INFLUENCE OF VESTIBULAR SIGNALS TO BODILY SELF-CONSCIOUSNESS AND DIFFERENT SENSORY WEIGHTING STRATEGIES

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ABSTRACT

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Experimental Psychology Master's Program

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Given that we experience the bodies that we live in as ours and look through life from the perspective of our bodies, "bodily self-consciousness" represents the totality of those processes and experience of being self-conscious within a body. This perception of bodily self depends on the integration of a wide variety of information that range from interoceptive signals such as heartbeat and muscular activity to exteroceptive signals such as vision and somatosensory. In addition to that numerous neurological conditions and experimental studies showed that bodily self can change by the weighting of different sensory inputs hence capable of creating a flexible embodied self-model of itself. Previous studies showed that although the vestibular system has important roles during multisensory integration, its contribution to bodily self-consciousness are not well understood. Thus, this thesis aimed to examine the influence of visuo-vestibular conflict on a full body illusion during a decreased vestibular input condition that is induced by supine position. Additionally, the contribution of individual weighting strategies was investigated. Subjective reports revealed increased ownership over a virtual body for synchronous visuo-tactile stimulation. Examination of subjective and objective results showed that people heavily weighting visual information perceived themselves at the location of the virtual body after synchronous visuo-tactile stimulation. Further analysis of objective measurements provided quantitative demonstration of full body illusion revealing changes in perceived body orientation. Altogether, findings of this study provided understanding for contribution of vestibular system and sensory weighting strategies respectively to different aspects of bodily self-consciousness, in addition to visuo-tactile integration.

Keywords: Bodily self-consciousness, multisensory integration, full body illusion, rod and frame test, vestibular system, sensory weighting

ÖZET

VESTİBÜLER SİNYALLERİN BEDENSEL ÖZ-BİLİNCE ETKİSİ VE FARKLI DUYU AĞIRLIKLANDIRMA STRATEJİLERİ

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İçinde yaşadığımız bedenleri bizim olarak deneyimlediğimiz ve hayata bedenlerimizin bakış açısından baktığımız göz önüne alındığında, "bedensel öz-bilinç" bu süreçlerin bütünlüğünü ve beden içinde öz bilinçli olma deneyimini temsil etmektedir. Bu bedensel benlik algısı, kalp atışı ve kas aktiviteleri gibi içsel sinyallerden görme ve somatosensori gibi dışsal sinyallere kadar çeşitli duyusal bilgilerin birlikte işlenmesine bağlıdır. Buna ek olarak, birçok nörolojik durum ve deneysel çalışma, bedensel benliğin farklı duyusal girdilerin ağırlıklandırılmasıyla değişebileceğini ve dolayısıyla esnek bir bedenleşmiş kendilik modeli oluşturabildiğini göstermiştir. Önceki çalışmalar, vestibüler sistemin duyusal tümleştirmedeki önemini göstermesine rağmen bedensel öz-bilince katkısı tam olarak anlaşılmış değildir. Bu nedenle bu tez, sırtüstü yatma pozisyonuna bağlı olarak azalan vestibüler girdi durumunda çelişkili görsel-vestibüler sinyallerin tüm vücut illüzyonuna etkisini incelemeyi amaçlamıştır. Ayrıca, bireysel duyusal ağırlıklandırma stratejilerinin katkısı araştırılmıştır. Öznel raporlar, eş zamanlı görsel-dokunsal uyarımların sanal bedene karşı sahiplik hissini arttırdığını ortaya koymuştur. Öznel ve objektif sonuçların incelenmesi, görsel bilgilere daha çok ağırlık veren kişilerin, eş zamanlı görsel-dokunsal uyarımlardan sonra kendilerini sanal bedenin yerinde algıladıklarını göstermiştir. Objektif ölçümlerin daha detaylı analizi, algılanan beden oryantasyonundaki değişiklikleri ortaya çıkararak tüm beden illüzyonunun nicel olarak gösterilmesini sağladı. Bu çalışmanın tüm bulguları, görsel-dokunsal sinyallerin birlikte işlenmesine ek olarak vestibüler sistemin ve duyusal ağırlıklandırma stratejilerinin bedensel öz-bilincin farklı yönlerine katkılarının anlaşılmasını sağlamıştır.

Anahtar Kelimeler: Bedensel öz-bilinç, duyusal tümleştirme, tüm beden illüzyonu, çerçeve ve çubuk testi, vestibüler sistem, duyusal ağırlıklandırma

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CHAPTER 1: INTRODUCTION

Our bodies are at the centre of our experiences and with them we are deeply embodied into this physical world. We are always aware of our bodies with the help of interoceptive signals that generate different physiological responses. Besides that, exteroceptive signals that comes through the sensory organs (i.e., eyes, ears, and skin) we are connected to this the world and we are aware of our own bodies in relation to our environment. All of these sensations underpin a unique experience of having a self, where the physical body becomes the essential foundation for it. Different concepts of self, referring to bodily domain, were described in previous studies. These concepts include, proto-self (Damasio, 1999), physical self (James, 1891), minimal self (Gallagher, 2000) and phenomenal self (Metzinger, 2003). During the early 1960s French philosopher Merleau-Ponty emphasized this view as "the flesh of the world" (Merleau-Ponty, 1968). According to this view, he grounds the body to the core of the foundations of perception. Based on the embodied nature of the body within the physical world, he thus suggests that the body is the fundamental source of self-consciousness (Merleau-Ponty, 1968). Furthermore, the philosophical approaches led to alternative explanations highlighting the role of the body in cognitive science such as, embodied cognition (Clark, 1997) and enactivism (Varela, Thompson, and Rosch, 1992). All of these approaches in general suggest that the sensorimotor and cognitive processes to be grounded in the interaction of the body within the world (Prinz, 2012; Wilson, 2002).

The notion of being embodied in a physical body full of senses provides new lines of research to evidence for understanding the self such as bodily self-consciousness. Studies on "bodily self-consciousness" suggest that our brain's multisensory integration capacity is the key feature for the unique experience of having a self (Blanke, 2012; Blanke, Slater, and Serino, 2015). Thus, bodily self-consciousness is defined as a type of representation for multisensory mental state, that integrates bodily inputs from different senses, however it is separate from higher-level or explicit aspects of self-consciousness such as memory, thought, or language (Blanke, 2012; Gallagher, 2000; Metzinger, 2007). As mentioned in more detail below the simplest form of bodily self-consciousness is conceptualized as "minimal phenomenal selfhood" and defined as identification with a physical body, spatiotemporal self- location and first-person visuospatial perspective (Blanke, and

Metzinger, 2009).

Theories in the field of neuropsychology put emphasis on these three components of the minimal phenomenal selfhood and design experiments to test different aspects of body-ownership (This is my body), self-location (I am in my body), first-person perspective – 1PP- (I see the world with a given location of my body) on bodily self-consciousness (Blanke, and Metzinger, 2009, Serino et al., 2013). That is to say that, bodily self-consciousness refers to a unique subjective experience of the world from the perspective of the physical body that is owned by the individual. Although this is a unique experience for humans, most of the time we are not explicitly aware of it, such that either we get used to it or it was neglected from our attention (Glasgow, 2017). Considering lower-level multisensory nature of bodily self-consciousness, various animals was also considered as having states of minimal phenomenal selfhood (Metzinger, 2009). In fact, recent experimental studies provided evidence for the presence of the sense of body ownership and revealed the cortical networks of bodily self-consciousness in mice and macaque monkeys (Buckmaster et al, 2020; Fang et al., 2019; Wada et al, 2016).

Our understanding of bodily self-consciousness obtains great benefits from bodily illusions in which the perceived body representation dynamically changed by experimental manipulations with respect to the multisensory integration. One such example of bodily illusion in which bodily self-consciousness manipulated is called the Pinocchio illusion. In the Pinocchio illusion, participants perceive their arm or nose as elongated by vibro-tactile stimulation (Lackner, 1988). This was induced if the tendon of bicep muscle was vibrated while blindfolded participants touch their nose. In another bodily illusion that was called the Phantom nose illusion, blindfolded participants tapped the nose of someone else who is sitting in front of them while the experimenter synchronously touch their nose (Ramachandran, and Hirstein, 1998). This experimental paradigm also led participants to experience as if they were touching their very long nose. These and other similar illusions provided the first evidence for how easy is to manipulate one’s body perception through the manipulation of multisensory information processing.

These bodily illusions underlie the more controlled and systematic experimental manipulations to investigate bodily self-consciousness. Many of the early experimental works in the field of bodily self-consciousness focused on flexibility of body-part representations (Botvinick, and Cohen, 1998; Ehrsson, Spence, and

Passingham, 2004; Ramachandran, and Hirstein, 1998). However, recent studies addressed the unitary aspect of bodily self-consciousness in experimental setups that use technological advances such as high-resolution head-mounted displays and virtual reality systems (Ehrsson, 2007; Lenggenhager et al., 2007; Lenggenhager, Mouthon, and Blanke, 2009; Maselli, and Slater, 2013, 2014; Petkova, and Ehrsson, 2008). Given the strong link between multisensory integration and bodily self-consciousness, the role of different sensory modalities has been investigated that includes visuo-motor (Tsakiris, Prabhu, and Haggard, 2006), visuo-interoceptive (Adler et al., 2014; Aspell et al., 2013), as well as proprioceptive-tactile (Ehrsson, Holmes, and Passingham, 2005) interactions. More recently, the contribution of vestibular system on bodily self-consciousness has been emphasized (Ferrè, Lopez, and Haggard, 2014; Macauda et al., 2015; Pfeiffer et al., 2013; Thür et al., 2019).

The vestibular system differs from other sensory modalities since the processing of vestibular signals themselves are incorporated with other sensory modalities such as vision, somatosensory and proprioception (Guldin, and Grüsser, 1998). Studies with humans and non-human animals showed that a highly distributed region of cortical areas are involved in processing vestibular signals (Büttner, and Henn, 1976; Deecke, Schwarz, and Fredrickson, 1977; Dieterich et al., 2005; Kotchabhakdi et al., 1980; Lang, Büttner-Ennever, and Büttner, 1979; Marlinski, and McCrea, 2008a, 2008b; Matsuo et al., 1999). Studies that use artificial vestibular stimulation (i.e., galvanic or caloric stimulation) provide the basis for understanding the vestibular contribution to changes in the bodily self-consciousness. These studies examined the effects of vestibular system on the perception of touch (Ferrè, Bottini, and Haggard, 2011), pain perception (Ferrè et al., 2015), and even perceived hand size (Lopez, Schreyer et al., 2012).

Further evidence for the contribution of vestibular system was based on neuropsychological case studies that examine people who experience dissociation between their body and the self which is called out-of-body experiences (OBEs) (Blanke et al., 2002; Blanke et al., 2004). During OBEs, people experience themselves to be localized at illusory body which is in elevated position followed by the sensation of floating or flying (Blanke et al., 2004). These experiences mostly reported after the artificial stimulation (transcranial magnetic stimulation) or damage to the temporo-parietal junction (TPJ) region of the brain which is an area involved in vestibular processing (Blanke et al., 2002; Ionta, Gassert, and Blanke, 2011). Moreover, OBEs are frequently experienced when the participants are in a supine position (i.e., lying in the bed) (Blanke et al.,2004) suggesting the influence of graviceptor signals which is encoded by the vestibular sensory receptors on bodily self-consciousness (Lopez and Blanke, 2010). Of interest, a wide range of experimental studies showed the influence of body orientation on different aspects of perception, such as perceived distance (Harris, and Mander, 2014), perceived orientation of an object (Yamamoto, and Yamamoto, 2006), localization of the sensory stimuli (Parise, Knorre, and Ernst, 2014), visual perception (Peru, and Morgant, 2006) and judgements of stability (Lopez et al., 2009). All these studies highlighted the importance of the body orientation in interpretation of multisensory signals that are associated with bodily self-consciousness. According to Lopez, and Blanke (2010), the interaction of multisensory signals with respect to the body orientation was likely due to the difference in weighting of visual, somatosensory, and vestibular signals. Within this context, studies on bodily self-consciousness showed that individual differences on the degree to which sensory modality is weighted affects the experience of bodily self (Pfeiffer et al., 2013; Thür et al., 2019). Although much is written on how the body position influences the weighting process of multisensory information, there is no direct evidence on the weighting of these sensory signals on bodily self-consciousness.

In the rest of this thesis, firstly, the importance of multisensory mechanisms on bodily self-consciousness and its neural correlates will be introduced. In the second section, the relationship between multisensory integration and body representation will be explained. Furthermore, disorders related to bodily self-consciousness and different experimental paradigms for examining bodily self-consciousness will be described. Particularly, the role of 1PP on bodily self-consciousness will be explained in detail. Moreover, in order the study the contributions of the vestibular system on bodily self-consciousness, the current thesis focuses on the influence of reduced vestibular information. Therefore, in the third section, the vestibular system and its neural foundation will be introduced which is followed by the role of body orientation on vestibular system. Lastly, the effects of artificial vestibular stimulations on bodily self-consciousness will be summarized.

1.1. Multisensory Integration and Sensory Weighting

We constantly receive sensory information from different sources. Our brain’s ability to integrate these signals allows us to generate a meaningful experience of the world. For instance, if there is a police car with siren sound, our brain processes the visual and auditory signals at the same time, not separately, and concludes that this is the police car making the sound of siren. A representative example of how we use multisensory information to perceive is the McGurk effect (McGurk, and MacDonald, 1976). The effect relies on seeing a video of a mouth saying “ga” while hearing a sound of “ba” resulting in perception of hearing “da”. A related example called the double flash illusion in which presenting a flash with two beeps leads to perception of seeing two flashes indicating the integrated process of sensory modalities (Shams, Kamitani, and Shimojo, 2000). These examples demonstrate that our brain integrates information from different sensory information and creates a multisensory representation of the world. This process of multisensory integration has also evolutionary advantages since it enables us to perceive and interact appropriately with the world which are fundamental requirement for survival (Stein, Standford, and Rowland, 2014). For example, it was shown that multiple sensory information about the same dangerous stimulus triggers the motor response more rapidly compared to single sensory information (Sereno, and Huang, 2006). This enhanced ability to process sensory signals from multiple sources indicates the evolutionary advantage of multisensory integration.

Neurophysiological studies discovered that this multisensory integration processed by bimodal neurons that respond to multiple sensory inputs from different modalities (Graziano, Yap, and Gross, 1994; Graziano, Hu and Gross, 1997; Rizzolatti et al., 1981). The bimodal neurons are responsible for receiving and weighting multisensory signals compared to the unimodal neurons that only respond to one sensory modality (see Figure 1). In a fMRI study by Graziano, Hu and Gross (1997), monkeys’ right arms were placed on a table in front of them and then a stimulus approaching the hand presented along several trajectories. The firing rate of the neurons increased both for the tactile stimulus applied to the hand and the visual stimulus just approaching to the hand (see Figure 2). Further studies observed that receptive fields of these sensory neurons are attached to the given body part (Fogassi et al., 1996; Graziano, Hu, and Gross, 1997) and the temporal and spatial congruence

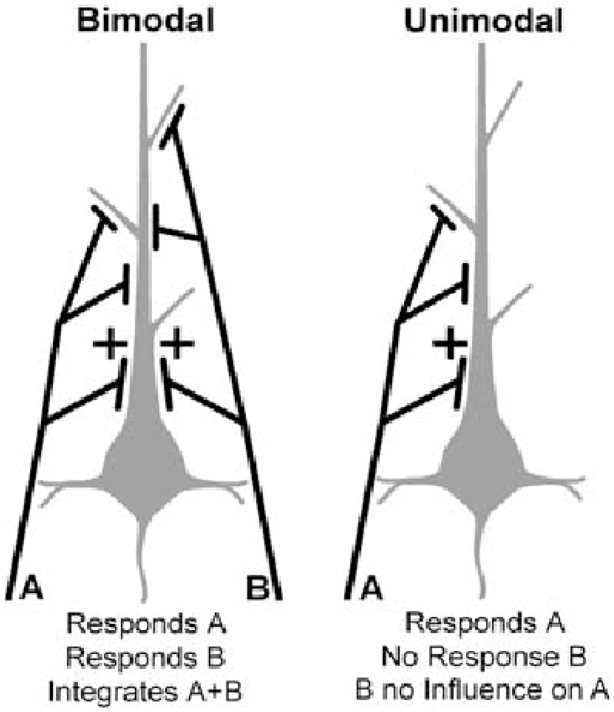


Figure 1. Illustration of bimodal and unimodal neurons and their processing of different sensory modalities. These sensory modalities depicted as A and B. The bimodal neuron receives inputs both from A and B, then integrates them together. However, the unimodal neuron only receives input from A and does not respond to B or integrated signals of A and B (Source: Allman, Kesinton, and Meredith, 2009).

of the stimuli affected the integration process (Avillac, Hamed, and Duhamel, 2007) indicating the dynamic processing of multiple signals with respect to the body. Most of these neurons are found in the primary visual and somatosensory cortical regions which are involved in processing of multisensory integration (Calvert, Spence, and Stein, 2004, Stein, and Stanford, 2008).

Brain imaging studies revealed that there is a similar multisensory integration mechanism in humans (Làdavas, and Farnè, 2004; Makin, Holmes, and Zohary, 2007). Functional magnetic resonance imaging (fMRI) studies have found that the premotor cortex and intraparietal cortex respond to both visual and tactile stimuli in respect to certain limbs (Lloyd et al., 2003, Makin, Holmes, and Zohary, 2007). Crucially, the multisensory integration was found only when the stimuli are within a space close to

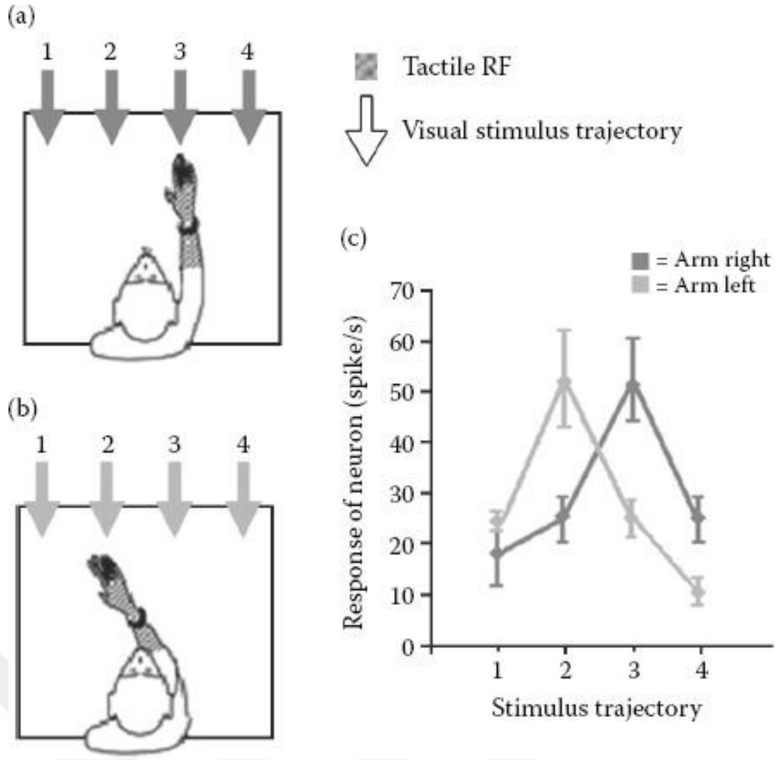
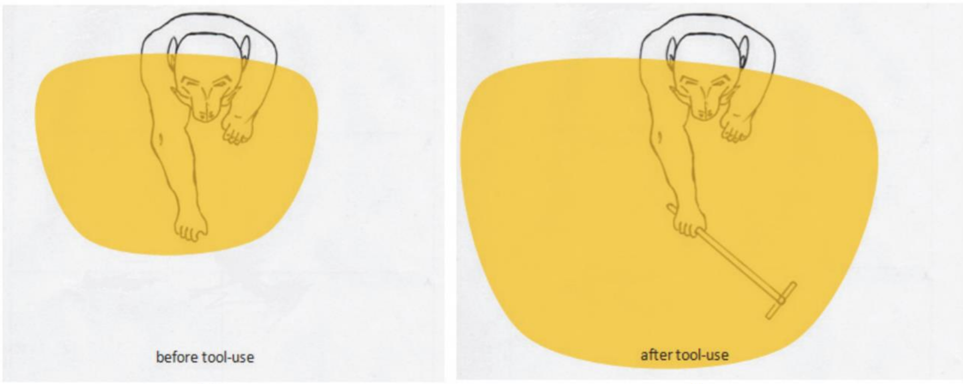


Figure 2. Representation of responses of bimodal neurons. The arm of the monkey either placed on a) the right side or b) left side and visual stimulus presented thorough one the four paths (1-4). C) Responses of visual receptive field of the bimodal neurons. The neurons mostly responded to visual stimulus approaching tactile receptive fields from the pathway 3 when the arm of the monkey placed on the right side. The neurons mostly responded to visual stimulus approaching tactile receptive fields from pathway 2 when the arm of the monkey placed on the left side (Source: Brozolli et al., 2012).

surrounding of the body which is called peripersonal space (PPS) (Maravita, and Iriki, 2004). A study by Iriki, Tanaka, and Iwamure (1996) showed that receptive fields of bimodal neurons in monkeys can be modulated by the tool use which leads an extension of PPS. Specifically, they found that neurons in the visual receptive fields respond to tactile stimulus on the tool instead of the hand following the tool use (see Figure 3). The existence of PPS in humans supported by studies in right brain damage patients with neglect (Berti, and Frassinetti, 2000). Patients with neglect have difficulties in perceiving sensory modalities and respond to stimuli on contralesional side of the brain damage (Driver, and Vuilleumier, 2001). Berti, and Frassinetti (2000) measured the effects of tool use in patients with neglect by using line bisection test in



(a) (b)

Figure 3. Representation of changes in peripersonal space before and after tool use. a) Visual receptive fields of bimodal neurons are restricted to near space around the monkey (yellow area). b) Visual receptive fields of bimodal neurons extended following tool use (yellow area) (Source: Rybarczyk et al., 2012).

which patients displaced midpoint mark towards the brain damage side (Schenkenberg, Bradford, and Ajax, 1980). In their experiment, a patient with neglect was asked to mark the midpoint of a line presented far away from her by using a stick. They found a similar asymmetry in the patient’s markings as in the line presented near to her indicating her neglect space was extended as their PPS expanded through tool use. Further evidence for multisensory integration in PPS derived from the studies in which patients fail to perceive contralesional stimulus (extinction) only if presented with ipsilesional stimulus at the same time although they can detect single stimulus on both sides if presented separately (Brozzoli et al., 2006). Extinction can occur both within and across sensory modalities (Maravita, Spence, and Driver, 2003). For instance, Làdavas, Zeloni, and Farnè, (1998) revealed that presenting a visual stimulus near the ipsilesional hand blocks detection of tactile stimulus on contralesional hand. Similar to findings in neglect patients with tool use, cross-modal extinction was found to extend after a tool use (Farnè, and Làdavas, 2000). These findings from tool use studies both with the neglect and extinction patients demonstrate the collaborative functioning of multisensory integration and PPS. Taken all together, the fact that integration of multisensory signals constrained to PPS points out the fundamental role of multisensory body-related signals for bodily self-consciousness (Salomon et al., 2017).

