An Investigation of Heart Rate Validity and Psychological Correlates of the Out-of-Body Illusion Paradigm

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Abstract

Ehrsson (2007) reported that individuals who experienced the experimentally induced out-of-body illusion (OBI) perceived themselves from a different viewpoint and displayed higher scores of disowning their physical body, which indicated a possible out-of-body experience (OBE). However, previous investigations of the OBI paradigm did not test heart rate as an objective marker to evaluate whether the paradigm successfully induced OBEs or include other relevant variables that could impact responding to the OBI paradigm. Thus, the first goal of this study was to test the validity of the OBI paradigm using heart rate as an objective marker. We further investigated whether sleep quality influences the OBE and the extent to which this relationship is mediated through depersonalization. To accomplish this, 163 undergraduate psychology students underwent the experimental procedure and were startled by a fake threat stimulus after seeing their congruent self-images. Participants wore a Cortrium C3 heart rate monitoring device (Cortrium, 2016). They completed an OBI questionnaire (OBIQ: Ehrsson, 2007), the Pittsburgh Sleep Quality Index (PSQI: Buysse et al. 1989), and a Cambridge Depersonalization Scale (CDS: Sierra and Berrios, 2000). The results from a three-way mixed ANOVA and an independent samples t-test indicated that synchronous tapping did not create a working illusion. This implied that participants did not perceive themselves from a different perspective. An exploratory mediation analysis showed that participants who had sleep deprivation would be more likely to experience depersonalization. There was no significant evidence provided for the mediation effect of depersonalization on sleep quality and OBE. Despite the lack of significant findings, the study is the first to test heart rate as an objective marker and it paves the way for further exploration of the underlying psychological factors contributing to OBEs.

Introduction

Have you ever had the experience in which you saw your body from a different perspective and perceived your sense of self from that point of view while you were awake? If your answer is yes, then you might have experienced a phenomenon called an out-of-body experience (OBE). OBEs are sensations where individuals perceive their bodies and sense of self from a different point of view while they are awake (Ehrsson, 2007). OBEs have captured the attention of researchers for several decades, as they often occur in patients suffering from schizophrenia, migraines, depersonalization and derealization (Blackmore, 1986; Comfort, 1982; Lopez and Elziere, 2017). They also occur in healthy populations (Blanke and Mohr, 2009; Milne et al. 2019). It is hard to estimate the prevalence of OBEs due to variations among studies. For example, studies used different questions to investigate the occurrence of OBEs or asked questions via different communication mediums such as mail, telephone, or personal interviews (Blanke and Dieguez, 2009). The prevalence of OBEs in the general population can be estimated at 5% (Blanke and Dieguez, 2009) and over 25% of college students have reported experiencing OBEs (Irwin, 1989; Braithwaite et al. 2011). Thus, an OBE incidence can be considered a common occurrence, and this has inspired researchers to gain a deeper understanding of the neurological and psychological mechanisms underlying OBEs.

The current psychological models of OBEs argue that OBEs are likely related to specific disturbances in cognitive and sensory processes (Irwin 1989; 2000). It is claimed that the sensory processing of kinesthetic and somesthetic stimuli serves to maintain the assumption that thinking and perceiving of oneself resides in the physical body. However, this may not be the case for OBEs (Irwin, 1996). In this sense, OBEs may be a dissociative phenomenon by nature (Irwin, 2000). Dissociation refers to disruptions in the integration of thoughts, emotions, and consciousness (American Psychiatric Association, 2013).

Dissociative symptoms can give rise to feelings of disembodiment and disconnection from the self and the world (Van Heugten-Van der Kloet et al., 2018). Briere et al. (2005) found that depersonalization and derealization is the symptom cluster of dissociation which would be in line with the many clinicians' views. Furthermore, Depersonalization and Derealization Disorder is one of the dissociative disorders in DSM-5 (American Psychiatric Association, 2013). Relatedly, depersonalization is characterized by an impairment of self-awareness, primarily resulting in feelings of disembodiment and subjective emotional numbing (Sierra and David, 2011). Disembodiment experience may range from a non-specific sensation of feeling detached from a physical body to an OBE (Sierra and David, 2011). Several researchers have found positive relationships between depersonalization experiences and OBEs. For example, depersonalization-derealization was the only significant predictor of OBEs in healthy individuals (Lopez & Elziere, 2017).

The relationship between depersonalization and other psychological factors such as sleep quality has been investigated in the context of OBE as well. Sleep has been suggested to be a relevant factor associated with the occurrences of OBEs because OBEs can occur during hypnagogic (before falling asleep), resting, and hypnopompic (after waking up) states (Jalal and Ramachandran, 2017, Blackmore, 1984a. Blackmore (1984b) suggested that the combination of disruptions to body sensations and imaginary processes might induce OBEs (e.g., being disconnected from sensorimotor input while falling asleep). While hypnagogic and hypnopompic states are often associated with OBEs, they are the most frequent among participants who had trouble falling asleep (Ohayon and Sagales, 2010). Furthermore, Ohayon (2000) found that having a perception of overlong sleep duration was significantly associated with the OBE occurring weekly or less. Meanwhile, overly short sleep was significantly related OBEs that occur at least once a month.

In a similar vein, several researchers have examined a sleep hygiene intervention to improve sleep quality which would lead to a decrease in dissociation (van der Kloet et al., 2012a). Though their findings indicated that the improvement of sleep did not have an effect on dissocative symptoms, they found that the disturbances in the sleep-wake cycle may yield increased dissociation experiences. Selvi et al. (2015) observed a significant increase in dissociation levels after restricting the amount of sleep participants had. Using a virtual reality setup, researchers investigated dissociation, the sense of embodiment, and sleep quality in experimentally induced OBEs (van Heugten-van der Kloet et al. 2018). They found that poor sleep quality was a symptom correlate of acute dissociation in pre-experiment self-reports. Arora et al. (2020) showed that poor sleep quality indicating self-reports and objective markers is significantly related to depersonalization in female university students. Taken together, the overall findings indicated that there might be an association between sleep quality, depersonalization, and OBEs.

