may be important to consider various sensory components for interface design (i.e., visual-only versus visual and haptic feedback). Future research could examine how difference affordances of VR relate to cognition, such as including haptic feedback to enhance learning different types of content or when controlling novel bodies that improve task performance.

Previous research has demonstrated that individuals are able to map their body schema onto artificial or virtual representations like an avatar. This was further supported in this study, as there were no significant differences in self-presence according to condition. The avatar's appearance is not a prerequisite to create an embodiment illusion or body transfer (e.g., feeling of ownership of an avatar with a functional tail), but sensorimotor correspondences can elicit a strong sense of body transfer. This may be one possible explanation for the lack of difference in self-presence according to condition. Participants used the same arm movements in the physical environment to control their avatars. In the virtual environment their avatars' arm movements looked the same; however, those movements happened in different areas of space (either the right or left side). Sensorimotor correspondences can create feelings of ownership and agency of an avatar. Although the arm movements were visually different by condition (i.e., normal versus switched), in both cases the avatars responded synchronously with participants' movements. The results support the importance of aligning the movement of users with their avatars, not just how the avatars look or the type of movement they make.

An EC framework may provide insight as to why there was not a significant shift toward preferring the left side. Although participants were getting visual feedback on how their avatar's arms were performing, they were still feeling how their physical bodies were moving. Perhaps if changing the mapping between participants' virtual and physical arms had been accompanied by a noticeable change in motor fluency, then the manipulation would have caused more of a shift in the switched condition.

Although a null effect, these results provide promising implications for using the embodied cognition framework to understand user's mediated experiences. Through the unique capability of immersive VR, the study created a dissociation between the visual and motor movement of the arm/hand movement, such that when participants used their left (ostensibly less fluent) hand/arm, they saw their avatar's hand/arm move the same way in virtual reality. There has been limited embodied cognition research that has dissociated the space in which body action occurs (i.e., hand/arm movement), where participants feel that action, and the possible effects on space-valence associations in the physical world. In the past, it has been achieved by having participants cross their arms in front of them; however, this changes the physical position of their bodies, potentially introducing other types of effects (e.g., de la Vega, Dudschig, De Filipis, Lachmair, & Kaup, 2013).

The VR literature contains many examples in which users take on virtual bodies that function differently than their physical world bodies. For example, Salomon, Lim, Kannape, Llobera, and Blanke (2013) used VR to examine participants' ability to recognize their avatar after delaying the avatars' movements from their physical world movements. As mentioned previously, Banakou, Groten, and Slater (2013) showed that embodying a child avatar influences adult users' perception of size. The example study presented in this article illustrates how EC and VR literature can merge together to examine the underlying mechanisms related to EC theory, how they may relate to experiences in VR, and how virtual embodiment may or may not influence perception of the world beyond the avatar.

Our study is one of many possible ways of using VR to explore and test issues of cognition and virtual embodiment. The next generation of media-technology may require the users to expand the meaning of a "body" and how to use it to complete tasks for entertainment, education, or work. For instance, participants controlling their avatar's legs with their arm movements to complete a task in a gaming scenario can help facilitate arm rehabilitation for patients with complex regional pain syndrome (Won et al., 2015). Future research could examine how task performance may relate to virtual embodiment and perception. How well participants perform or how much concentration a task requires could act as moderators (e.g., Won, Bailenson, Lee, & Lainer, 2015).

This study did not use a within-participants design. This was done to be congruent with the study conducted by Casasanto and Chrysikou (2011), in which they used a physical world paradigm. Future studies could utilize the unique capabilities of immersive virtual reality to allow participants to act as their own controls. A within-participants design may have strengthened the weak effect found in this study. In addition, there is wide variation in presence measures in the field and with various applications. Although the presence measures from this study were adapted from previous research, it was particularly challenging to make explicit comparisons to previous research. One way to improve this limitation would be to identify common concepts and measurements for presence in EC and VR research that could be utilized across studies.

6.1 Conclusion

Currently, virtual reality technology is becoming more accessible to the public. Tens of millions of people have purchased the Microsoft Kinect, a device for video game consoles that uses a person's body movements to control a virtual character (Rigby, 2012), and the *New York Times* sent out millions of cardboard-made HMDs to its Sunday paper subscribers (Somaiya, 2015). In addition, one of the most popular current social networking websites, Facebook, spent $2 billion to purchase Oculus VR, a company that created a lightweight immersive virtual reality headset (Solomon, 2014).

Developers continue to create media that seamlessly integrates into life, melding the tool and the body via size, mobility, or interfaces controlled by body movement or touch. From video game play to automobile navigation systems, the design choices for interface may implicitly shape how users form mental representations about their digital experience and those outside the media interactions. With cognition rooted in the body and learning occurring at an unconscious level, memories and mental representations may be extended out from the physical body onto technology, blurring the physical and the mediated.

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Appendix

For both self- and spatial presence items, the response options for each question were: *not at all, slightly, moderately, strongly, or very strongly.*

Self-Presence Questions

1.) To what extent was the avatar an extension of yourself?
2.) To what extent did you feel if something happened to the avatar it felt like it was happening to you?
3.) To what extent did you feel that the avatar's body was your own body?
4.) To what extent did you feel that the avatar was you?
5.) How much did the avatar's actions correspond with your commands?

Spatial Presence Questions

1.) To what extent did you feel like you were really inside the virtual room?
2.) To what extent did you feel surrounded by the virtual room?
3.) To what extent did you feel like you really visited the virtual room?
4.) To what extent did you feel that the virtual room seemed like the real world?
5.) To what extent did you feel like you could reach out and touch the objects in the virtual room?