Although the brain integrates multisensory signals, weighting of the signals from different sensory modalities varies based on their reliability (Erdeniz, and Tükel, 2020). Integrating sensory signals by their reliability helps us to form more coherent perception. That is, if there is a mismatch or ambiguity between information coming from two different senses, one of them dominates the other. However, the degree to contribution of the senses is not equal and may change depending on the conditions as well as reliability of the sensory signals (Ernst, and Bülthoff, 2004). According to Bayesian approach, humans employ the optimal strategy of weighting each sensory cue in proportion to its reliability (Ernst, and Banks, 2002). For instance, the dominance of the vision was found for spatial tasks (Rock, and Victor, 1964) whereas the tactile sense was found as dominant when the vision is not reliable (Heller, 1983). This dynamic nature of the weighting of different sensory cues enhances the reliability of perception. Furthermore, evidence for the support of using optimal weighting strategy comes from the individuals with sensory loss. For instance, studies on blind individuals revealed enhanced abilities in the sensory domains of auditory (Collignon et al., 2009) and tactile (Goldreich, and Kanics, 2003). Similarly, studies on deaf individuals showed enhanced performance in processing other sensory signals such as visual or tactile (Dye, Hauser, and Bavelier, 2009; Levänen, and Hamdorf, 2001). Therefore, these enhanced abilities are likely to be attributed to the compensation of available senses for the impaired sensory system to increase perceptual reliability. Although the neural basis of the sensory weighting process is not clear, Fetsch, DeAnglis, and Angelaki (2013) revealed a relation between the activity of multisensory neurons in dorsal medial superior temporal area and differences in weighting of sensory signals. This indicates that multisensory integration and sensory weighting processes have complementary roles for each other.

1.2. From Multisensory Processing to Bodily Self-Consciousness

As mentioned previously, integration of multisensory body-related information underlies representation of the body (Blanke, 2012; Blanke, and Metzinger, 2009). Here, multisensory integration does not only allow us to interact with the environment by creating a multimodal representation of the world but also provides us a complete representation of our body. However, there is a fundamental difference between representation of the world and the body in the brain. To obtain a coherent representation of the world, the brain needs to decide whether multisensory signals originate from the same or a different object and needs to integrate different sensory signals coming from that object or objects. However, this is not the case for the representation of the body since all multisensory signals originate from the physical body such as interoception, vestibular and nociception which are continuous and not possible to access from any external object. This unique multisensory nature of the body provides basis for exploring the role of multisensory integration on bodily self-consciousness (Blanke, 2012).

How the body is represented in the brain has always received great attention from neuroscientists, neuropsychologists, and philosophers. Penfield, and Boldrey (1937) introduced the term of "homunculus" which refers to the representation of the body in somatosensory and motor cortex. They found disproportional representation of body parts in relation to the associated cortical surfaces. For example, hand and face related signals represented in a larger cortical area whereas trunk related signals represented in a relatively smaller area. The proportional differences are interpreted in terms of somatosensorial sensitivity of the body parts (Saadon-Grosman, Loewenstein, and Arzy, 2020). Further studies found somatosensory representations of the body in the middle cingulate cortex (Arienzo et al., 2006), frontal operculum (Hagen et al., 2002) and parietal lobules (Huang et al., 2012; Young et al., 2004). A recent study by Saadon-Grosman, Loewenstein, and Arzy (2020) also demonstrated somatosensory representations of the body in the insula, temporal operculum and anterior parietal lobules which are known to be involved in bodily self-consciousness and multisensory integration (Blanke, 2012). Involvement of these brain areas provides evidence for existence of higher-order representation of the body rather than just a map of body-parts (Haggard, and Wolpert, 2005).

With respect to various conceptualization of body representation, body schema and body image has become useful concepts to study bodily self-consciousness (Gallagher, 1986). Although these different concepts are somehow related, there are conceptual differences between them. The general notion that the body schema reflects a dynamic information of position and size of the body/body-parts by incoming multisensory inputs whereas the body image includes perceptual, cognitive and emotional representations of the body (Gallagher, 1986; Keromnes et al., 2019; Schwoebel, and Coslett, 2005). According to this framework, the body schema and the body image were proposed to be related however, different dimensions such as, action-perception (Paillard, 1999), conscious-unconscious (Head, and Holmes, 1911) and flexibility-stability (Morton, and O'shaughnessy, 1986) in the nervous system. Considering these different definitions, there is consensus on multisensory integration is necessary to construct the body schema contrary to body image. Therefore, in the rest of this thesis we exclude using these terms and just used "bodily self-consciousness" to indicate subjective body representation.

1.2.1. Disorders of Bodily Self-Consciousness

Neurological observations provide a direct link between bodily self-consciousness and multisensory integration. Failure to integrate information from various sensory modalities may lead to perceive bodily self as different than the physical self. There are various types of neurological conditions in which people have distorted representation of their own body. A rare disorder called asomatognosia is defined as forgetting or being unaware of one's own arm (Gerstmann, 1942). Asomatognosia is frequently experienced after brain damage to the right hemisphere, especially in temporoparietal cortex, affecting the contralesional body-part (Feinberg et al., 2000). Moreover, this experience was found to be associated with visual and somatosensory loss (Arzy, Overney et al., 2006; Feinberg et al., 2010) suggesting the importance of coordinated multisensory processing for a coherent sense of bodily self.

A related syndrome called somatoparaphrenia which is categorized as a subtype of asomatognosia, where patients feel loss of ownership or misattribute their own body-parts (Vallar, and Ronchi, 2009). Somatoparaphrenia is mostly associated with damage to the right hemisphere resulting in the contralesional arm, hand or leg belong to someone else. Visual, tactile or motor deficits are not associated with the somatoparaphrenia; however, proprioceptive deficits were found to be accompanied especially with the feeling of disownership for a body-part (Vallar, and Ronchi, 2009). The loss of proprioceptive signals might be accounted for failure in multisensory integration. Moreover, the fronto-temporo-parietal network, the insula and the prefrontal cortex was revealed to be associated with somatoparaphrenia (Feinberg et al., 2010). Involvement of these multisensory regions supported the relation between abnormal feelings of ownership and failure in multisensory processing.

Similar to neurological pathologies mentioned above, another psychiatric disorder is called "xenomelia" which is described as a feeling of non-acceptance for a body-part or parts resulting in desire for amputation (Brugger, Lenggenhager, and Giummarra, 2013). Although social and individual aspects of xenomelia were attracted more attention at first, recent neuroimaging studies revealed the association for a desire to amputate left limb with changes in the right parietal lobe and the right insula (Hilti et al., 2013; McGeoch et al., 2011). Thus, it has been linked with the disintegration of multisensory signals from the left limb.

Another disorder of bodily self-consciousness is called personal neglect identified as inattention to the contralesional hemibody and external space, frequently after damage to the right hemisphere (Committeri et al., 2007). For instance, patients do not wash, shave or make up the left side their face or comb the left part of their hair. Although personal neglect is not characterized as disturbed sense of ownership, recent research using rubber hand illusion showed that personal neglect for left hand leads to greater feeling of ownership over a left rubber hand compared to a right rubber hand (Ronchi et al., 2017). The implication of the susceptibility for the affected hand suggests an association between personal neglect and body representation, particularly the sense of body ownership. Furthermore, the link between experience of personal neglect and lesions in white matter connecting to frontal and parietal cortex which are involved in processing proprioceptive and somatosensory signals confirms the role of multisensory integration for a coherent sense of self (Committeri et al., 2007).

Phantom limb is another fascinating phenomenon that shows alterations of the perceptual experience of the bodily self. The experience of phantom limb is characterized by the sensation of a limb which is not exist (Ramachandran, and Hirstein, 1998). More strikingly, people even report somatic sensations originating from phantom limb, such as touch, warmth, position and more frequently pain (Jensen et al., 1984; Kooijman et al., 2000). This phantom phenomenon is commonly explained by the remapping of sensory networks (Flor, Nikolajsen and Jensen, 2006) or residual representation of the amputated limb (Makin et al., 2013). These explanations are based on the presence of a body part once in order to feel phantom pain. However, a case study on a person with phantoms of congenitally absent limbs challenged the previous explanations (Brugger et al., 2000). Besides the conflicting explanations of phantom limb, Ramachandran, and Hirstein (1998) revealed that the interaction between different sensory modalities can modify phantom limb sensation. They created a therapy called mirror-box illusion in which amputees' intact limb was reflected onto the space corresponding the phantom limb by using mirror. As amputees move their intact hand, they had an illusion as if their phantom also moved leading to decrease in phantom pain. The experience of pain relief is thought to be due to congruence between visual, proprioceptive and sensorimotor signals (Ramachandran, and Altschuler, 2009). Furthermore, it was found that transcranial stimulation of primary motor and sensory cortex evoked the feeling of movement of the congenitally phantom limb suggesting the role of multisensory signals for the sense of bodily self (Brugger et al., 2000). Taken all these together, the common characteristic of these pathologies is the incompatibility between multisensory inputs supported by multisensory brain regions.

In addition to these disorders which are only affecting body parts, there are disorders involving disruptions in representation of the whole bodily self which are called autoscopic phenomena. Different than the previously mentioned disorders, autoscopic phenomena do not always associated with pathological conditions and might be experienced by healthy individuals occasionally. In general, this phenomenon is described as seeing an imaginary body outside of the one's own body which alters the sense of body ownership, self-location and 1PP due to the different disturbances of multisensory integration (Blanke, and Mohr, 2005). It is categorized in three forms which are autoscopic hallucination, heautoscopy and out-of-body experience (OBE) with respect to the changes in these subcomponents (Brugger, Regard, and Landis, 1997) (see Figure 4). In autoscopic hallucination, one sees an illusory copy of one's own body from the location of physical body with no change of self-identification, self-location and 1PP (Blanke et al., 2004). In heautoscopy, one sees an imaginary body of one's own body with the experience of the 1PP and self-location as either in the physical body or the imaginary body. Alterations in 1PP and self-location accompanied by the feeling of identification with the imaginary body mostly cause to sensation of being divided in two rather than disembodiment even if the self is localized at the imaginary body (Blanke, and Mohr, 2005). In OBEs, one experiences own self-location and 1PP in position of the illusory body which identified oneself. During OBEs, people reported as if seeing their physical body from elevated location with the sense of disembodiment (Blanke et al., 2004). Given the fact that abnormalities in the sense of ownership, self-location and 1PP regarded as absent in autoscopic hallucination, partially present in heautoscopy and fully present in OBE. It was proposed that the differences in autoscopic phenomena are due to failure to integrate sensory signals depending on the dysfunction of the vestibular system (Blanke et al., 2004; Blanke, and Mohr, 2005). Autoscopic hallucinations are highly associated with visual deficits suggesting the disruption in integration of visual signals

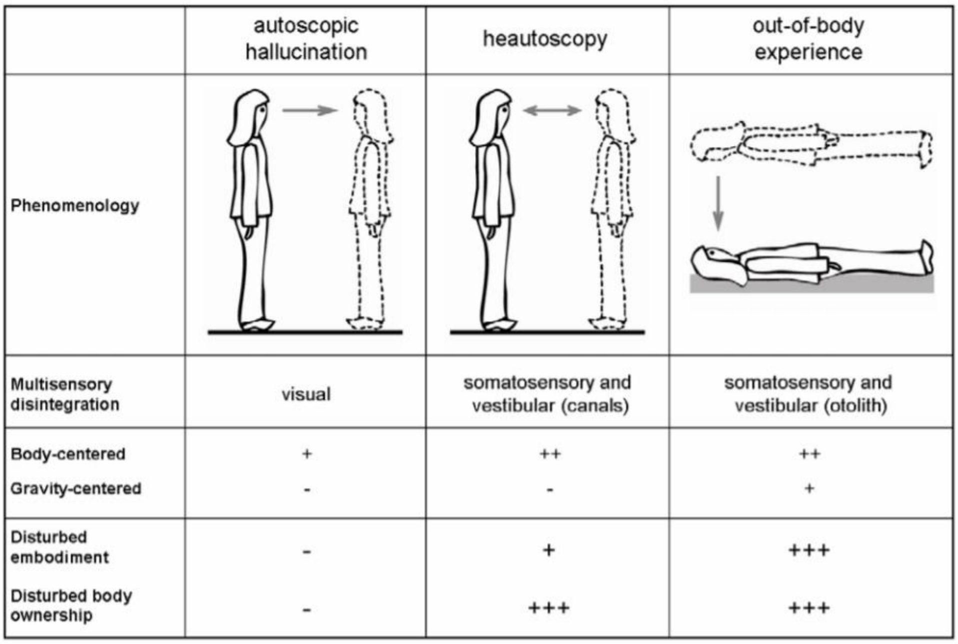


Figure 4. Illustration of autoscopic phenomena. Solid line drawings represent the physical body, dashed line drawings represent the illusory body. The direction of the arrow indicates where the 1PP and the self is located. In autoscopic hallucination, self-location and 1PP are at the congruent location with the physical body. In heautoscopy, self-location and 1PP might be in the location of the physical body, in the illusory body or change simultaneously between them. In out-of-body experiences, both of the self-location and 1PP are located at the illusory body. Thus, out-of-body experiences was attributed to abnormal body-centered reference frame (self-location outside the body) and abnormal gravity-centered reference frame (elevated self-location) (Source: Lopez, and Blanke, 2007).

with other sensory signals as a main factor for the abnormal sense of self (Blanke et al., 2004; Lopez, and Blanke, 2007). Neurological case studies support that autoscopic hallucinations are mostly reported after damage to extrastriate visual cortex (Heydrich, and Blanke, 2013). The cases of heautoscopy are mostly linked with the reports of depersonalization and abnormal interoceptive signals such as increase heart rate (Heydrich, and Blanke, 2013). Such experiences were found occur after epilepsy affecting temporal-parietal lobes (Brugger et al., 1994), lesions on the insular cortex (Brugger et al., 2006). The implication of temporo-parietal lobes and the insular cortex represented that the heautoscopy is linked with deficits in vestibular signals and coding of interoceptive-emotional signals, respectively. Similar to the heautoscopy, OBEs are more frequently reported following epilepsy, stroke and migraine as well as damage to the TPJ and electric stimulation of the TPJ (Blanke et al., 2002; Blanke et al., 2004). In addition, a recent case study performed with a patient that subcortical tissue of the TPJ stimulated during awake craniotomy provided a first direct evidence for a link between OBE like experiences with the posterior thalamic radiation (Bos et al., 2016). Furthermore, there is evidence that OBEs usually occur in supine position with the abnormal feelings of vestibular sensations such as floating and elevation (Blanke et al., 2004). Considering the role of the TPJ in multisensory integration, effect of body position related to sensitivity of vestibular receptors and the abnormal vestibular sensations, OBEs are proposed to be associated with disintegration of both visual-somatosensory and visual-vestibular information (Blanke et al., 2004). To sum, strength and type of disturbances in multisensory integration underlies the differences in forms of autoscopic phenomena.

Another bodily disorder is called Alice in Wonderland syndrome, a condition that leads to unusual perception of the body size such as bigger or smaller than usual, commonly associated with migraine (Blom, 2016). With respect to the associated brain region, temporoparietal-occipital junction which is involved in integration of visual and somatosensory inputs with vestibular inputs has been proposed as a key area (Brumm et al., 2010). Although the pathological mechanism of the syndrome is not clear and highly complex, it has been proposed that deterioration in internal representation of the body due to disintegration of multisensory signals is the primary cause (Mastria et al., 2016).

Probably one of the most interesting syndromes from bodily self-consciousness perspective is called clinical Lycanthropy. In clinical Lycanthropy, people believe that they transformed into a wolf (Blom, 2014). For instance, people may report that they want to eat raw meat, their body covered with wolf hair or they see a wolf while looking at the mirror. Although the term has been known since ancient centuries, there is no clear understanding because of the limited number of cases. There is no evidence that Lycanthropy is associated with a specific disease however, it is frequently observed in schizophrenia and affective disorders (Keck et al., 1988; Moselhy, 1999). Besides the unclear nature of the phenomenon, the condition can be considered as a bodily self-consciousness related disorder since it disrupts the relation between the individual and the body. Considering delusional misidentification syndromes such as

Capgras, Shrestha (2014) suggested Lycanthropy as a global misidentification of self which is related to disintegration of neural information.

Observations from neuroscientific studies and clinical cases mentioned above implicate the association between process of multiple information from bodily sources and the sense of bodily self. Given the disturbances in different sensory modalities among disorders of the bodily self, it is suggested that aspects of bodily self-consciousness modulated by different underlying mechanisms (Lopez, and Blanke, 2007).

