Toward a Physiological Understanding of Presence and Embodiment

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Introduction

- Accumulating evidence suggests that the origins of self-consciousness are the consequence of integrating information from multiple sensory modalities. This illusion of the self is referred to as bodily self-consciousness (BSC).
- Current scientific literature proposes that BSC results from the perception of presence and embodiment.
- Traditionally, embodiment is induced by applying congruous visual/auditory stimulation between a virtual or rubber extremity, and real extremity hidden from the subject's awareness. Presence alters experiencing such as use cameras or virtual reality head mounted displays (HMDs) to alter the user's visual perspective.
- While there are numerous peripheral perceptual experiences that can influence subjective experiences of BSC, research suggests that embodiment and presence may be supported by partially, or fully dissociated networks (Longo et al., 2008).

BSC Components May Have Distinct Neural Correlates

- Areas perceived to be activated during experiences of bodily self-consciousness include the dorsal and ventral visual streams, the premotor cortex, the mesial temporal areas (including the hippocampus, amygdala and insula), precuneus, the insula and the thalamus (Figure 2) (Blasberg et al., 2006; Pellecchia, 2011; Ionta et al., 2011, 2014; Clemente, 2013; Gutierrez et al., 2015).
- Embodiment particularly has been associated with areas including the ventral premotor cortex and intraparietal sulci. These areas have been linked to the integration of multisensory signals that are believed to exist an accurate central representation of one's body in space (Gazzaniga et al., 1997; Gutierrez et al., 2015).
- Presence has been largely attributed to the hippocampus, retrosplenial cortex, insula, posterior cingulate cortex, precuneus, and temporoparietal junction, which are areas that have been implicated in episodic and allocentric representations of self-reference, and the perception of head direction in virtual worlds (Gutierrez et al., 2015; Ionta et al., 2011, 2014).

The Significance of the Insula in the Culmination of BSC in Virtual Reality

- The insula regulates the integration of multisensory signals linked to interoceptive attention (awareness of bodily signals including the gut, heartbeat, ventilatory and proprioceptive fields, sense of agency, awareness of pain and emotion (Figure 3), and our perception of time (Craig, 2009; visualization A, Olson, 2015)).
- The anterior insula is considered to be a key region that mediates interoceptive information including the perception of bodily signals, including visceral sensations and interoceptive interoceptive information (Craig, 2009; visualization B, Olson, 2015).
- It is predicted that embodiment is a prerequisite for presence and that the functional significance of the insula in virtual reality is its role in interoceptive information and self-awareness.

Specific Aims

1. Identify the neural correlates of embodiment in virtual environments.
2. Identify the neural correlates of presence in virtual environments.
3. Compare two peripheral models of BSC

Current Study

- Subjects will participate in a large-scale game which will be compatible with standard HMDs and standard game controllers.
- Cameras outside the scanner will track the movement of subject's feet so that the feet left and right enables the virtual avatar to move and avoid obstacles on the course.
- A first-person, or third-person view of the body, clad, and obstacle course will be presented via an MR compatible goggle.
- Generically, subjects should navigate various courses without crashing.

The insula is highly interconnected with many brain regions involved with BSC including emotion-related structures like the amygdala, anterior cingulate cortex, and orbitofrontal cortex. Exteroceptive and interoceptive information believed to diverge into insula giving rise to self-awareness. The insula may provide richer neural activity in response to presence and embodiment stimulation. This insula may provide as a potential region of interest given the accumulating evidence that the insula is crucial to mediate experiences associated with presence and embodiment as suggested by Guterstam et al. (2015) and Tsakiris (2017).

Methods

- Experiment 1: Embodiment
  - Designed to measure whether foot-parasite-like networks, including the insula, are correlated with perceived embodiment in virtual environments.
  - The high embodiment condition will involve controlling the avatar in first-person with the visual feedback corresponding to the subject's actual movement.
  - The low embodiment condition will be identical except that virtual feedback for the avatar will be uncorrelated with the subject's body motion. Moving the feet will move the feet correctly, but the avatar's legs will make random movements that are not correlated with the user input.

- Experiment 2: Presence
  - Will measure whether temporal-parasite-like networks, including the insula, are correlated with presence in virtual environments.
  - The high-presence condition will be identical to the high-embodiment condition above.
  - In the low-presence condition, the subject will view the avatar from the third-person perspective.

Expected Outcomes

- Comprised of both virtual and visual feedback viewed from first-person perspective should elicit a greater subjective experience of embodiment and presence compared to low embodiment and presence conditions (measured by subjective reports).
- High embodiment and high presence conditions should elicit a greater functional or higher responses than low embodiment or low presence conditions in brain regions corresponding with embodiment and presence, respectively.
- An increase in insula activity for high embodiment and presence conditions should also be observed, given its role in sensory integration and self-awareness.
- It is predicted that embodiment is a prerequisite for presence and that the BSC of presence and presence experiences of BSC are mediated by the insula in addition to the PCC.
- Unlike the model proposed by Nakay and Slater, specific regions within the brain are predicted to mediate experiences associated with presence and embodiment as suggested by Guterstam et al. (2015) and Tsakiris (2017).

Conclusions

- This study seeks to develop a mechanistic explanation for BSC in virtual reality, and ultimately establish a more rigorous scientific foundation for the imminent wave of virtual reality technology on the horizon.
- This insula may provide a potential region of interest given the accumulating evidence showing its recruitment during virtual, non-interactive and interactive situation and back blocking BSC induction paradigms.
- The insula has been implicated in subjective experiences involving emotional valence, heartbeat awareness, and integrating bodily signals (Wang et al., 2019).
- Further exploring the role the insula in mediates embodiment and presence during fully immersive virtual games may be important in establishing physiological mechanisms of BSC.
- Exploring the physiological mechanisms of BSC in virtual reality may further validate its usefulness in science, business, and education, providing answers to foundational questions that may make educational designers of how virtual reality should be developed to improve engagement, engender motivation, and fostering learning. Furthermore, conclusions drawn from this experiment may be used to develop further understand clinical alterations of body representation (Case et al., 2020).

References