1.2.2. Rubber Hand Illusion

Given the role of multisensory interactions on perception of bodily self, experimental studies on bodily self-consciousness have grounded on presenting conflicting multisensory bodily information to participants. For example, rubber hand illusion is one of the most well-known experiment which allows to study the changes in body representation in a controlled manner. In the experiment designed by Botvinick, and Cohen (1998), participants' real hand was placed behind a cover out of their view and a rubber hand was put in front of them where their real hand was supposed to be while applying either synchronous or asynchronous stroking to the real and rubber hand (see Figure 5). After watching synchronous stroking on the rubber hand and feeling stroking on their real hand for a while, participants began to perceive the rubber hand as their own and reported that they feel the strokes they saw on the rubber hand. Additionally, when the participants were asked to point out their real hand while their eyes closed, they pointed a place closer to the rubber hand which is called proprioceptive drift. The drift in perceived location of the real hand is considered as a implicit measure indicating that the brain begins to perceive the real hand as if it is at the place of the rubber hand. As another implicit measure, the autonomic physiological responses are registered while a threatening the rubber hand after the illusion. For example, if the experimenter bends a finger of the rubber hand backwards (Armel, and Ramachandran, 2003) or orients a needle towards the rubber hand (Ehrsson et al., 2007), the skin conductance responses increased. Two different interpretation was proposed for these results. Firstly, the change in skin conductance responses was explained in terms of involvement of the rubber hand into the body representation as an additional third hand (Ehrsson et al., 2007). However, subjective reports regarding the illusion revealed that participants feel as their real hand disappearing and replacing

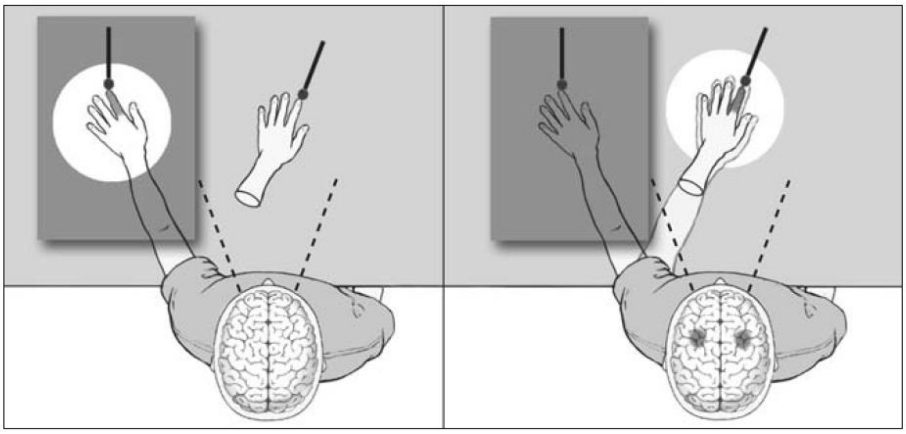


Figure 5. The rubber hand illusion. Participants real is occluded (gray square). Participants receive tactile stroking on their real hand (dark area on the index finger of the real hand) simultaneously with visual stroking on a rubber hand place in front of them (dark area on the index finger of the rubber hand).The right side of the illustration represents that participants perceived their real hand at the location of the rubber hand (Source: Metzinger, 2009).

by the rubber hand. In addition, another study found a decrease in body temperature of the participants' real hand during the illusion observed by laser thermometer (Moseley et al., 2008). In favour of these findings, Barnsley et al. (2011) also found increased histamine activity for disowned hand during the illusion. These physiological findings provide evidence that the illusion leads to replace the real hand with the rubber hand rather than accepting the rubber hand as an additional body-part. This experimental paradigm simply creates conflict in visual, tactile and proprioceptive signals which is solved by integrating synchronous visuo-tactile signals but weighting higher the visual information. However, when the rubber hand and the real hand stroked asynchronously, the illusory ownership and the proprioceptive drift disappears or decreases. This indicates that when the visual and tactile information is incongruent, weight of the visual information becomes weaker and the tactile information becomes more reliable. Thus, this paradigm is the basis for dynamic multisensory aspect of the bodily self-consciousness. On the other hand, the illusion is not only constrained by synchrony among multisensory signals but also dependent on spatial and anatomical constraints. For instance, replacing the rubber hand with a neutral object (Haans, Ljsselsteijn, and de Kort, 2008; Tsakiris, and Haggard, 2005), locating the rubber hand anatomically incompatible position with the participant (Lloyd, 2007), or presenting anatomically incongruent rubber hand, such as putting left rubber hand while stimulating participant's right hand (Tsakiris, and Haggard, 2005) result in decrease in the illusion. These constraints are in line with the research in multisensory neurons which showed increased firing rates when the seen and the felt arm positions are congruent (Graziano, 1999). In addition, it was shown that presenting a very long virtual arm (Kilteni et al., 2012) or an arm in different colour (Martini et al., 2013) can induce illusory ownership when the virtual arms connected to virtual body. These demonstrated that the extension of peripersonal space by connecting the body and the arm can compensate some spatial and physical constraints (Perez-Marcos, Sanchez-Vives, and Slater, 2011).

In line with the physiological and behavioural findings, brain imaging studies using functional magnetic resonance imaging (fMRI) and Positron emission tomography (PET) have revealed the neural correlates of the rubber hand illusion. The induction of the rubber hand illusion has been shown to be associated with magnitude of the activity in premotor and intraparietal areas (Ehrsson, Spence, and Passingham, 2004). Furthermore, the activity in the insula and sensory-motor areas was found to be critical for the ownership feeling whereas the activity in the insula with somatosensory areas was associated with proprioceptive drift (Tsakiris et al., 2007). These discrete brain areas were also supported by the studies showing the proprioceptive drift towards the rubber hand even when the feeling of ownership was not reported (Holmes, Snijders, and Spence, 2006; Rohde, Di Luca, and Ernst, 2011). Findings from the physiological and behavioural studies indicate the distinct mechanisms of multisensory integration for the ownership feeling and proprioceptive drift.

1.2.3. Full Body Illusions

Findings from the rubber hand illusion provide insights only into understanding of body-part representations because perception of participants regarding the rest of the body is not modulated. Concerning the theoretical definition of bodily self-consciousness, full body illusion has been adapted to investigate the body as a whole entity (Ehrsson, 2007; Lenggenhager et al., 2007). Using a similar protocol to the rubber hand illusion, body-ownership, self-location and 1PP which are the critical subcomponents of bodily self-consciousness was investigated in different experimental setups. In these studies, a visual stimulus presented on a virtual body or video image of participants' body through head-mounted display while a tactile stimulus was being applied on their physical body which is out of their visual field. The tactile and the visual stimuli are either in synchrony or asynchrony. The general logic behind these studies is to explore different aspects of bodily self-consciousness by manipulating different components and sensory modalities.

In one of the first studies conducted by Lenggenhager et al. (2007), systematic paradigm was developed to study bodily self-consciousness in experimental environment with healthy individuals. Video images of participants' back, mannequin back or a rectangular object were filmed by a camera placed behind participants and presented them through head-mounted display (HMD) while they were standing (see Figure 6). Thus, participants saw the virtual images in front of them. A tactile stroking was applied to participants' back while projecting the stroking on the virtually seen image either in synchrony or asynchrony. As in the RHI, synchronous visuo-tactile stroking led participants to report that they felt the touch they saw on the video image and identified themselves with the virtually seen body. Additionally, as an implicit measure of self-localization, participants were displaced and asked to return their initial location while their eyes closed. The results showed that participants returned a location ahead of their physical position, closer to the virtually seen body. It is worth to note that, participants did not feel ownership for rectangular object or localize themselves towards to it regardless of the visuo-tactile synchrony. In another study by Ehrsson (2007) used a slightly different experimental procedure. Participants saw their own back through head-mounted display connected to the camera behind them (see Figure 7). Thus, participants experienced origin of their view as being located at the position of the camera. A tactile stimulus which is a rod touching the participants' chest was applied while participants viewing a rod approaching just below the camera. Participants reported that they felt as if the video image of their back was someone else. Also, it was found that they felt the touch of the rod approaching below the camera and localized themselves to the location of the camera. The latter was indexed by higher skin conductance response to threating stimulus approaching below of the camera.

These pioneering studies showed that perception about our body that we experienced in everyday life can be modulated by manipulation of multisensory signals. In both studies, the illusion was induced only by synchronous visuo-tactile stimuli. However, Lenggenhager et al. (2007) and Ehrsson (2007) concluded with

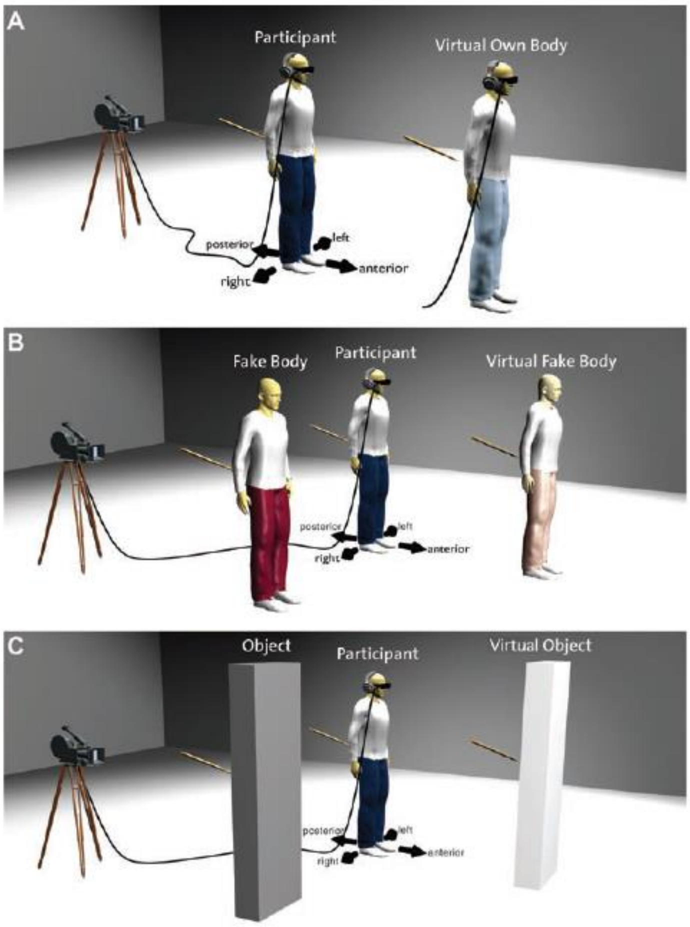


Figure 6. Full body illusion with a video image of real body, mannequin and object. Participant depicted as wearing dark trousers receive tactile stroking on the back while seeing a synchronous or asynchronous visual stroking on own backs (A), on back of a fake body (B) or on a rectangular object (C) (Source: Lenggenhager et al., 2007).

some differences in bodily experiences of the participants. In the former, virtually seen body was identified as own body and biased the participants' perception about self- location. In the latter, however, self-location was biased by the origin of participants' perspective eliciting an illusory body and virtually seen body did not lead to self-identification. Regarding these differences, Meyer (2008) proposed that the location of the seen stimulus responsible whereas Blanke, Metzinger, and Lenggenhager (2008) considered differences in weighting of sensory modalities. To make more reliable conclusion, a comparative study was carried out with identical

Figure 7. Illusory out-of-body experience by Ehrsson (2007). Participant depicted with solid drawing received tactile stroking on own chest while the experimenter approaching a visual stroking below viewpoint of the camera which corresponds to participant's physical chest. Participant sees own back through HMD (Source: Wolfe et al., 2015).

body positions and measurements by Lenggenhager, Mouthon, and Blanke (2009). Participants saw their video image while a tactile stimulus was being applied to their back and chest either synchronously or asynchronously with the use of mental ball dropping task (MBD) as an implicit measurement of self-location. Results revealed that seeing back of the virtual body from 3PP synchronously stroking led to stronger self-identification with the body and shift in self-location towards the virtual body. However, seeing chest of an illusory body is stroking from 1PP while viewing a virtual body in the front led to decreased in self-identification with the virtually seen body and drift in self-location towards the illusory body. In another related study, Petkova, and Ehrsson (2008) induced body swap illusion by connecting the cameras worn by the experimenter and the participants. In this way, participants looked at their physical body from the experimenter's perspective while shaking their hands. Synchronous handshake led participants to feel ownership over experimenter's body. More interestingly, skin conductance responses revealed that participants were more scared if the threating object approached to the experimenter's body rather than their physical body. Taken all these findings together, these studies showed the influence of congruent visuo-tactile integration, origin of visuo-spatial perspective and their interactions for experience of bodily self. Further studies investigated how the other sensory modalities impact bodily self-consciousness such as visual-motor (Kannape et al., 2010), visual-cardiac (Aspell et al., 2013), visual-respiratory (Adler et al., 2014) and more recently, visual-gravitational (Thür et al., 2019), visual-vestibular (Blom, Arroyo-Palacios, and Slater, 2014; Macauda et al., 2015; Pfeiffer et al., 2013) resulting in different phenomenological and behavioural outcomes. These provided insights about that not only visuo-tactile stimuli but also integration of other exteroceptive and interoceptive signals from the body on bodily self-consciousness.

Beyond these findings, studies on brain areas underpinning different subcomponents of bodily self-consciousness provide clear understanding by implicating several key brain areas. It has been suggested that body ownership and self-location are distinct but related components whereas self-location and 1PP proposed as associated (Serino et al., 2013). An fMRI study with body swap illusion conducted by Petkova et al. (2011) revealed that strength of illusory ownership for virtual body was accompanied by the activity in ventral premotor cortex (vPMC). This gave rise an argument whether the vPMC was activated only because of multisensory integration or not. Using Rubber hand illusion, Brozzoli, Gentile, and Ehrsson (2012) revealed that vPMC was activated only after the illusory ownership for the rubber hand indicating the specific role the vPMC on the feeling of ownership. Noting that the insula was also found as another activated region involved in feeling of ownership beyond the vPMC (Tsakiris et al., 2007).

Another fMRI study conducted by Ionta et al. (2011) inducing full-body illusion found that change in self-location towards the virtual body was correlated with activity in temporo-parietal junction (TPJ). More strikingly, although same visuo-tactile stimuli were applied to participants, half of them experienced themselves as looking upward to the virtual body whereas other half experienced as looking downward to the virtual body. Experienced direction of participants' visuo-spatial perspective was also accompanied by changes in self-location. These changes in self-location and visuo-spatial perspective was found to be associated with activity in TPJ. It was suggested that multisensory integration at TPJ reflects the feeling of being in a space which coincides with visuo-spatial perspective where the world is experienced from (Ioanta, Gassert, and Blanke, 2011).

1.2.3.1. The role of 1PP on Bodily Self-Consciousness

Our perception about the self, body and world is only available from a specific form of perspective, experiencing through our eyes within the body which is known as 1PP (see Figure 8). However, we are also able to adopt someone else's viewpoint which is called third-person perspective. At cognitive level, the former use egocentric reference frame which is originated from the body whereas the latter use allocentric reference frame which is localized at outside the body in space (Vogeley, and Fink, 2003). At phenomenal level, the key distinction between 1PP and 3PP is that 1PP is underlying of our all multisensory experiences which relates the self and body as well

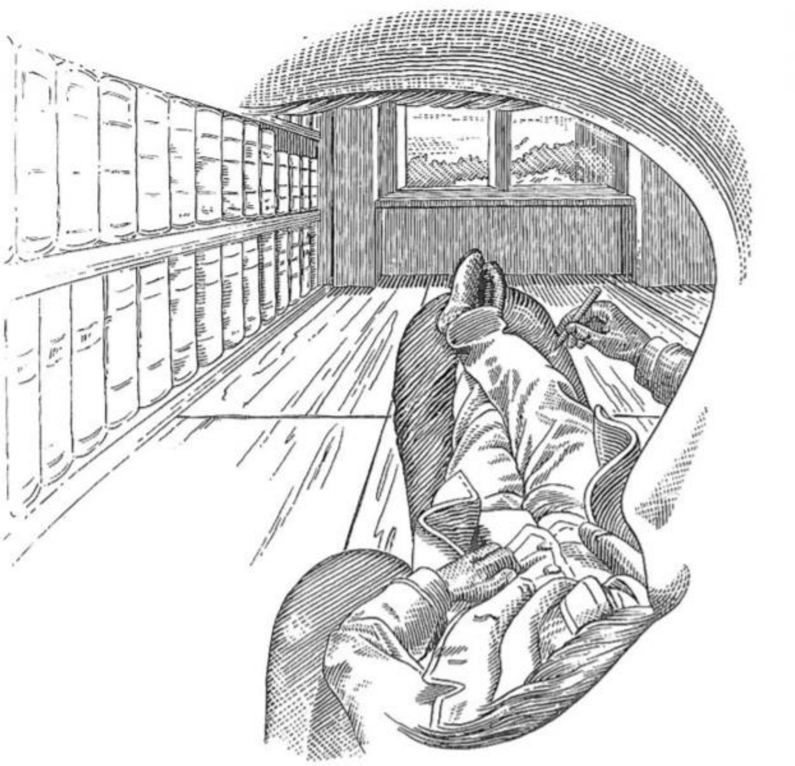


Figure 8. Ernst Mach's illustration of his subjective visuo-spatial perspective. He illustrated unity among his body, his perspective, and the world by depicting a viewpoint only from his left eye (Source: Mach, 1914).

as perception of the world (Vogeley et al., 2004). Thus, this incorporated nature of 1PP on our overall experiences suggests the visuo-spatial perspective as a fundamental component for bodily self-consciousness in addition to influence of multisensory signals. In line with this, it is thought that 1PP has major role in creating body schema in the brain (Berlucchi, and Aglioti, 1997).

Most of the studies investigating 1PP are in the field of spatial cognition research such as perspective taking tasks which includes mentally adopting another perspective (van Elk, and Blanke, 2014; Vogeley et al., 2004). These studies show that cognitive abilities differ depending on whether having 1PP centered on the body or having 3PP corresponding to viewpoint of another. Vogeley et al. (2004) conducted an fMRI study to identify neural process related to 1PP and 3PP. They presented participants with an image of an avatar surrounded by balls. The task of the participants was to determine number of the balls that can be seen from either avatar's perspective (3PP) or their own perspective (1PP). They found an association between increased activity in medial prefrontal and parietal cortex during 1PP whereas increased activity in superior parietal and premotor cortex was observed during 3PP. This provided an evidence for the differential neural processing of 1PP. Furthermore, it was shown that reaction times of participants increase when they need to adopt a viewpoint which does not coincide with origin of their viewpoint (van Elk, and Blanke, 2014; Vogeley et al., 2004). This was suggested as evidence for that perspective taking requires transformation of the body implicating the embodied process of 1PP and the body (Kessler, and Thomson, 2010). Visuo-spatial perspective thus can be considered as a reference frame that enable us to make self-other distinction. This indicates the essential role of 1PP on bodily self-consciousness (Gallagher, 2000).

In terms of the feeling ownership of a body, full body illusions showed that the ownership can be induced by both 1PP (Petkova, and Ehrsson, 2008; Petkova et al., 2011; Slater et al., 2010) and 3PP (Gorisse et al., 2017; Lenggenhager et al., 2007; Lenggenhager, Mouthon, and Blanke, 2009). In the experiments in which participants watch a video image of their body from 3PP, the sense of body ownership was elicited only if synchronous multisensory stimuli were being applied to the virtual body and the physical body (Adler et al., 2014; Aspell et al., 2013; Lenggenhager et al., 2007; Lenggenhager et al., 2009). Petkova, and Ehrsson (2008) were the first ones to demonstrated that in addition to synchronous multisensory stimuli, having 1PP over a mannequin or another person's body can induce an illusory ownership. Further, Slater at al. (2010) directly investigated the influence of 1PP and 3PP. They found dominance of 1PP for the feeling of ownership with enhancing effect of visuo-tactile synchrony which was supported by increased physiological response to threating situation when participants had 1PP with respect to the virtual body compared to 3PP. Extending these findings, it has been showed that seeing a virtual body from 1PP while only having able to control head movements of the virtual body results in the feeling of ownership regardless of any other congruency between visuo-motor or visuo-tactile stimuli, supported by physiological changes (Debarba et al., 2017; Kokkinara et al., 2016). Moreover, Debarba et al. (2017) found similar sense of body ownership for a virtual body seen from 3PP and 1PP but only when participants could control whole movements of the virtual body and receive synchronous visuo-tactile stimuli. Further studies supported the fact that the sense of ownership can be induced with virtual body which is different in terms of gender, age and race while 1PP and visuo-motor synchrony (Banakou, Groten, and Slater, 2013; Peck et al., 2013; Slater et al., 2010). Another study by Maselli, and Slater (2013) showed sole effect of seeing a realistic and gender matched virtual body from 1PP for inducing the feeling of body ownership without any need for visuo-tactile or visuo-motor including head movements. Taken together, although these findings point out the advantageous role of 1PP on the feeling of body ownership, it is clearly shown that the ownership feeling depends on correlation of multiple factors.

Research on bodily illusions also investigate the relation between the sense of self-location and 1PP. The relation between self-location and perspective is more complex aspect of bodily self-consciousness since the experienced position of them is at the same location in daily life. Experimental investigations showed changes in self-location can be induced for a video image of participants'' back (virtual body) seen from 3PP by synchronous visuo-tactile stimuli (Ehrsson, 2007; Gutersdam, and Ehrsson, 2012; Lenggenhager et al., 2007). However, the changes in self-location influenced by the origin of perspective. In the study by Lenggenhager et al. (2007), participants saw visual touch on back of the virtual body from 3PP while feeling touch on the back of their physical body resulting in drift towards the virtual body. However, in studies by Ehrsson (2007) and Gutersdam, and Ehrsson (2012), participants saw the virtual body's back from 3PP while visual stimulus approaching origin of their 1PP which was matched with the felt touch. This induced change in self-location towards the location of 1PP. Maselli (2015) proposed that the spatial congruency might be accounted for these differences. Accordingly, feeling the seen touch is unexpected creating a spatial conflict in the back stimulation whereas the seen touch is expected to be felt without any conflict in the chest stroking. Another explanation for changes in the back stroking proposed by Noel et al. (2015). They investigated the relationship between change in self-location and peripersonal space by adopting the experimental design by Lenggenhager et al. (2007). It was supported that extension of the boundaries of PPS towards the virtual body is accompanied by change in self-location towards the virtual body. On the other hand, Pfeiffer et al. (2013) showed that self-location depends on the experienced direction of 1PP in addition to the synchrony of visuo-tactile stimuli suggesting the critical role of 1PP. Furthermore, it was revealed that seeing someone else's body from 1PP which is spatially congruent with the physical body induces a change in self-location without the need of synchronous visuo-tactile stimulation (Gutersdam et al., 2015; Maselli, and Slater, 2013). More recently, the definition of self-location was addressed since some of the previous studies related it with body-location and others with location of 1PP (Huang et al., 2017). Body-location and location of 1PP were found as distinct but related which collectively contribute to the sense of self-location. They suggested that the sense of self-location result from correlation between location of 1PP and body-location. To conclude, all these findings point the importance of 1PP on the sense of self-location, as in the sense of body ownership.

1.3. The Vestibular System

The vestibular system is responsible for a variety of processes involving spatial navigation (Angelaki et al., 2009), balance (Horak, 2010), attention (Figliozzi, et al., 2005), perception of self-motion (Green et al., 2005), mental transformations (Lenggenhager, Lopez, and Blanke, 2008; Mast, Merfeld, and Kosslyn, 2006; van Elk, and Blanke, 2014) and verticality perception (Lopez et al., 2007). However, its exclusive function is to sense body orientation and body motion by sensing gravitational acceleration in head movements (Day, and Fitzpatrick, 2005a). Two different vestibular organs exist, the semicircular canals and the otolith sensors. Both of these organs by using hair cells calculate the fluid shift and inform the brain about spatial orientation and motion of the physical body (Angelaki et al., 2009; Day, and Fitzpatrick, 2005a). When the head is rotated, endolymph which is a liquid found in semicircular canals flow through the canals causing pressure on hair cells. This allows brain to detect plane of the head rotation. On the other hand, otolithic organs, the utricle and saccule, are responsible for detecting horizontal and vertical movements, respectively. The calcium carbonate crystals attached to the hair cells within these organs pulls the hair cells in response to the orientation of the head relative to the gravity. These shift pulls the hair cells and provide the brain with information about linear accelerations and gravitational forces (Lacquaniti et al., 2014). These two integrative sensory organs constantly sense the orientation and motion of the body in space.

The vestibular system differs from other sensory modalities by means of its distributed cortical network which is shared with other sensory modalities such as somatosensory, vision, proprioception which underpins the multisensory nature of the vestibular system (Lopez, and Blanke, 2011). The central nervous system consists of several pathways which are responsible for vestibular signal projections to the vestibular nuclei and thalamus from peripheral sensory organs and then to the cerebral cortex from the thalamus (Barmack, 2003; Lopez, and Blanke, 2011). The vestibular nuclei which known to be a main relay structure for vestibular signals participate in vestibulo-ocular reflexes to compensate eye movements (Lackner, and DiZio, 2005), vestibulo-spinal reflexes to maintain postural control (Wilson, and Peterson, 1978). In addition, the vestibular nuclei play crucial role in motor control by differentiating self-generated movements from passive movements (Roy, and Cullen, 2004). Signals from the vestibular nuclei projected into several thalamic nuclei rather than specific thalamic nucleus (Meng et al., 2007), unlike other sensory modalities which has specific thalamic nucleus except olfactory processing (Pinault, 2004, but also see Tham, Stevenson, and Miller, 2009). Several electrophysiological studies in monkeys found activation corresponding to vestibular inputs in ventroposterior complex of the thalamus which is involved in process of somatosensory signals (Büttner, and Henn, 1976; Marlinski, and McCrea, 2008a). Further anatomical studies revealed vestibular projections in the ventroanterior thalamic nucleus, ventrolateral thalamic nuclei in animals (Kotchabhakdi et al., 1980; Lang, Büttner-Ennever, and Büttner, 1979; Matsuo et al., 1999), as well as in posterolateral thalamus in humans (Dieterich et al., 2005). Another role of the thalamus is identified as differentiating active and passive head movements by neural processing within it indicating the integration of vestibular and motor inputs (Marlinski, and McCrea, 2008b). Electrophysiological studies also found response of vestibular neurons in thalamus to somatosensory inputs (Deecke, Schwarz, and Fredrickson, 1977). Furthermore vestibular information from the thalamic nuclei is projected to the cerebral cortex, however there is no well-identified vestibular area in the cortex for vestibular processing (see Kotchabhakdi, and Walberg, 1978; Lai et al., 2000; de Waele, and Vidal, 2005). In one of the first study in cortical processing of vestibular signals by Guldin, and Grüsser (1998), vestibular neurons were identified in parieto-insular vestibular cortex (PIVC). Most of the neurons in this area not only play role in vestibular processing but also somatosensorial and visual processing, in addition to the integrating vestibular, visual, proprioceptive and somatosensorial information (Grüsser, Pause, and Schreiter, 1990; Grüsser et al., 1994). In addition, other studies on humans revealed several cortical areas processing vestibular information such as posterior insula and temporo-parietal junction (TPJ) (Kahane et al., 2003). All these studies suggest that there is a highly distributed vestibular activation exists in various cortical regions indicating the multisensory nature of the vestibular system (Lenggenheger, and Lopez, 2015).

Regarding the multisensory processing of vestibular signals and its role on sensing the body orientation, the vestibular system is considered as critical for spatial aspects of bodily self-consciousness (Lopez, 2015; Pfeiffer, Serino, and Blanke, 2014). The fact that the vestibular system encodes the orientation of the body with respect to environment suggests the association between the vestibular signals and self-location and 1PP (Lopez, Halje, and Blanke, 2008). This association was supported by the evidence showing that the combined processing of vestibular signals with other sensory signals at the TPJ reflects changes in the experience of self-location and visuo-spatial perspective (Ionta, Gassert, and Blanke 2011). In the following sections, the contribution of vestibular system to bodily self-consciousness will be described in more detail reviewing the effects of natural and artificial vestibular stimulations on different aspects of bodily self.

1.3.1. The Vestibular System for Self-Orientation Perception

Self-orientation described as the sensation about the position and the orientation of the body with respect to the world. As already mentioned above, the vestibular system is essential for processing the body orientation. For instance, the fact that we can sense our body position even when our eyes closed implies the unique feature of the vestibular system for body orientation (Lacquaniti et al., 2014). However, integration of the vestibular signals with information from other sensory signals also plays important role in perception of body orientation (Lackner, and Dizio, 2005). Proprioceptive information from neck muscles, somatosensory information from the soles, visual information about the environment, interoceptive information from blood vessels jointly generate representation of body orientation. Integration of these signals from different senses with graviceptive information from the vestibular system establish internal model of gravity (Angelaki et al., 2004; Mittelstaedt, 1983). These studies suggest that this internal model enables us to determine our body orientation (Barra et al., 2010). Since this internal model evolved on earth gravity, any modulation of it disrupts the perception of the world and body. It is crucial to understand how this integration processes works. For example, space flight studies showed that when the graviceptor signals are missing, astronauts lose their sense of verticality and experience illusion of orientation reversal (Lackner, 1992; Oman, 2003). These illusions in perception of verticality and body orientation under micro gravity environments are evidence for multisensory nature of the internal model of gravity and the effect of gravity on perception of the body. Given the limited numbers of studies under weightless environments, past research mostly focused on reorientation illusions to specify the contribution of visual orientation changes and physical body changes on perceived self-orientation (Carriot, DiZio, and Nougier, 2008) (see Figure 9). Typically, reorientation illusions aim to alter perceived self-orientation by modulating the visual information (Goodenough et al., 1982; Held, Dichgans, and Bauer, 1975; Sigman, Goodenough and Flannagan, 1978; Witkin, 1949), changing the body position (Groen, Howard, and Cheung, 1999; Carriot et al., 2006), or manipulating both the visual information and the body orientation (Howard, and Hu, 2001; Witkin, and Asch, 1948).

Regarding the visual information, several factors like visual frame, polarity of visual scene and visual motion were found to be important for self-orientation perception (Howard, and Childerson, 1994). A good example for this is, when upright participants asked to judge their orientation in front of a tilted frame, they report as if they perceived their body as tilted (Goodenough et al., 1982; Sigman, Goodenough, and Flannagan, 1978; Witkin, 1949). Moreover, the influence of polarized scene such as a room with furniture and objects on perceived self-orientation was also shown in previous studies (see for example, Howard, and Childerson, 1994). For example, in an earlier study, a square frame tilted 28° was found to induce illusory self-tilt only about 2.8° (Sigman, Goodenough, and Flannagan, 1978). However, a fully furnished room

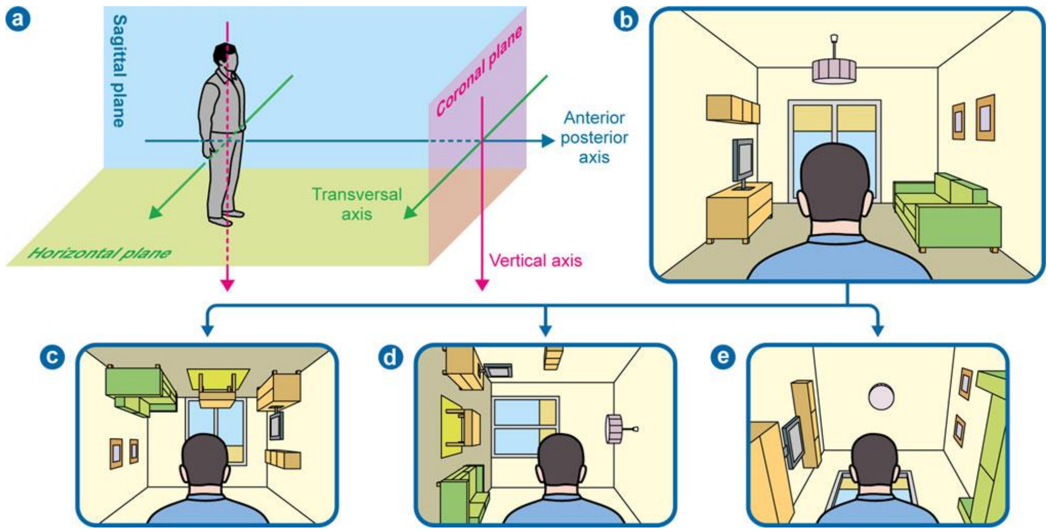


Figure 9. Illustration of a room tilt and reorientation illusions. a) Participants' planes and axes with respect to the room. b) Participants' point of view when the room is vertical. c) Participants' view when the room is inverted upside down. d) Participants' view when the room rotated in 90° towards right. e) Participants' view when the room rotated in 90° towards vertical axis (Source: Sierra-Hidalgo et al., 2012).

tilted 120° led participants to experience themselves as 15° tilted (Howard, and Childerson, 1994). When people were in the upright body position, it was shown that they rely heavily on the vestibular signals and this was accounted for the findings in both of these previously mentioned studies on self-orientation (Groen, Jenkin, and Howard, 2002). This is also supported by a previous finding that showed, when the participants were in supine position, they experienced themselves as 12° tilted in front of a 28° tilted frame whereas the upright participants perceived themselves tilted only about 5° (Witkin, and Asch, 1948). Furthermore, Howard, and Hu (2001) investigated the effect of different body positions on self-orientation in a tilted furnished room by asking participants to estimate "down direction" and orientation of their body with respect to the gravity. In their experiment, participants were standing, supine, prone, lying on their side or totally inverted. The room was either vertical, inverted or tilted 90° with respect to each body position. They showed that estimations of standing participants were aligned with the gravity regardless of orientation of the room. On the other hand, estimations of non-standing participants were influenced by gravitational direction provided by the room. Thus, the authors concluded that reorientation illusions are less likely to occur in upright body position. Finally, visual motion has also found to influence perceived self-orientation. For example, rotating a visual scene in roll axis produced illusory self-tilt about 15° in upright participants with the perception of self-motion in the opposite direction (Held, Dichgans, and Bauer, 1975). Similarly, tumbling illusion in which a furnished room rotated while participants were sitting in the room induced an illusion of self-motion in the opposite way (Allison, Howard, and Zacher, 1999; Howard, and Childerson, 1994). It was also shown that tilted body position produced greater illusory self-motion (Young, Oman, and Dichgans, 1975).

These reorientation illusions emphasized the importance of processing multisensory information for self-orientation perception. The differences in illusory self-orientation based on body position were attributed to specific contribution of vestibular, somatosensory, and proprioceptive information about gravity (Lackner, and DiZio, 2005). For instance, Mittelstaedt (1999) highlight the importance of compensatory contributions of proprioceptive and somatosensory inputs in addition to the vestibular signals for perceived body orientation. More recently, Bringoux et al. (2003) suggest that the somatosensory inputs as more important than vestibular signals for perception of body orientation while moving at slow velocities. On the other hand, artificial vestibular manipulation was found to induce illusory body rotation indicating the role of vestibular system (Day, and Fitzpatrick, 2005b). Taken together, the influence of body position on reorientation illusions supports the contribution the vestibular signals on self-orientation. The fact that participants are more susceptible to reorientation illusions in supine position was attributed to decreased sensitivity of vestibular receptors (Howard, and Hu, 2001).

1.3.2. From Verticality Perception to Bodily Self-Consciousness

Verticality perception is based on the same mechanisms of perception of self-orientation. Specifically, our perception of verticality and self-orientation requires the process of weighting and integration of vestibular, somatosensory, and visual signals providing information about gravity, body position and visual environment, respectively. (Lopez et al., 2011). In general, the perception of verticality was studied by asking participants to orient a line with respect to their inner representation of gravitational direction. A well-known experimental paradigm to study perception of verticality is the rod and frame test (RFT) (Witkin, and Asch, 1948). In RFT, people are asked to orient a tilted line which is embedded in a tilted frame into the vertical position relative to gravity (see Figure 10). The degree of perceived verticality deviates as function of participants' reliance on different sensory signals. Participants with greater deviations are classified as Visual Field Dependent implying highly weighting of visual signals whereas participants with smaller deviations are classified as Visual Field Independent indicating higher weighting of vestibular or somatosensory signals (Lopez et al., 2006; Pfeiffer et al., 2013; Witkin, and Asch, 1948). Independently of visual field dependency, body tilt was found to increase the amount of deviation in verticality judgements (Guerraz, Poquin, and Ohlmann, 1998; Van Beuzekom, and Van Gisbergen, 2000). Further studies investigated the effect of body position and showed that more accurate verticality judgements were performed during standing position compared to supine (Goodenough et al., 1981; Lichtenstein, and Saucer, 1974; Templeton, 1973) and in unbalanced postures compared to standing and sitting positions (Bray et al., 2004). In line with these findings, supine position was confirmed to be associated with less accurate verticality judgements when compared to sitting and standing positions (Lopez et al., 2008). These differences are likely explained by reduced vestibular signals in supine position since the body is not aligned with gravity (Lopez, and Blanke, 2010). Supporting the role of vestibular signals and body

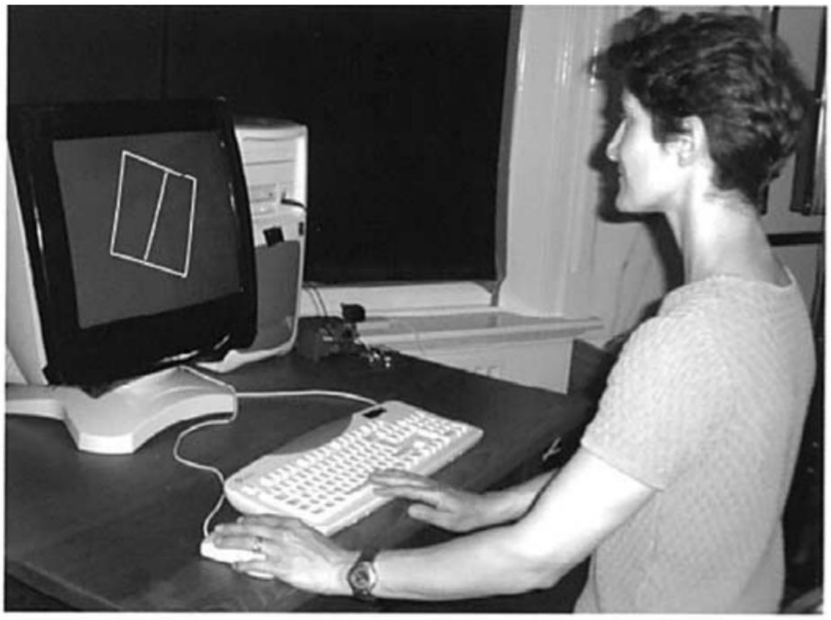


Figure 10. Computer based Rod and Frame Test. Participants sat in front of a computer. The rod and the frame were presented tilted either in left or right direction (Source: Bagust, 2005).

orientation, Lopez et al. (2008) found that patients with unilateral vestibular deficiency which leads to impairment in vertical perception and postural control performed more accurate verticality judgements in standing position after a surgical treatment. Further evidence that supine body position is related with decreased vestibular signals comes from a study by Saj et al. (2005) who studied patients with spatial neglect. They revealed that spatial neglect patients made more accurate verticality judgements in supine position than sitting. Since the spatial neglect is associated with asymmetrical otolith signals from the inner ears (Pizzamiglio, Vallar, and Doricchi, 1997), the improvement in verticality judgements was proposed to be related to more symmetrical otolith signals due to decreased sensitivity in those signals in supine position (Lopez et al., 2008).

Extending the findings from verticality perception, OBEs provide evidence that body position is also important for bodily self-consciousness. Around 73% of healthy individuals (Green, 1968) and 80% of neurological patients (Blanke, and Mohr, 2005) reported that OBEs occurred while they were in supine position. The fact that OBEs mostly occur in supine position is proposed to be due to modification of the weighting of sensory signals depending on the body position (Lopez, and Blanke, 2010). That is, supine position decreases vestibular, motor, and somatosensory signals, thus the weighting of vision enhances resulting in visual dependent form of bodily self. In line with these, full-body illusions support the link between body position and vestibular signals showing that inducing full body illusion in supine position lead to change in self-location and vestibular sensations such as, floating (Ionta et al., 2011; Lenggenhager, Mouthon, and Blanke, 2009). Moreover, Pfeiffer et al. (2013) revealed a positive association between individual differences in the weighting strategies of different sensory signals with the alterations in self-location and 1PP. In their study, they induced full body illusion and additionally provided participants with visuo-vestibular conflict by manipulating the visual cues about the gravity while the participants were in supine position. Visual field dependent participants put themselves in the virtual body’s position and switched their perspective into imagined position whereas visual field independent participants experienced their self-location and perspective at the location of their physical body. This influence of visual field dependency also corroborates with a study of rubber hand illusion showing that FD participants experience greater proprioceptive drift towards the rubber hand compared to FI participants (David, Fiori, and Aglioti, 2014). Another study created full body illusion with conflicting visuo-graviceptive information by presenting the virtual body in tilted orientation (Thür et al., 2019). They also showed that only visual field dependent participants changed their perception about body orientation in tilted condition. It is worth to note that this change in perception was specific to synchronous visuo-tactile stimulation indicating the importance of weighting of different sensory signals. In a more recent study by Macauda et al. (2015), the influence of conflicting visuo-vestibular information on full body illusion was investigated in a relatively different setup. In their study, participants were presented with visual information about self-motion from 1PP in virtual reality while they were passively moving on a motion platform. They did not find an influence of visuo-vestibular conflict on subjective expressions of body ownership, but they reported that visuo-vestibular congruency led decrease in skin temperature which is accounted as an indicator of the feeling of ownership (Salomon et al., 2013; but also see de Haan et al., 2017). This data is compatible with previous studies showing reduced skin temperature during illusory feeling of ownership for a rubber hand (Moseley et al., 2008; Tsakiris, Tajadura-Jimènez, and Costantini, 2011) or a virtual body (Salomon et al., 2013). All these findings emphasize the importance of vestibular information for bodily self-consciousness.

1.3.3. The Effects of Vestibular Stimulations on Bodily Self-Consciousness

In addition to previously mentioned studies exploring the effects of vestibular system on self-orientation, application of caloric vestibular stimulation (CVS) and galvanic vestibular stimulation (GVS) is another approach to systematically investigate the contribution of vestibular signals on bodily self-consciousness (Lopez, and Blanke, 2007). These techniques differ in the way how they applied to participants and sensory organs they activated in the vestibular system. For example, CVS is applied by injecting cold/warm water/gas to external acoustic meatus resulting in stimulation of horizontal semicircular canals that encode yaw rotation whereas GVS is applied by fixing anode and cathode on mastoid bone resulting in stimulation of vertical canals that encode pitch and roll rotation (Lopez, Blanke, and Mast, 2012). Although both techniques are widely used, GVS offer easier control for the properties of the stimulation compared to CVS. Besides the physiological and technical differences, the most promising evidence for the contribution of vestibular signals to bodily self-consciousness comes from the studies with artificial vestibular stimulations leading alterations in bodily senses. For instance, Ferrè, Bottini, and Haggard (2011) found that CVS improved sensitivity to detect a somatosensory stimulus in healthy participants. Moreover, CVS and GVS are found to increase somatosensory pain perception in healthy participants (Ferrè, Vagnoni, and Haggard, 2013). An fMRI study showed that application of a painful stimulus and CVS result in activation of same brain areas (Zu Eulenburg et al., 2012) indicating the involvement of vestibular signals on bodily senses. Further research in healthy participants by Ferrè, Vagnoni, and Haggard (2013) and Lopez et al. (2012) showed that artificial vestibular stimulations led alterations in perception of hand size confirming the contribution of vestibular on body perception. Interestingly, a recent study investigating body perception in virtual reality by Karnath et al. (2019) did not find any influence of either GVS or CVS on body representation.

Clinical observations also revealed beneficial effects of vestibular stimulation on bodily disorders and provided evidence for the link between vestibular signals and body representation. For example, application of GVS and CVS in patients with somatosensory extinction due to brain damage temporarily showed enhanced perception of somatosensory signals (Kerkhoff et al., 2011; Vallar et al., 1990). Additionally, a case study of a patient with macrosomatognosia (a disorder in which body parts perceived as disproportionately) demonstrated the transient improvement of the body perception by CVS (Rode et al., 2012). Similarly, CVS improved symptoms of neglect syndrome (Rossetti, and Rode, 2012). It was also found that CVS led alterations in perceived orientation and shape of the phantom limb (Le Chapelain et al., 2001). Furthermore, André et al. (2001) applied CVS to amputees and showed that the stimulation not only change the phantom perceptions but also can create the phantom limb sensation even the sensations was not experienced before.

Although there are not many studies that directly investigate the influence of artificial vestibular stimulation on full-body illusions, clinical and experimental observations emphasize the contribution of vestibular signals on different aspects of bodily self-consciousness. For instance, one of the earlies evidence comes from a patient with somatoparaphrenia who believe that her left hand was belong to someone else (Bisiach, Rusconi, and Vallar, 1991). After the application of CVS, the patient reported normal sense of ownership for her hand. Experimental evidence of vestibular contribution to the sense of ownership in healthy participants obtained by the rubber hand illusions with artificial vestibular stimulation. Lopez, Lenggenhager, and Blanke

(2010) found that GVS led to stronger subjective feeling of ownership. By contrast, any influence of the vestibular stimulation was not found in a non-visual version of the rubber hand illusion suggesting the dominant role of the vision compared to vestibular signals for ownership (Lopez, Bieri et al., 2012). However, another study by Ferrè, Berlot, and Haggard (2015) showed that GVS reduced the sense of ownership and proprioceptive drift in the rubber hand illusion. They suggested that GVS plays a modulatory role of reweighting different sensory modalities. More interestingly, a recent study by Ponzo et al. (2018) found that there is a significant influence of GVS on proprioceptive drift but not on the feeling of ownership in the rubber hand illusion. Taken together, all these previously mentioned studies suggest that there is a influence of vestibular stimulation on multisensory integration by indirectly promoting vision (Lopez, Lenggenhager, and Blanke, 2010; Ponzo et al., 2018), proprioception (Ferrè, Berlot, and Haggard, 2015) or no influence in the absence of vision (Lopez, Bieri et al., 2012). Recently, Preuss, and Ehrsson (2019) investigated the influence of GVS on full body illusion. They applied GVS to evoke illusion of congruent visuo-vestibular conflict. Their results showed that the sense of ownership for the virtual body increased solely result of congruent visuo-vestibular conflict. Although the results appear as conflicting, they highlight the critical role of vestibular signals on sensory reweighting process of various sensory signals and thus changes in bodily self-consciousness.

Further studies demonstrated the influence of vestibular stimulations on other components of bodily self-consciousness (Lenggenhager, and Lopez, 2015). The coexistence of vestibular dysfunction in patients experiencing disrupted sense of unity between the body and the self provided basis for the vestibular contribution to self-location and its related component 1PP. OBEs which lead to experience the world from a perspective outside of the self-location are mostly associated with damage at the TPJ that is considered as main vestibular region (Blanke et al., 2004; Ionta, Gassert, and Blanke, 2011). Depersonalization, characterized by losing familiarity or being detached from the self and the body (Simeon, and Abugel, 2006), is also more frequently found in vestibular patients (Sang et al., 2006). The involvement of the vestibular system from these observations supported by the experimental evidence showing that OBEs and depersonalization symptoms can be evoked by stimulating TPJ (Blanke et al., 2002) and by application of CVS (Sang et al., 2006), respectively. Indirect evidence for the vestibular contribution to self-location also comes from the studies indicating that GVS induces the sense of body rotation (Fitzpatrick et al., 2002) and body sway (Fitzpatrick, and Day, 2004). Similarly, another line of research supported the role vestibular signals by using mental own body rotation tasks (Lenggenhager, Lopez, and Blanke, 2008; Mast, Merfeld, and Kosslyn, 2006; van Elk, and Blanke, 2014). In these tasks, participants are presented with a picture object or body and asked to make left-right judgements from the perspective of the object or the body. It was proposed that to solve the task with the body, but not with the object, participants mentally rotate their own body (Zack, and Tversky, 2005). The mental own body rotation tasks were also found to activite the TPJ supporting the involvement of vestibular processing (Arzy, Thut et al., 2006). In addition to that neurological evidence showed that it is more difficult for patients with bilateral vestibular dysfunction to perform mental own body rotation tasks (Grabherr et al., 2011). In support of the vestibular contribution, Lenggenhager, Lopez, and Blanke (2008) showed GVS impairs the mental own body rotation performance in healthy participants, however, controversial findings have been observed. One controversial finding by Falconer, and Mast (2012) showed that CVS improves the performance on mental own body rotation. More recently, Ferrè, Lopez, and Haggard (2014) used graphesthesia task to understand whether participants interpret ambiguous tactile letters (e.g. b, d, p, q) drawn on their body from 1PP or 3PP. That is, participants can perceive “d” when “b” drawn on their body (1PP) or participants can perceive “d” when “d” drawn on their body (3PP). They applied GVS during the task and found that GVS leads participants to interpret the letters from 1PP. Taken together, experimental findings and neural correlate of abnormal bodily experiences point out the crucial influence of vestibular processing on self-location and visuo-spatial perspective.

CHAPTER 2: EXPERIMENT

2.1. The Aim of the Thesis

The aim of the present thesis is to demonstrate the influence of vestibular system and to test differences in sensory weighting strategies of individuals on bodily self-consciousness. In order to reach that goal, full body illusion was induced in a supine position while the virtual body was standing upright resulting in visuo-vestibular conflict. This experimental setup allowed testing for the influence of decreased vestibular signals on solving visuo-vestibular conflicts. Synchronous visual stimulus on the virtual body and tactile stimulus on the physical body were applied to create full body illusion while asynchronous visuo-tactile stimuli used as a control condition. Considering the multisensory nature of the RFT and bodily self-consciousness, a virtual version of RFT was used for the first times in a full body illusion. RFT was performed in three conditions. In standing condition, participants' performance on prior RFT was measured while standing upright and used to differentiate two groups as FD and FI depending on their sensory weighting strategies. Participants performance during supine condition and virtual standing condition was used to evaluate the influence of vestibular system on full body illusion. In supine condition, participants performed RFT in a virtually upright environment while they were lying on their back. Virtual standing condition was technically same as supine condition but administered after full body illusion. This is the first study that used RFT as a quantitative indicator of full body illusion. Experiences regarding full body illusion was also gathered by collecting subjective reports from the participants at the end of the experiment. According to our knowledge, there is no study investigating bodily self-consciousness by comparing the verticality judgements in different body positions (upright and supine) with the judgements after full body illusion. We believe that this is the first study that investigate such an effect with full body illusion. To this end, we developed the following hypothesis:

Hypothesis 1: The subjective reports will result in increased feeling of ownership for the virtual body and altered sense of self-location after synchronous visuo-tactile stimuli compared to asynchronous visuo-tactile stimuli.

Hypothesis 2: Performance on the RFT in supine position will result in larger errors than the RFT performance in virtual standing condition after synchronous visuo-tactile stimuli.

Hypothesis 3: FD participants will feel stronger sense of ownership for the virtual body and make less errors in verticality judgments during RFT after synchronous visuo-tactile stimuli.

2.2. Materials and Methods

2.2.1. Participants

Fifty-six all right handed volunteers (24 male, 32 female) from İzmir University of Economics between the ages of 18 and 37 were participated to the experiment but only 52 participants (21 male, 31 female) were included in the analysis (M_{age}= 24, *SD*= 4.33). One of participants had to be excluded due to technical problems and three of them due to motion sickness during the experiment. All participants reported that they had no previous history of any psychological, psychiatric, or neurological disorder and they had normal or corrected to normal vision. Before the experiment take place participants signed a written informed consent form and completed a questionnaire about demographic information including their age, sex, education levels as well as their previous experiences on, yoga/meditation practices and experiences such as out-of-body experiences and lucid dream prior to the experiment. Additionally, all participants were asked whether they have any previous experience of virtual reality technologies and their experience level (see Appendix B and C respectively for Informed Consent and Demographic Form). All participants reported no or limited (1 or 2 times) past experience in virtual reality. The present study was approved by the ethics committee of the İzmir University of Economics (see Appendix A for Ethical Board Approval).

2.2.2. Equipment and Setup

Virtual Environment: HTC VIVE head-mounted display (HMD) was used to present a virtual environment (1080 x 1200 pixels per eye, 110° field of view, 90 Hz). The virtual environment was built by game development platform UNITY 3D version 2019.3.9. The simulated virtual reality environment that takes place was designed similar to the real experimental room using custom assets (see Figure 11).

Virtual Bodies and Interaction with the Environment: In addition to the simulated virtual environment, two virtual characters were designed as a standard male and female avatars. Both of these virtual bodies were created in order to match the participants' gender and they were designed by using Make Human software. In addition to that Final IK was used to implement inverse kinematics into virtual bodies.

Figure 11. Example of the real experimental room and the virtual room. Left image was taken in the real room, right image is a screenshot of the virtual room.

This helped the participants to accurately animate their body postures and to have smooth movements. The gender-matched virtual bodies can be seen in Figure 12. Two HTC VIVE controllers were used to reflect participants' arm movements into the virtual body during the adaptation period of the full body illusion. In addition to that in the simulated virtual environment a full-height virtual mirror was located in front of the participants which let them to see their virtual bodies' reflection (Gonzalez-Franco et al., 2010).

Visuo-tactile stimulus delivery: The controllers were also used to present visuo-tactile stimuli either in synchrony or asynchrony during the experiment. In the synchronous condition, only one of the controllers was connected to VR system and it was used to deliver the tactile stimulus to the participants' physical body. During the delivery of the visual stimulus to the virtual body there was a spatial and temporal match in the synchronous condition. In the asynchronous condition, one of the controllers connected to VR system was used to present the visual stimulus on virtual body and the other controller which was turned off used for providing tactile stimulation. The tactile stimulation was provided with either temporal and spatial matching or mismatching way with the visual stimulus on participants' physical body. The visuo-tactile stimuli were presented randomly as long stroking (1500ms) or short tapping (500 ms) (Petkova, and Ehrsson, 2008; Pfeiffer et al., 2013) by the experimenter.

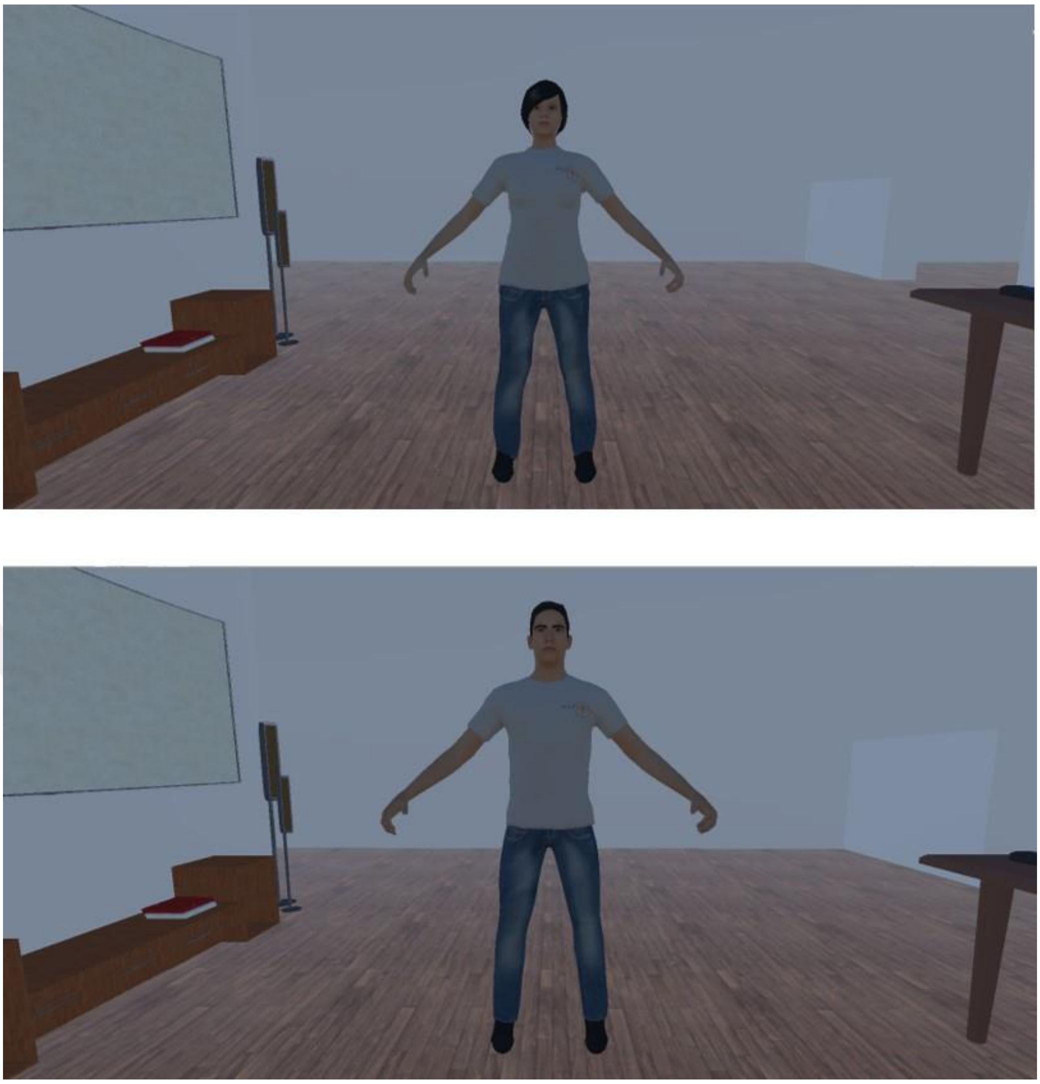


Figure 12. Female and male avatars used in the experiment.

Rod and Frame test: Subjective visual verticality was assessed with Rod and Frame test (RFT) in virtual reality designed by Virtualis (https://virtualisvr.com/en/). Virtual version of RFT was found to result in comparable results with classic RFT (Bringoux et al., 2009). A rod embedded onto a realistic tilted room with bedroom objects was presented (see Figure 13). This type of furnished room has been shown to induce larger errors in visual verticality judgements (Allison et al., 1999; Howard, and Childerson, 1994; Witkin, and Asch, 1948). The virtual RFT showed high validity and reliability (Odin et al., 2018) which is line with the studies validating the use of virtual reality for subjective verticality estimations (Bringoux et al., 2009; Jenkin et al., 2003; Ulozienė et al., 2018). During the RFT, the virtual room was either tilted with an angle of 28° clockwise or 28° counter-clockwise such that the angle was known to produce maximum deviation in verticality judgements(Bringoux et al., 2009; Lichtenstein, and Saucer, 1974; Oltman, 1968; Witkin, and Asch, 1948). The initial tilt of the rod was 28° either in clockwise or counter-clockwise with random order (Pfeiffer et al.,2013, Witkin, and Asch, 1948; Piscicelli, and Pérennou 2017). During the RFT, participants hold the HTC VIVE controllers within their hands by the side. By pressing the buttons on both controllers, they manipulated the rod either towards right or left.

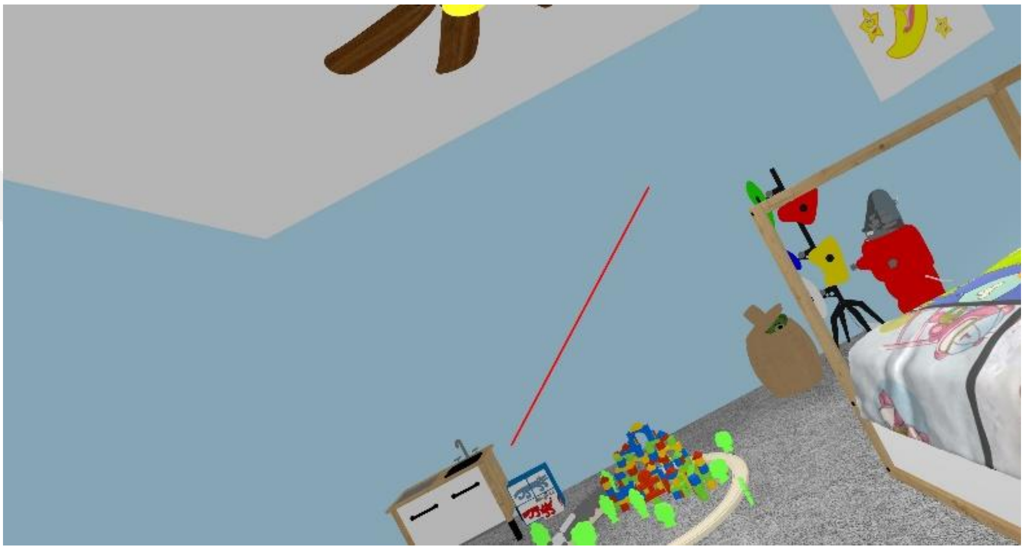


Figure 13. Presentation of Rod and Frame test through the HMD.

2.2.3. Procedure

After signing the informed consent form and completing the demographic information sheet, participants wore the HMD and hold the VR controllers in their hands. The use of the controllers was explained and the first RFT was introduced. Participants were instructed to ignore the tilt of the room and to align the rod vertically with respect to their subjective judgements of verticality. The experiment began with performing RFT either in standing condition (participants standing upright) or supine condition (participants lying on their back with support of a steady platform under their feet). The order of the conditions was counterbalanced.

After completing the RFTs in standing and supine conditions, participants were placed in supine position and the steady platform supported their feet again. Then, the

HMD was turned on and adaptation period of the full body-illusion started. During the adaptation period which took approximately 1 minute, participants were asked to move their head and arms but were instructed not to move their feet while observing the virtual body as standing up position. This period allowed participants to get familiarization with the simulated virtual environment and the virtual body. Following the adaptation period, the controllers were taken back, and participants were informed about that they are going to see a visual touch on the virtual body and feel a tactile touch on their physical body. For the full-body illusion participants were randomly assigned to either synchronous or asynchronous visuo-tactile condition. During the full body illusion phase of the experiment, all participants were instructed to focus on the visual touch and not to make any movements for 2 minutes. Participants were allowed to look either to their virtual avatars body directly or they gaze their virtual body from the virtual mirror located in the virtual environment while seeing their virtual body as standing position.

After completion of full body illusion, participants were immediately asked to close their eyes and the HMD was removed for approximately 15 seconds to calibrate the HMD for the RFT in virtual standing condition. The experimenter then put on the HMD on the participants' head again and present the RFT. Following the completion of RFTs in virtual standing condition, the HMD was taken off and participants completed the subjective report of full-body illusion. Finally, participants were thanked and debriefed; if they have any questions about the experiment, they were answered. The general procedure of the experiment is shown in Figure 14.

2.2.4. Experimental Design

The study was designed as mixed-subject experiment. Two variables were manipulated which are visuo-tactile stimuli as a between-subject factor and body position as a within-subject factor. Rod and Frame test was used as an implicit measure of perceived body orientation. It is well known that body orientation influence subjective visual vertical judgements by modifying weighting of multisensory signals (Lopez et al., 2009; Templeton, 1973). Previous studies showed that errors in judgements of subjective visual verticality increase in supine position compared to standing position (Goodenough et al., 1981; Lichtenstein, and Saucer, 1974; Lopez et al., 2008; Templeton, 1973). In the present study, the first two RFT measurements performed in standing and supine conditions before full-body illusion serving as

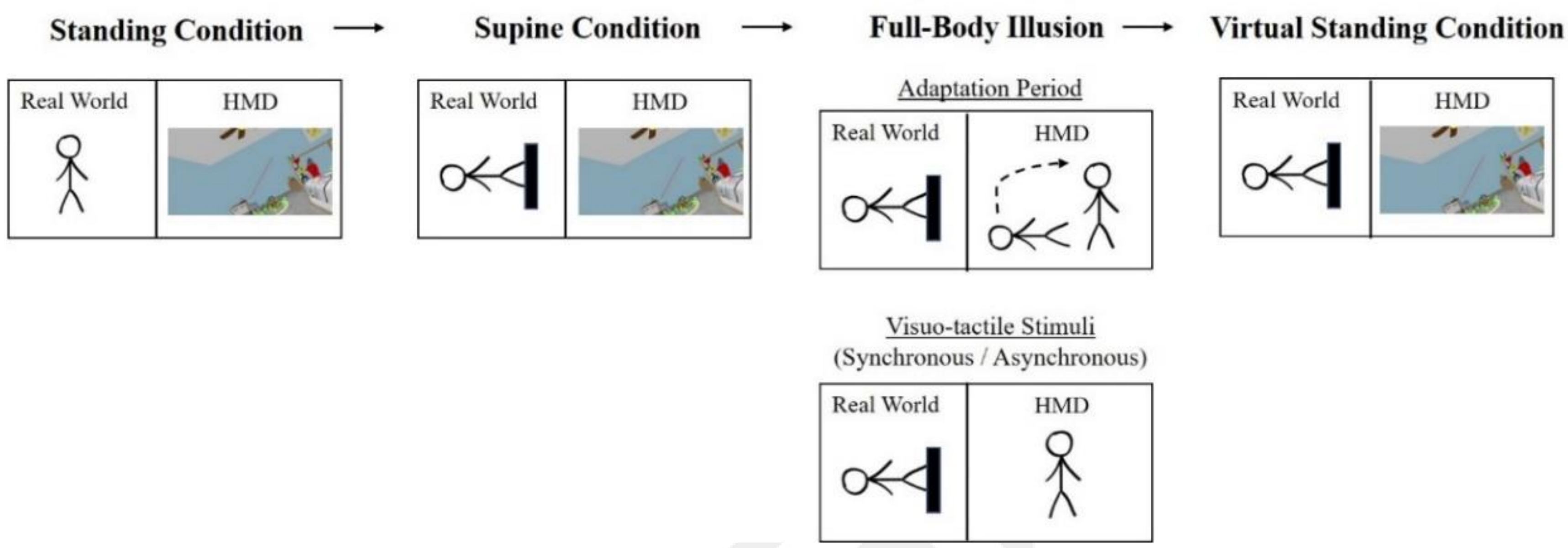


Figure 14. Illustration of the general procedure of the experiment.

baselines for participants' subjective visual verticality. The last RFT performed after full-body illusion was induced with a standing virtual body while the participants were in supine position, so-called virtual standing condition. Comparing the subjective verticality judgement from supine and virtual standing conditions made possible to see effect of the full-body illusion in addition to the report assessing participants' subjective experiences about the full-body illusion.

Independent Measures

Visuo-tactile stimulation: The full-body illusion was induced by presenting a visual stimulus on the virtual body and a tactile stimulus on the participants' physical body either synchronously or asynchronously. Visual and tactile stimuli were applied on the torso of participants' physical and virtual body for 2 minutes. The underlying idea of this application was based on the previous finding that showed that people are more likely to locate themselves within the face and the torso than other body regions (Alsmith, and Longo, 2014). Participants were randomly assigned one of the two conditions. Both types of visuo-tactile stimuli were employed to the participants seeing the virtual body in standing position on HMD while they were physically in supine position on the medium stiff yoga mat. In synchronous visuo-tactile condition, participants saw a temporally and spatially matched visual on the virtual body with respect to the felt touch on their physical body. In asynchronous visuo-tactile condition, the visual touch was spatially incongruent with the felt touch and presented with a delay (approximately 1 second).

Body orientation: Participants completed RFTs in three conditions which are standing, supine and virtual standing. RFTs in standing and supine positions were performed before the full-body illusion. Half of the participants started in standing condition, half in the supine condition. After completing the RFTs in two body orientation and presenting with full-body illusion, participants performed the last RFT in virtual standing condition which was technically same with supine condition. For both the supine and virtual standing position, given that the previous studies showed the contribution of vestibular and somatosensorial systems on perception of body orientation (Bringoux et al., 2003; Lackner, and DiZio, 2005; Mittelstaedt, 1999), a steady platform under participants' feet and yoga block under their head were placed to compensate the pressure from their back in both supine and virtual standing conditions. In this method, tactile cues from the somatosensorial system were aimed to be minimized and the contribution of the vestibular system was investigated

(Trousselard et al., 2003).

Dependent Measures

Subjective report of full body illusion: At the end of the experiment, after having completed the RFTs and presented with full-body illusion, participants were asked to rate statements about their subjective experience of the illusion. The statements were reformulated based on the previous experiments (Huang et al., 2017; Preuss, Brynjarsdóttir, and Ehrsson, 2018; Thür et al., 2019). 7-items paper questionnaire was structured as self-report statements, shown in Table 1, and presented in a form of visual analogue scale (VAS) below each statement. VAS formed as 10 cm continuous horizontal line that the left end represented "strongly disagree" and the right end "strongly agree". Participants were instructed to draw a line on the scale based on intensity of their agreement or disagreement.

The statements of the subjective report were formulated to assess ownership (Q1), self-location (Q2), first-person perspective (Q3), orientation perception (Q4) and 3 items (Q5, Q6, Q7) were control statements to validate the full-body illusion. A further question (Q8) was included regarding participants' estimation of their perceived body orientation during full-body illusion in order to assess explicit sense of body orientation. For Q8, participants were asked to indicate their estimation of perceived tilt by drawing an angled line on the graph. Q8 about the perceived body orientation is presented in Figure 15. All the statements were presented in Turkish to the participants (see Appendix D for Subjective Report of Full Body Illusion).

Rod and Frame Test (RFT): Rod and Frame test was used as an implicit measure of perceived body orientation. In order to investigate perceived changes in body orientation, participants performed RFT in two different body orientation (standing, supine) before the full-body illusion and once after the full-body illusion in a conflicting body orientation condition (virtual standing). In all body orientation conditions, participants head and trunk were free to move and before each measurement all devices and software were calibrated. Head orientation was controlled by fixating the view angle of HMD. For standing condition, the view angle was fixated while participants wearing HMD and standing still. For supine and virtual standing conditions, HMD was put on the ground and the view angle fixated before participants wearing the HMD. Thus, participants experienced the virtual environment as if they were standing while they were lying on their back. For each body orientation, RFT was performed in the tilted room both with clockwise and counter-clockwise

Table 1. The list of statements used to measure subjective experience of the full-body illusion.

Item names	Item statements
Ownership(Q1)	I felt as if the virtual body was my own body.
Self-location(Q2)	I felt as if my body was located at where the virtual body was.
1PP(Q3)	I felt as if the position of my 1PP had changed.
Orientation	I felt as if I was standing.
Control(Q5)	I felt as if I had two bodies.
Control(Q6)	I felt that the experimenter touched on my abdomen.
Control(Q7)	I felt as if the virtual room rotated around the virtual body.

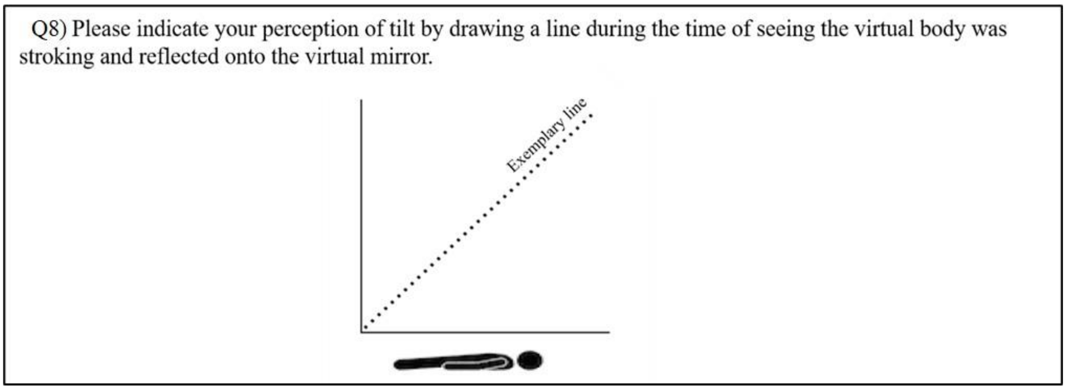


Figure 15. Drawing used in Q8 that measure subjective perception of body orientation.

orientations. Each room orientation included 8 trials resulting in 16 measurements for each body orientation and 48 measurements for each participant in total. In the literature, 6 trials for each condition was proposed as sufficient to identify verticality biases (Piscicelli, and Pérennou, 2017).

2.3. Results

2.3.1. Statistical Analysis

Statistical analysis was performed with SPSS 20. Firstly, Kolmogorov-Smirnov test was used to check for normality assumption which showed that the data was normally distributed. For the subjective reports of full body illusion, scores for each item was calculated and analysed using separate two-way ANOVAs with the *visuo-tactile stimulation* (synchronous, asynchronous) and *visual field dependency* (FI, FD) as a between-subject factor. In order to analyse the effects on the second dependent measure that is the changes in subjective visual vertical (RFT) was investigated using 2 x 2 mixed ANOVA with *visuo-tactile stimulation* (synchronous, asynchronous) as a between-subject factor and *body orientation* (supine, virtual standing) as a within-subject factor. For further analysis, *visual field dependency* (FI, FD) was included into the analysis as a between subject factor and 2 x 2 x 2 mixed ANOVA was conducted.

Visual Field Dependency/Independency: For each participant, subjective visual verticality was calculated by subtracting or adding the head angle from/to each trial depending on directions of the head angle and perceived visual verticality judgement. Then the means were calculated for each body orientation condition. Following that a hierarchical cluster analysis was conducted on the data for the standing condition to separate participants as visual field dependent (FD) and visual field independent (FI). As a standard procedure for the hierarchical clustering analysis, Euclidean distance and Ward's aggregation method was used (Lopez et al., 2006; Pfeiffer et al., 2013; Thür et al., 2019). Hierarchical cluster analysis revealed a group of 24 visual FD participants (mean value of subjective visual vertical = 14.48, *SE* = 1.08) and a group of 28 visual FI participants (mean value of subjective visual vertical = 4.55, *SE* = .36).

2.3.2. The Effect of Multisensory Stimuli and Visual Field Dependency on Subjective Report of Full Body Illusion

In order to investigate the effects of visuo-tactile stimulation and visual field dependency, separate two-way ANOVAs were conducted for each item in the subjective report. The summary of the report's results is presented in Figure 16.

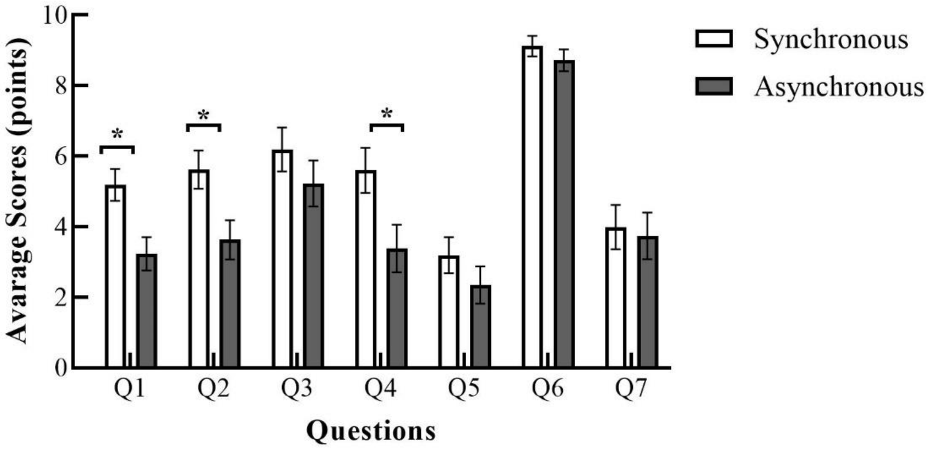


Figure 16. Average scores of the subjective report of full-body illusion. Error bars represent standard errors of the mean.

Statistical analysis for the ownership (Q1) showed a significant main effect of visuo-tactile stimuli, $F(1,48) = 9.10$, $p = .004$, $\eta^2 = .159$. That is, the sense of ownership was rated statistically significantly higher after synchronous visuo-tactile stroking ($M = 5.19$, $SE = .45$) compared to asynchronous stroking ($M = 3.23$, $SE = .47$). However, effect of visual field dependency on ownership was not statistically significant, $F(1,48) = .431$, $p > .05$. There was no significant interaction between visuo-tactile stimulation and visual field dependency for ownership, $F(1,48) = .097$, $p > .05$.

Statistical analysis of the self-location (Q2) revealed a significant main effect of visuo-tactile stimuli, $F(1,48) = 6.64$, $p = .013$, $\eta^2 = .112$. This reflects that participants perceived themselves at the location of the virtual body after synchronous visuo-tactile stimuli ($M = 5.62$, $SE = .54$) compared to asynchronous visuo-tactile stimuli ($M = 3.63$, $SE = .56$). Additionally, a significant interaction effect of visuo-tactile stimuli and visual field dependency was found for the self-location (Q2), $F(1,48) = 8.36$, $p = .006$, $\eta^2 = .148$. Simple main effect analysis showed that FD participants significantly had stronger feeling of themselves at the location of the virtual body than FI participants after synchronous visuo-tactile stimuli ($p = .007$) but not during the asynchronous visuo-tactile stimuli condition ($p = .192$) (see Figure 17).

Statistical analysis for the 1PP (Q3) did not show significant effects of visuo-tactile stimulation, $F(1,48) = 1.158$, $p > .05$, or visual field dependency, $F(1,48) = .746$, $p > .05$. The interaction effect was also not statistically significant, $F(1,48) = .282$, p

> .05.

Statistical analysis for the orientation perception (Q4) revealed a significant main effect of visuo-tactile stimuli, $F(1,48) = 5.79$, $p = .020$, $\eta^2 = .108$. This suggests that participants experienced illusory change of their perceived orientation after synchronous visuo-tactile stimuli. There was no significant main effect of visual field dependency, $F(1,48) = .642$, $p > .05$ or interaction effect, $F(1,48) = .235$, $p > .05$. Finally, none of the control questions (Q5, Q6, Q7) showed a statistically significant difference between the groups as expected, (all $F < 1.373$, $p > .247$).

For the perceived tilt (Q8), a significant main effect of visuo-tactile stimuli was also found, $F(1,48) = 6.21$, $p = .016$, $\eta^2 = .114$. Participants had illusory sense of self-tilt towards the position of virtual body after synchronous visuo-tactile stimuli ($M = 43.41$, $SE = 6.24$) compared to the asynchronous visuo-tactile stimuli ($M = 20.93$, $SE = 6.52$) (see Figure 18). There was no main effect of visual field dependency, $F(1,48) = .270$, $p > .05$. Lastly, interaction effect was not statistically significant, $F(1,48) = 1.054$, $p > .05$.

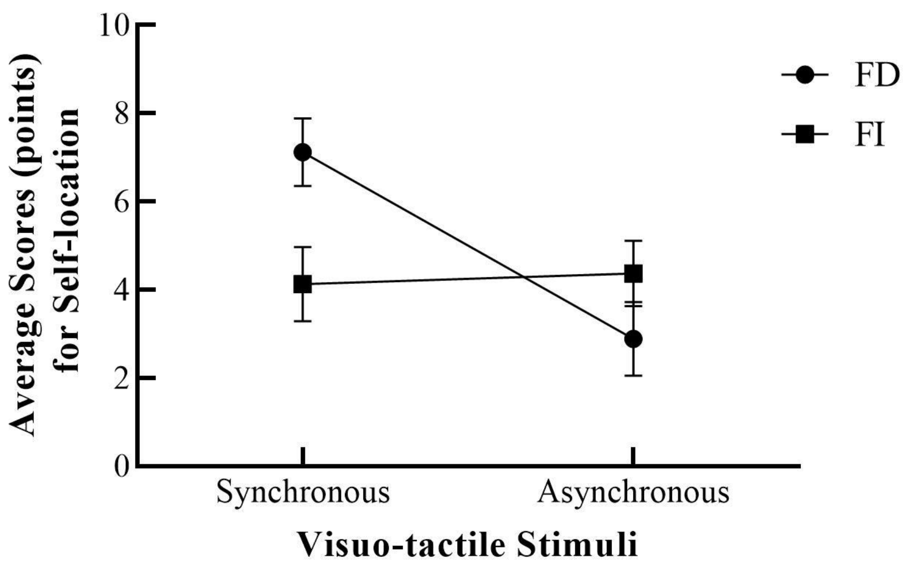


Figure 17. Average scores for self-location item on the subjective report for FD and FI participants based on visuo-tactile stimuli. Error bars represent standard errors of the mean.

Additionally, in order to investigate whether there is a relationship between the sense of ownership and perceived tilt of the body (the subjective degree of body orientation) a Pearson correlation was conducted to all participants' data. Bivariate correlation analysis showed that there was a statistically significantly positive relationship between participants' subjective ratings for the ownership and the perceived verticality, r = .541 [.289, .748], p = .000.

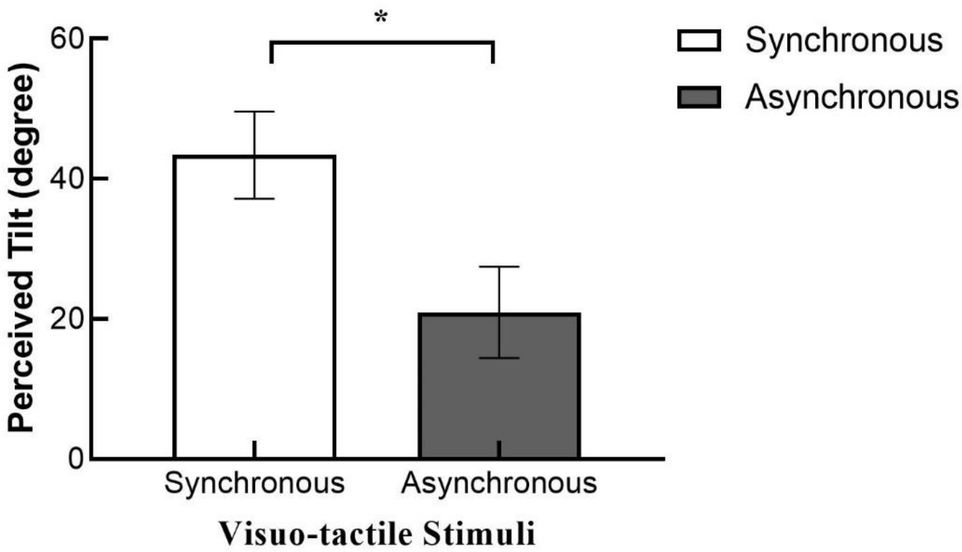


Figure 18. The means of estimations of perceived body orientation. Error bars represent standard error of the mean.

2.3.3. The Effect of Body Orientation and Multisensory Stimuli on Subjective Visual Verticality

Looking at the overall RFT data from standing and supine conditions revealed differences in subjective visual vertical judgements across body orientations. The deviations from true verticality was higher in the supine position (M = 10.17°) compared to standing position (M = 9.14°) as expected (Templeton, 1973; Goodenough et al., 1981; Lopez et al., 2008). In order to compare changes between subjective visual vertical judgements regardless of multisensory stimuli a series of paired sample t-test was conducted between standing - supine, standing – virtual standing and supine - virtual standing conditions. Although an increased errors was found in supine condition relative to standing condition, there was a significant difference only in the subjective verticality judgements between the supine (M = 10.17, SE = .99) and the virtual standing (M = 8.77, SE = .75) conditions, $t(51) = 2.06$, p = .044.

Furthermore, the RFT data was inspected to see changes for subjective visual vertical judgements in virtual standing condition with respect to supine condition depending on the visuo-tactile stimulation. A 2 x 2 ANOVA with a between-subject factor *visuo-tactile stimulation* (synchronous, asynchronous) and a within-subject factor *body orientation* (supine, virtual standing) was performed. The results revealed a significant main effect of *body orientation* on subjective visual verticality judgements, $F(1,50) = 4.15$, $p = .047$, *partial* $\eta^2 = .077$. Supine condition (M = 10.18, SE = 1.01) induced significantly larger errors of subjective visual vertical than virtual standing condition (M = 8.83, SE = .74) indicating the illusory sense of standing (see Figure 19). No significant main effect of *visuo-tactile stimulation* was observed, $F(1,50) = 1.137$, $p > .05$. There was no statistically significant interaction effect between *body orientation* and *visuo-tactile stimulation*, $F(1,50) = 3.054$, $p > .06$.

2.3.4. The Effect of Visual Field Dependency, Body Orientation and Multisensory Stimuli on Subjective Visual Verticality

In order to investigate the full data, a 2 x 2 x 2 ANOVA with between-subject factors *visual field dependency* (FD, FI), *visuo-tactile stimulation* (synchronous, asynchronous) and within-subject factor *body orientation* (supine, virtual standing) was conducted. The results of the ANOVA revealed a significant main effect of *visuo-tactile stimulation*, *visual field dependency* and *body orientation* respectively $F(1,48) = 4.24$, $p = .041$, *partial* $\eta^2 = .084$, $F(1,48) = 62.09$, $p = .00$, *partial* $\eta^2 = .564$, $F(1,48) = 5.20$, $p = .027$, *partial* $\eta^2 = .098$ (see Figure 20). Furthermore, significant two-way interaction effect was found between *visuo-tactile stimulation* X *visual field dependency*, $F(1,48) = 4.98$, $p = .030$, *partial* $\eta^2 = .094$. Simple effect analysis showed that FD participants made significantly higher errors in estimating verticality after asynchronous visuo-tactile stimuli compared to synchronous visuo-tactile stimuli condition ($p = .005$). However, FI participants did not get affected by the type of visuo-tactile stimuli and made more accurate and similar verticality estimations both in

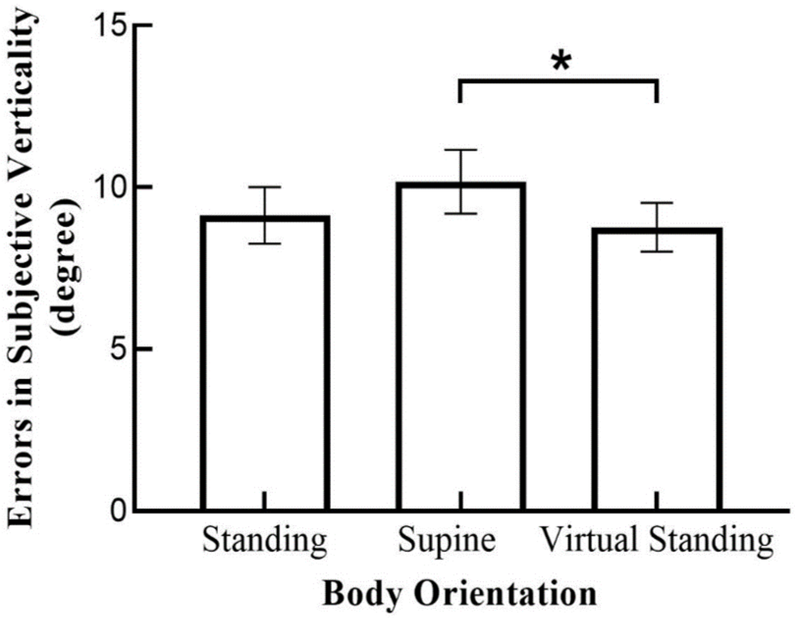


Figure 19. Average estimation errors of verticality in RFT during different body orientations which are Standing, Supine, Virtual Reality. Error bars represent standard error of the mean.

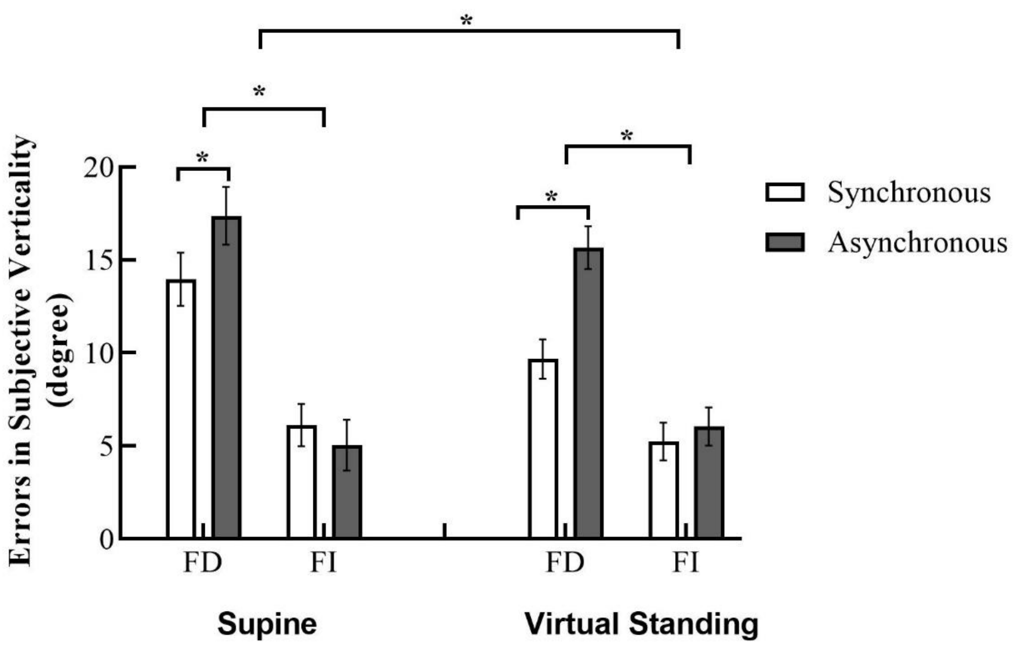


Figure 20. Main effects of Visuo-tactile Stimuli, Visual Field Dependency and Body Orientation. Error bars represent standard error of the mean.

synchronous and asynchronous conditions (p = .924) (see Figure 21). This interaction shows that the effect of the type of visuo-tactile stimuli on subjective verticality estimations depends on the type of visual field dependency.

Additionally, significant interaction effect was found for visual field dependency X *body orientation*, $F(1,48) = 5.69$, $p = .021$, *partial* $\eta^2 = .106$. Simple main effect analysis revealed that FD participants' verticality judgements became more accurate in virtual standing condition compared to supine condition (p = .002). Accuracy of verticality judgements for FI participants was similar regardless of the condition (p = .939) (see Figure 22). This interaction reflects that the effect of body orientation on subjective verticality estimations was modulated by the type of visual field dependency. There was no three-way interaction among *visuo-tactile stimulation* X *visual field dependency* X *body orientation*, $F(1,48)= .073$, $p= .789$, *partial* $\eta^2 = .002$.

2.3.5. Exploratory Analysis

To see the influence of practicing yoga/meditation and lucid dream experience on full body illusion, we used the data from demographic form. For the former, we asked participants whether they are practicing yoga/meditation. If the answer is yes, we asked them to indicate the frequency of practice. For the latter, we asked participants to describe their experience of lucid dream if they ever had. We checked the normality for RFT performances on supine and virtual standing conditions and each item in subjective reports excluding control questions. Kolmogorov-Smirnov test showed that the data was non-normally distributed. Thus, Mann-Whitney tests were used to investigate the effects of yoga/meditation and lucid dream on the dependent variables.

Regarding yoga/meditation, descriptive statistics revealed that a group of 13 participants practicing yoga/meditation and a group of 39 participants with no practice. Statistical analysis on subjective reports of full body illusion showed that there is no statistically significant effect of practicing yoga/meditation on the *ownership*, U = 193.00, z = -1.28, p = .206, r = -.18, *self-location*, U =239.00, z = -.307, p = .766, r = -.04 , *1PP*, U = 199.5, z = -1.14, p = .259, r = -.16, *orientation perception*, U = 218.5, z = -.740, p = .467, r = -.10 and *perceived tilt*, U = 245.50, z = -.171, p = .870 r = -.02. Statistical analysis for RFT revealed that subjective visual verticality judgements of yoga/meditation practitioners (*Mdn* = 19.77) did not significantly differ from the non-practitioners (*Mdn* = 28.74) in supine condition, U = 166.00, z = -1.85, p = .066, r = -

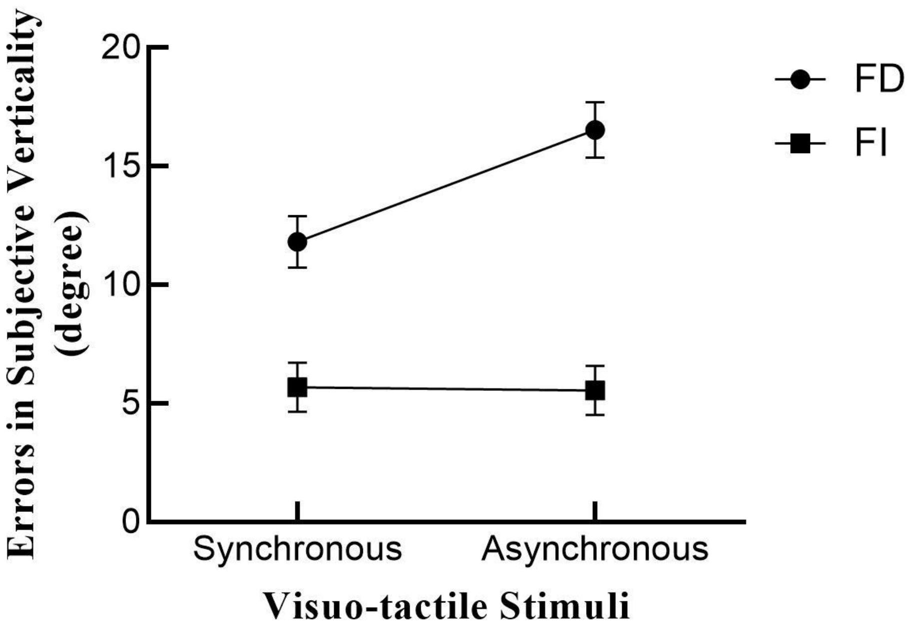


Figure 21. Average estimation errors in subjective verticality in synchronous and asynchronous visuo-tactile stimuli for FD and FI participants. Error bars represent standard error of the mean.

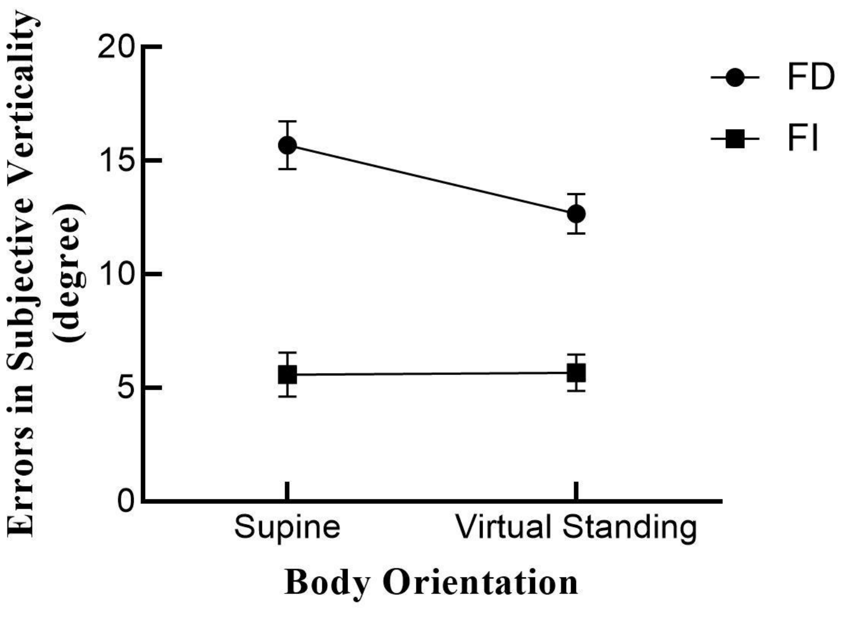


Figure 22. Average estimation errors in subjective verticality in supine and virtual standing body orientations for FD and FI participants. Error bars represent standard error of the mean.

.26. However, in virtual standing condition, participants practicing yoga/meditation (*Mdn* = 17.77) made statistically more accurate judgements compared to non-practicing participants (*Mdn* = 29.41), *U* = 140.00, *z* = -2.40, *p* = .015, *r* = -.33. This is in line with a previous research showed that Ashtanga yoga practitioners made less errors in estimating verticality during RFT than non-practitioners (Fiori, David and Aglioti, 2014).

Descriptive statistics of having lucid dream showed that a group of 35 participants experienced the lucid dream whereas a group of 17 participants did not have such experience. Statistical analysis on subjective reports of full body illusion revealed a statistically significant effect only for *perceived tilt*, *U* = 196.00, *z* = -2.01, *p* = .045, *r* = -.28. That is, participants who experienced lucid dream had stronger illusory sense of standing upright compared to the participants with no experience of lucid dream. There was no statistically significant effect of having lucid dream for *ownership*, *U* = 289.50, *z* = -.156, *p* = .881, *r* = -.02, *self-location*, *U* = 239.50, *z* = -1.13, *p* = .263, *r* = -.16, *1PP*, *U* = 216.00, *z* = -1.59, *p* = .113, *r* = -.22 and *orientation perception*, *U* = 237.00, *z* = -1.18, *p* = .242, *r* = -.16. Lastly, statistical analysis on RFT performance did not show a significant effect of having lucid dream either on supine condition, *U* = 232.00, *z* = -1.278, *p* = .207, *r* = -.18 or virtual standing condition, *U* = 233.50, *z* = -1.248, *p* = .207, *r* = -.17.

CHAPTER 3: DISCUSSION

3.1. General Findings

The main finding of this experiment was to demonstrate the contributions of visual and vestibular signals on bodily self-consciousness. To do this, full body illusion was induced to participants in a supine position while their virtual body were standing upright which results in visuo-vestibular conflict. Additionally, we combined the full-body illusion with RFT in order to check their perceived verticality. Results of the study supported the first hypothesis in which we proposed that participants should feel increased sense of ownership for the virtual body and their sense of self-location will change to a greater extend after synchronous visuo-tactile stimulation compared to the asynchronous visuo-tactile stimuli. Hypothesis 2 and 3 were partially supported. Regarding hypothesis 2, interaction between visual field dependency, body condition and visuo-tactile stimuli was not found for RFT performance but modulatory role of visual field dependency on RFT. That is, RFT performance was found to influenced by visual field dependency separately interacting with the body orientation and the visuo-tactile stimuli. Regarding hypothesis 3, the influence of field dependency was found for RFT after synchronous visuo-tactile stimuli, but no influence of field dependency was found for the feeling of ownership. In addition to the proposed first three hypotheses, the study revealed further findings. Firstly, influence of visual field dependency with respect to the visuo-tactile stimuli on the sense of self-location was found. FD participants showed greater adaptation for self-location of the virtual body compared to FI participants after synchronous visuo-tactile stimuli. Moreover, the sense of ownership showed significant correlation with the perception of body tilt. All of these results will be discussed in detail in below.

Previous experiments showed that sense of ownership over a virtual body increased during synchronous visuo-tactile-stimuli compared to the asynchronous visuo-tactile stimuli (Ehrrson, 2007; Lenggenhager et al., 2007; Petkova, and Ehrsson, 2008). In these previous studies, participants' physical body was in a congruent position with the virtual body. Considering the role of vestibular system on bodily self-consciousness, recent studies investigated the contribution of visual and vestibular signals in full body illusions (Ferrè et al., 2014; Ionta et al., 2011; Macauda et al., 2015; Pfeiffer et al., 2013; Preuss, Brynjarsdóttir, and Ehrsson, 2018; Thür et al., 2019). First investigations were based on creating visuo-vestibular conflict indirectly by manipulating the gravitational cues on the virtual body resulting in impression of being in different body position (Ionta et al., 2011; Pfeiffer et al., 2013). More recently, Thür et al. (2019) used a different setup in which the participants see the virtual body either in congruent body position with their physical body or in tilted position to the left or right. In all of those previous studies, participants exposed to conflicting visuo-vestibular information while seeing the virtual body from a 3PP.

The present experiment differs from those previous studies in regard to experimental setup. Firstly, we investigated conflicting visuo-vestibular signal by presenting the virtual body from 1PP. Secondly, we created visuo-vestibular conflict by presenting supine participants with an upright virtual body. Thirdly, we modelled the virtual room similar to the real experimental room and placed a full-height mirror in front of the participants. The virtual room included objects and furniture which is known to induced larger reorientation illusions (Howard, and Childerson, 1994). Thus, we provided participants with strong impression of the being in upright body position. This experiment extends the experimental setup of Blom, Arroyo-Palacios, and Slater (2014) in which they presented the virtual body seen from 1PP and the virtual environment rotated in 15° to investigate spatial congruence of virtual body's viewpoint compared to the viewpoint of physical body. However, this amount of rotation was not noticeable for all participants. To eliminate this ambiguity thus, we rotated the virtual body 90° vertically.

Another important aspect of the present experimental setup was combining RFT with full body illusion in order to investigate the contribution of sensory weighting on bodily self-consciousness. Pfeiffer et al. (2013) used a computer based RFT at the beginning of their experiment to differentiate the influence of individual strategies of sensory weighting on 1PP. Another study by Thür et al. (2019) also used a computer based RFT at the end of the experiment to examine the relationship between individual sensory weighting strategies and judgements of subjective body orientation. These experimental setups linked the RFT performances in the real world with the experiences of full body illusion in virtual reality. On the other hand, it was assumed that human responses in virtual reality is associated with the feeling of presence in the virtual environment (Sanchez-Vives, and Slater, 2005). Of interest, Bringoux et al. (2009) suggested that verticality judgements in virtual reality might account for the level of the being immersed in the virtual environment. Therefore, we presented RFT in virtual reality. We grouped participants based on individual sensory weighting strategies as FD and FI using the verticality judgements in standing condition.

Furthermore, we presented RFT while participants in supine position and after full body illusion in which participants were in supine position, but the virtual body was upright. The underlying reason was that errors in RFT changes depending on body orientation (Goodenough et al., 1981; Lichtenstein, and Saucer, 1974; Lopez et al., 2008; Templeton, 1973). Thus, we used RFT in supine and virtual standing conditions as an indicator of perceived body position. This experimental setup allowed us to directly get quantitative data about the influence of sensory weighting strategies on full body illusion. The data showed that participants made smaller errors in virtual standing condition compared to the supine condition indicating the illusory perception of being in an upright position.

3.2. Multisensory Mechanisms of the Sense of Ownership

Data from subjective reports of participants on full body illusion showed that the sense of ownership for the virtual body is higher after synchronous visuo-tactile stimulation compared to asynchronous visuo-tactile stimulation. In the present study, participants saw the virtual body as standing upright while they were in supine position. This could be considered as strong visuo-vestibular conflict. Pfeiffer et al. (2013) found that strong visuo-vestibular conflict reduces the feeling of ownership compared to the weak visuo-vestibular conflict during synchronous visuo-tactile stimuli. However, they created the visuo-vestibular conflict by only manipulating gravitational cues on the virtual body which can be considered as weak visuo-vestibular conflict in general. Moreover, we found relatively higher scores for ownership during synchronous visuo-tactile stimuli compared to the strong visuo-vestibular conflict condition in Pfeiffer et al.'s study. This indicated that participants in the present study experienced a stronger full body illusion. Furthermore, Thür et al. (2019) could not show the influence of visuo-tactile synchrony on ownership during visuo-vestibular conflict in contrast to our findings. These differences in the feeling of ownership might be interpreted in two different ways.

Firstly, the association between visuo-spatial perspective and the feeling of ownership offers the first explanation for the findings. It was shown that ownership of a virtual body seen from 3PP can be induced when there is synchronous visuo-tactile stimuli or visuo-motor synchrony (Debarba et al., 2017; Lenggenhager et al., 2007).

However, other studies revealed that seeing a humanoid virtual body from 1PP can create illusory sense of ownership even without synchronous visuo-motor or visuo-tactile stimuli (Maselli, and Slater, 2013; Petkova et al., 2011). Thus, the fact that the participants experienced illusory sense of ownership for the virtual body in the current study might a product of advantageous role of 1PP. This is also supported by the study Blom, Arroyo-Palacios, and Slater (2014) showing that people can feel ownership while seeing a virtual body from 1PP which is slightly incongruent with the viewpoint of the physical body.

An alternative explanation for participants had illusory sense of ownership during visuo-vestibular conflict in the present study may be caused by the decreased sensitivity of vestibular signals depending on the supine body position. The support for the effect of the vestibular signals based on body position on bodily self-consciousness comes from the fact that OBEs mostly occur in supine position (Blanke, and Mohr, 2005). This suggested the contribution of gravitational information on bodily self-consciousness in addition to the influence of somatosensory information (Lopez, and Blanke, 2007). However, it was generally proposed that vestibular signals are related with self-location and 1PP whereas ownership depends on visual, somatosensory and proprioceptive signals (Lopez, Halje, and Blanke, 2008; Blanke, 2012). In line with this, vestibular stimulation studies with healthy participants resulted in changes in perceived self-location and abnormal vestibular sensations such as floating (Blanke et al., 2002; Lenggenhager et al., 2008). More recently, clinical observations and experimental studies provide evidence for the involvement of the vestibular signals on ownership using artificial vestibular stimulations (Lopez, Lenggenhager, and Blanke, 2010; Preuss, and Ehrsson, 2019; Ronchi et al., 2013; but also see Ferrè et al., 2015). Although these studies suggested the influence of vestibular system on ownership, they did not demonstrate the contribution of sensory weighting. In the present study, we did not apply artificial vestibular stimulation, but we manipulated visual information about body orientation which is incongruent with the experienced body position encoded by vestibular system. The significant increase in the sense of ownership was found after synchronous visuo-tactile stimuli compared to the asynchronous visuo-tactile stimuli. This data is contrast with the findings by Thür et al. (2019) showing no significant difference in ownership between synchronous and asynchronous visuo-tactile stimuli during visuo-vestibular conflict when participants were standing upright. Since the participants were in supine position in our study, these findings point out the impact of decreasing vestibular sensitivity, enhancing visual and somatosensory signals resulting in stronger feeling of ownership over the virtual body. In addition, Pfeiffer et al. (2013) revealed a similar finding with the present data but claimed that strong visuo-vestibular conflict reduces the feeling of ownership. This might be because of the participants' awareness of proprioceptive and somatosensory cues about their body orientation. Also, it could be related to the influence of somatosensory information during the weighting process of the sensory signals. For instance, it was found that tilted participants supported by a rigid surface rely more on visual information whereas tilted participants supported by a soft surface rely more on vestibular information (Nyborg, 1971). Thus, the fact that we were able to induce the feeling of ownership during relatively strong visuo-vestibular conflict might be explained by the use of support surface under participants' feet to eliminate non-vestibular information.

Another finding of the present experiment was the correlation between the feeling of ownership and perceived body orientation. The stronger the participants felt ownership for the virtual body, the more they experienced themselves closer to the orientation of the virtual body. This finding is line with the findings of Preuss, Brynjarsdóttir, and Ehrsson (2018) which showed the modulatory role of the ownership on perceived self-orientation. In their study, they induced self-motion illusion by rotating the virtual environment around the virtual body. This illusory self-motion might be explained by the pure effect of vection (Warren, 1995). There is no consistent explanation for multisensory underlying of vection. For instance, Young (1991) suggested the stronger influence of vection in supine position, whereas Watt, and Landolt (1990) proposed the stronger effect of vection during upright position. These conflicting findings imply the influence of vestibular system on vection, although it is not clear.

In the current study, we created illusory self-orientation rather than self-motion during decreased vestibular signals (supine position). We extended the findings of Preuss and colleagues (2018) by showing the similar relationship between feeling of ownership and orientation perception during decreased vestibular sensitivity. This provides evidence that the vestibular system plays selective role for the association between feeling of ownership and orientation perception. Altogether, these results indicate that decreased vestibular system leads to increase reliance on visual and tactile stimuli resulting in illusory feeling of ownership correlated with the perception of being at the orientation of the virtual body.

3.3. Integration of Visual-Somatosensory-Vestibular Information for Self-location

The data from the subjective reports of full body illusion showed for the first time that the influence of visuo-tactile stimulation on self-location modulated by visual field dependency. FD participants experienced themselves at the location of the virtual body compared to FI participants after synchronous visuo-tactile stimuli. This suggests the individual sensory weighting style as an important factor for self-location. Pfeiffer et al. (2013) found direct influence of visual field dependency on the experienced direction of 1PP during visuo-vestibular conflict. In addition to that, although they showed an influence of 1PP on self-location, they did not link the visual field dependency with self-location. As proposed by Serino et al. (2013), self-location and 1PP are closely related each other. The present study supports this assumption by extending the findings regarding the visual field dependency on 1PP into self-location. It is well known that sensory signals reweighted based on their reliability during multisensory integration (Carver, Kiemel, and Jeka, 2006). We found the selective role visual filed dependency, in addition to the synchronous visuo-tactile stimulation, on self-location during supine position. The platform under participants' feet could account for somatosensory information about the body in addition to the visual information. This suggests that illusory change in self-location is result of reweighting of visual-somatosensory-vestibular signals during decreased vestibular signals. This expands the conclusion of Pfeiffer et al.'s study suggesting that there is a greater weighting of visual information relative to the vestibular information on self-location. This influence of sensory weighting strategies is also in line with a study showing the correlation between heartbeat awareness and rubber hand illusion (Tsakiris, Tajadura-Jimènez, and Costantini, 2011). That is, when people put more weighting on interoceptive signals, they experienced stronger rubber hand illusion.

Furthermore, the influence of visual field dependency on self-location in our study was found while participants looking at the virtual body from 1PP in an incongruent position with their physical body. This experimental setup is contrary to setup with 3PP in the study of Pfeiffer et al. (2013). Given this difference an alternative explanation for the significant effect of visual field dependency with visuo-tactile stimulation on self-location might be related to multisensory integration from an egocentric reference frame. Spatial position of the body might be encoded either in egocentric reference frame or allocentric reference frame (Howard, and Templeton, 1966). The former corresponds to the body centered coordinate system whereas the latter reflects to the coordinate system relative to the world (Burgess, 2006). We normally observe our body from egocentric reference frame which known as fundamental for the sense of self (Petkova et al., 2011). Also, we constantly have access to egocentric cues from the body and allocentric cues from the environment relative to the world. In the current study, we presented participants with the egocentric reference frame of the virtual body and the allocentric reference frame relative to the virtual environment. However, Pfeiffer et al. (2013) only provided allocentric reference frame by gravitational cues on the virtual body seen from 3PP surrounded by black screen. It is worth to note that visual reorientation illusions are proposed to be evoked by change in allocentric reference frame relative to the body (Oman, 2007). Therefore, we believed that the current study provided natural reference frames as in the real world, thus resulting in significant change in self-location.

3.4. The Influence of Visual Field Dependency on Full Body Illusion

Considering the fact that judgements of verticality depends on the body orientation, we used RFT as a tool to investigate full body illusion. As a first step, we investigated the amount of deviations from verticality. RFT results showed large deviations from the verticality supporting the studies showing that larger verticality errors in virtual version of RFT (Bringoux et al., 2009; Reger et al., 2003). These increased errors were mostly explained by the virtual environments containing gravitational cues such as, furniture or objects as proposed by Howard, and Childerson (1994). Our data did not show significant effect of visuo-tactile synchrony between supine and virtual standing condition during RFT. The change in the perceived orientation without visuo-tactile stimulation might be related to some possible reasons. First, it was shown that rotating a room around a participant is sufficient to change perceived orientation (Bringoux et al., 2009). This illusory orientation was even strong enough to affect distance estimations which is known to modulated by the body position (Harris, and Mander, 2014). Thus, the virtual body and the virtual environment might provide enough information to participants for illusory sense of being upright with no need of visuo-tactile stimulation Alternatively, this might be explained by sensory reweighting. Previous studies showed that body orientation is maintained by integration and weighting of multisensory inputs relative to their reliability (Assländer, and Peterka, 2014; Peterka, 2002). For instance, people with vestibular loss rely more on visual information (Bronstein, 1995). In the present study, since the participants were in supine position which reduces the vestibular signals, their reliance on visual information might enhanced. Accordingly, they might feel as if they were standing upright after watching the upright virtual body (virtual standing condition) compared to supine condition with no need of extra visuo-tactile synchrony. Although this finding should be interpreted in caution, it highlights the involvement of the vestibular system.

Regarding the multisensory underlying of bodily self-consciousness, the current study showed the modulatory role of individual sensory weighting strategies on full body illusion. Previous studies revealed the influence of visual field dependency on proprioceptive drift during rubber hand illusion (David, Fiori, and Aglioti, 2014) and 1PP in full body illusion (Pfeiffer et al., 2013). In order to investigate effect of visual field dependency on perceived orientation during full body illusion, we used RFT. Independently of the visual field dependency, the amount of the verticality errors was known to reflect orientation perception (Carriot, DiZio, and Nougier, 2008). People make larger verticality errors in supine position compared to the upright position (Goodenough et al., 1981; Lichtenstein, and Saucer, 1974; Templeton, 1973). In the present study, participants' physical body was in supine position while the virtual body was standing upright during full body illusion. Firstly, we found that FD participants made less error in verticality judgements after synchronous visuo-tactile stimulation compared to the asynchronous visuo-tactile stimulation. This indicates that FD participants experienced themselves in the orientation of the virtual body as standing upright. This is in line with the findings of Thür et al. (2019) showing FD participants adjust their body orientation with respect to the virtually seen body. However, they suggested that participants are more likely to perceive the virtual body as in the orientation of the physical body. On the other hand, our results from the RFT clearly showed that participants perceived their orientation as in the orientation of the virtual body since the errors in verticality judgements were lower after synchronous visuo-tactile stimulation. This adaptation of the body into the virtual body orientation is further supported by the perceived tilt item in the questionnaire. Participants draw themselves as closer to the orientation of the virtual body after synchronous visuo-tactile stimuli regardless of visual field dependency. The influence of visual field dependency for RFT performance but not for orientation question agrees with the studies showing the influence of visual field dependency on implicit measures is not accompanied by explicit measures (Berger, Schulte-Pelkum, and Bülthoff, 2010; Prsa, Gale, and Blanke, 2012; Thür et al., 2019).

Secondly, we also found a significant effect for the influence of the body orientation condition on perceived orientation depending on the visual field dependency. FD participants made less verticality errors in the virtual standing condition compared to the supine condition. That is, FD participants experienced themselves as if they were standing upright independently of the visuo-tactile stimulation. FD people was known to rely more on visual information irrespectively of reliability of other sensory information (Borger et al., 1999). In the present study, visual information from the virtual body and somatosensory information from under participants' feet gave the impression of standing upright whereas vestibular information informed that they were lying down. These complementary visual and somatosensory signals might have predominated the vestibular signals for FD participants with no need of visuo-tactile stimulation. This suggests the key role of visual field dependency for spatial aspect of full body illusion. This also in line with findings from a rubber hand illusion showing the correlation between proprioceptive drift and the errors in verticality judgements (David, Fiori, and Agliotti, 2014). Altogether, the current findings indicate the importance of sensory weighting strategies for full body illusion. Alternatively, the changes in perceived verticality without visuo-tactile stimulation can be explained by awareness of body orientation. It was shown that body awareness provided by congruent vestibular and somatosensory information modulates the visual verticality judgements (Barra et al., 2012). In the present study, visual information was congruent with somatosensory information because there was a platform under feet of the participants indicating standing upright. Considering the fact that FD participants rely more on visual information, this combined visual and somatosensory information might have suppressed vestibular information resulting in perception of being upright. Thus, this illusory awareness of body orientation might account for decreased errors in verticality judgements independently of the visuo-tactile stimulation.

3.5. Conclusion and Limitations

In the current thesis, it was shown that full body illusion can be induced during a visuo-vestibular conflict. Crucially, the fact that full body illusion was induced during decreased vestibular input provide evidence for the involvement of the vestibular system on bodily self-consciousness. Reduced vestibular signals in supine position resulted in greater sense of ownership only in synchronous visuo-tactile stimuli condition suggesting that increased weighting of visual and somatosensory signals have crucial role for the ownership. The sense of ownership was also shown to be correlated with the subjective experience of the physical body orientation. That is, participants perceived themselves at the orientation of the virtual body as their ownership feeling over the virtual body increased. This data indicates the importance of vestibular system for the ownership but does not suggest the role of sensory weighting strategies.

Subjective changes in sense of self-location was found to be linked both with visuo-tactile stimulation and sensory weighting strategies. Verticality judgements and subjective evaluations of self-location of FD participants indicated that they experienced themselves in the orientation of the virtual body after synchronous visuo-tactile stimuli. Additionally, the role of sensory weighting strategies on full body illusion was also revealed with respect to the visuo-tactile stimulation and body orientation condition. FD participants showed lower verticality errors after synchronous visuo-tactile stimuli and in virtual standing condition independently of each other. Regarding these results, RFT might be suggested as a predictor of self-orientation.

Previous literature supported the close relationship between self-location and 1PP however, our results did not show any influence of visuo-tactile stimulation and sensory weighting strategies on subjective evaluations of 1PP. Considering the association between verticality judgements and visuo-spatial perspective, future studies could examine in more detail whether performances in RFT reflects changes in self-orientation or 1PP. Although there are numerous studies suggesting the involvement of the vestibular system on aspects of bodily self-consciousness, the present study aimed to show the influence of decreased vestibular signals during supine position. Direct comparison of decreased and normal vestibular signals is needed to clearly demonstrate the contribution of the vestibular system. For instance, future studies should induce full body illusion during visuo-vestibular conflict by manipulating participants' body orientation.

In conclusion, the results of the present study contribute greatly to our understanding of the vestibular mechanism involved in full body illusion and showed different influences of sensory weighting strategies on body ownership, self-location, and orientation perception. This study is the first to combine full body illusion during decreased vestibular signals with visuo-vestibular conflict and virtual RFT to investigate bodily self-consciousness. The results and the experimental setup of this study provide important insight into future studies for understanding full body illusion.

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APPENDICIES

Appendix A – Ethical Board Approval

SAYI : B.30.2.İEÜ.0.05.05-020-066 11.12.2018

KONU : Etik Kurul Kararı hk.

Sayın Burak Erdeniz,

"Yapay Gerçeklikte Bedensel Öz-Bilinç Algısının İncelenmesi" başlıklı projenizin etik uygunluğu konusundaki başvurunuz sonuçlanmıştır.

Etik Kurulumuz 04.12.2018 tarihinde sizin başvurunuzun da içinde bulunduğu bir gündemle toplanmış ve projenin incelenmesi için bir alt komisyon oluşturmuştur. Projenizin detayları alt komisyon üyelerine gönderilerek görüş istenmiştir. Üyelerden gelen raporlar doğrultusunda Etik Kurul 11.12.2018 tarihinde tekrar toplanmış ve raporları gözden geçirmiştir.

Sonuçta 11.12.2018 tarih ve 90 numaralı Etik Kurul toplantısında "Yapay Gerçeklikte Bedensel Öz-Bilinç Algısının İncelenmesi" konulu projenizin etik açıdan uygun olduğuna oy birliği ile karar verilmiştir.

Gereği için bilgilerinize sunarım.

Saygılarımla,

Prof. Dr. Filiz Başkan

Etik Kurul Başkanı

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Appendix B – Informed Consent

Bilgilendirilmiş Onam Formu

Projenin Adı: Sanal Gerçeklikte Bedensel Öz-Bilincin İncelenmesi

Proje yürütücülerinin adı ve iletişim bilgileri:

Yrd. Doç. Dr. Burak Erdeniz
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tel. +90 (232) 488 83 79

Ege Nuran Tekgün
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Projenin amacı: Bu projede, bedendeki duyulardan gelen sinyaller ile beden algısı arasındaki ilişkiyi anlamak amaçlanmaktadır. Bunun için insanların sanal bedenlerini nasıl algıladıkları hakkında genel bilgi edinmek istenmektedir.

Süreç: Bu amaçla araştırmacı fiziksel bedeninize bir fırça aracılığı ile dokunurken sizden istenen sanal gerçeklik ortamındaki bedeninizi izlemenizdir. Ardından verilen soruları değerlendirmeniz ve ölçümleri tamamlamanız istenecektir. Deney ortalama 20 dakika sürecektir.

Gizlilik: Sizden edinilen bilgiler tamamen gizli tutulacaktır ve sadece araştırmacılar tarafından erişilebilecek şekilde İzmir Ekonomi Üniversitesi, Psikoloji bölümünde korunacaktır. Deneyde aile mahremiyetine ve size zarar verici nitelikte hiçbir soru ve yöntem kullanılmamaktadır. Sizlerden elde edilen bilgiler bireysel değil, grup olarak değerlendirilecektir.

Gönüllü Katılım: Eğer bu araştırmaya gönüllü olarak katılmak istiyorsanız, lütfen formunun aşağısındaki ilgili kısmı imzalayınız. İstediğiniz an projeden ayrılmakta her zaman özgürsünüz. Araştırma ile ilgili bir sorunuz ya da sorularınız olursa yukarıda verilen iletişim bilgilerinden ulaşabilirsiniz. Değerli katkılarınızdan dolayı şimdiden çok teşekkür ediyoruz.

Yrd. Doç. Dr. Burak Erdeniz (Ekonomi Üniversitesi, Psikoloji Bölümü, tel. +90 (232) 488 83 79) tarafından yürütülen “Sanal Gerçeklikte Bedensel Öz-Bilincin İncelenmesi” isimli araştırma projesinin detaylarını okudum ve bu proje ile ilgili sorularım cevaplandı. **Bu formu okudum, anladım ve çalışmaya gönüllü olarak katıldığımı onaylıyorum.**

________________ ________________

İmza Tarih

Appendix C – Demographic Form

KATILIMCI BİLGİ FORMU

AD-SOYAD: TELEFON NUMARASI:

CİNSİYET: e-MAIL:

YAŞ / BOY: OKUL:

MESLEK/BÖLÜM: SINIF:

Aşağıdaki soruları yanıtlarken lütfen size en uygun olan seçeneği işaretleyiniz.

1. Daha önce hiç sanal gerçeklik deneyiminiz oldu mu?

   ☐ Evet ☐ Hayır

   Yanıtınız "Evet" ise kaç kere sanal gerçeklik deneyiminiz olduğunu belirtiniz.

   ……….

2. Yakın zamanda (son 1 sene dahil) başka bir psikoloji deneyine katıldınız mı?

   ☐ Evet ☐ Hayır

   ☐

   Yanıtınız "Evet" ise hangi deneye katıldığınızı belirtiniz.

   ……………………………………………………………………………

3. Herhangi ciddi bir görme bozukluğunuz var mı?

   ☐ Evet ☐ Hayır

4. Herhangi bir psikolojik rahatsızlık geçmişiniz var mı?

   ☐ Evet ☐ Hayır

   Yanıtınız "Evet" ise 5. sorudan, "Hayır" ise 7. sorudan devam ediniz.

5. Bir ruh sağlığı çalışanı tarafından rahatsızlığınıza konulan tanı nedir?

....

6. Rahatsızlığınız ile ilgili kullandığınız ilaç(lar) var mı?

☐ Evet ☐ Hayır

Yanıtınız evet ise lütfen kullandığınız/kullanmakta olduğunuz ilaç(lar)I yazınız.

....

7. Herhangi bir nörolojik hastalık geçmişiniz var mı?

☐ Evet ☐ Hayır

Yanıtınız "Evet" ise 8. sorudan, "Hayır" ise 10. sorudan devam ediniz.

8. Bir uzman tarafından hastalığınıza konulan tanı nedir?

....

9. Hastalığınız ile ilgili kullandığınız ilaç(lar) var mı?

☐ Evet ☐ Hayır

Yanıtınız evet ise lütfen kullandığınız/kullanmakta olduğunuz ilaç(lar)ı yazınız.

....

10. Daha önce kafa travması geçirdiniz mi?

☐ Evet ☐ Hayır

11. Düzenli olarak kullandığınız ilaç(lar) var mı?

☐ Evet ☐ Hayır

Yanıtınız "Evet" ise 12. sorudan, "Hayır" ise 13. sorudan devam ediniz.

12. Lütfen kullandığınız ilaç(lar)ı ve ilaç(lar)ın kullanım amaçlarını belirtiniz.
    İlaç(lar):…………………..………..…...
    Kullanım amacı:……………..………………..

13. Dün akşam kaç saat uyudunuz?

    ☐ 5 saatten az ☐ 6-8 saat ☐ 8 saaten fazla

14. Yoga veya meditasyon yapıyor musunuz?

    ☐ Evet ☐ Hayır

    Yanıtınız 'Evet' ise ne kadar sıklıkla olduğunu belirtiniz.

    ………………………………

15. Daha önce hiç berrak rüya (lucid dream - rüya sırasında rüya görüldüğünün farkında olunması durumu) gördünüz mü? Yanıtınız 'Evet' ise kısaca anlatınız.

    ....

16. Hiç fiziksel bedeninizin dışında bulunduğunuzu hissettiğiniz bir deneyim yaşadınız mı? Yanıtınız 'Evet' ise kısaca anlatınız.

    ....

17. Hiç bedeninizi başka bir görüş açısından gördüğünüz bir deneyim yaşadınız mı?
    Yantınız 'Evet' ise kısaca anlatınız.

    ....

18. Daha önce hiç uyku felci (uyandıktan sonra vücudun bir süre hareket edememe durumu) yaşadınız mı? Yantınız ‘Evet’ ise lütfen yaşadığınız deneyimi/deneyimleri kısaca özetleyiniz ve sıklığını belirtiniz.

....

19. Uyku apnesi (uykuda solunumun geçici olarak kesilmesi) olarak adlandırılan uyku bozukluğunuz var mı

☐ Evet ☐ Hayır

Yantınız ‘Evet’ ise lütfen yaşadığınız deneyimi/deneyimleri kısaca özetleyiniz ve sıklığını belirtiniz.

....

Appendix D – Subjective Report of Full Body Illusion

Lütfen aşağıdaki ifadelere katılım düzeyinizi belirtmek için ilgili ifadenin altındaki çizgi üzerine dik bir çizgi çekerek ne kadar katıldığınızı belirtiniz.

Örnek

Kesinlikle katılmıyorum — Kesinlikle katılıyorum

1. Sanal bedeni kendi bedenimmiş gibi hissettim.

Kesinlikle katılmıyorum — Kesinlikle katılıyorum

2. Sanki fiziksel bedenim sanal bedenimin bulunduğu konumdaymış gibi hissettim.

Kesinlikle katılmıyorum — Kesinlikle katılıyorum

3. Görüş açımın pozisyonu değişmiş gibi hissettim.

Kesinlikle katılmıyorum — Kesinlikle katılıyorum

4. Kendimi ayakta duruyormuş gibi hissettim.

Kesinlikle katılmıyorum — Kesinlikle katılıyorum

5. Sanki iki bedenim varmış gibi hissettim.

Kesinlikle katılmıyorum — Kesinlikle katılıyorum

6. Deneyi yapan kişinin karnıma dokunduğunu hissettim.

Kesinlikle katılmıyorum — Kesinlikle katılıyorum

7. Sanki oda sanal bedenimin etrafında dönmüş gibi hissettim.

Kesinlikle katılmıyorum — Kesinlikle katılıyorum

8. Aynada sanal bedeninizi ve b bedene uygulanan dokunuşları izlerken kendinizi hangi eğimde hissettiğinizi aşağıdaki grafik üzerine bir çizgi çizerek belirtiniz.