The relationship between sleep quality, depersonalization, and OBEs requires further investigation. Van Der Kloet et al. (2012b) argued that sleep-related cognitive control deficits might induce an inflow of vivid, dreamy states in everyday life, which can lead to dissociative symptoms including depersonalization. Depersonalization experiences may manifest themselves in moments of weakened self-awareness, feelings of disembodiment, and the perception of being an outside observer of oneself (Sierra & David, 2011; American Psychiatric Association, 2013). One can argue that in order to become an observer of the self, the center of awareness should move out from the corporal space. Several researchers proposed that interference with the center of awareness in body perception in space can lead to OBEs (Guterstam and Ehrsson, 2012). Such interferences may stem from exacerbated depersonalization levels as the depersonalization experiences may accompany perceiving oneself in another location in space. Therefore, it is conceivable to suspect that the effect of sleep quality on OBEs is mediated by depersonalization. However, this mediating effect has not yet been fully explored. To the best of our knowledge, there has not been a study that has conducted a mediation analysis of OBEs while using sleep quality as a predictor variable and depersonalization as a mediator.

Contemporary neurological models have proposed that OBEs occur due to a temporal disruption to the multisensory integration of bodily self-consciousness (Blanke et al. 2004). Multisensory integration refers to the neural process by which body signals are integrated with surrounding space while forging visual, tactile, proprioceptive, and other sensory stimuli (Blanke et al. 2002; Talsma, 2015), which represents the experience of the conscious "I" as being embodied and localized within corporal space (Ionta et al. 2011). There is a growing body of evidence from neurology that multisensory integration is a relevant mechanism in creating a corporal self-consciousness (Aspell, 2009; Lenggenhager, 2009; Blanke, 2012). In order to experience multisensory integration, two or more inputs from two or more sensory modalities must occur synchronously (Kalckert and Ehrsson, 2012). Integrating the different multimodal signals occurs automatically to help individuals navigate in this world and have a coherent self-identification (Bertelson et al. 2004; Blanke, 2012). A failure in multisensory integration located in the right angular gyrus may lead to OBEs (Blanke et al. 2002). Blanke et al. (2002) showed that a patient treated for epilepsy reported OBEs after a focal electrical stimulation to the right angular gyrus. These neurological outcomes resulted in the idea that an individual's perception of the embodied self may not be as stable as assumed and can be easily manipulated (Ehrsson et al. 2005; Ehrsson, 2007).

Based on the theoretical framework of multisensory integration, several empirical investigations aimed to manipulate body awareness and body ownership. Botvinick and Cohen (1998) created the rubber hand illusion (RHI), in which participants mislocated the perceived location of their own hand after 10 min of synchronous tapping on the rubber hand

and the participant's hand. Participants perceived their hand's position to be closer to the rubber hand, as if their hand had drifted toward the fake hand. Thus, the feeling of limb ownership was distorted by a multisensory correlation of visuotactile stimulation. Ehrsson (2007) adapted this experimental setup to manipulate body awareness in space and induced an out-of-body experience, called the out-of-body illusion (OBI) paradigm. Ehrsson (2007) designed an experiment in which a participant sits in front of a camera that recorded the participant's back in real-time. Participants wore a head-mounted display (HMD) that was connected to the left and right eye, corresponding to two cameras. The participants were, therefore, looking at their own back from the view of someone seated behind them. After this, the experimenter stood between the participant and the camera and tapped the participant's chest and the chest of the illusory body (the camera) with a rod both synchronously and asynchronously. The synchronous tapping (i.e., the simultaneous presentation of tactile stimulation and congruent visual input towards the camera) was expected to create out-of-body illusions because the multisensory integration theory suggested that the first-person perspective and temporal correlations of different sensory inputs from body-related directions create oneself in space (Guterstam and Ehrsson, 2012). Furthermore, asynchronous tapping was not expected to result in an OBI since the visual and tactile stimulation were not congruous. In order to test whether the participant's sense of self was perceived to be located where the camera was, the participant was startled by presenting a fake threat stimulus with a hammer to the so-called illusory body (camera) after two minutes of tapping. The startle response was physiologically assessed by measuring and recording the skin conductance response in the experiment.

The results showed that the participants who experienced the synchronous tapping exhibited higher startle responses after a fake threat stimulus to the illusory body than those who experienced the asynchronous tapping. Participants in the synchronous tapping group felt their sense of self localized in the illusory body. Therefore, these participants experienced higher startle responses and reported stronger OBE sensations. The synchronous visuotactile stimulation was considered to be a working out-of-body illusion (OBI). Meanwhile, the threat stimulus was only presented to the illusory body in the OBI experimental setup (Ehrsson, 2007). The researchers then added another attack condition in the OBI paradigm (Guterstam and Ehrsson, 2012) and presented threat stimuli to the real body of participants. The results suggested that attacking the real body after synchronous tapping led to a significantly lower fear response, indicating that the participants did not experience their selves as located in their real bodies. Thus, in light of this, the threat stimulus to the real body is employed as a control condition in the current study. In addition to adding a control variable to the attack condition, the present experiment used another physiological marker to detect startle response. Physiological measures have often been used to overcome limitations in research techniques. Physiological assessments can be a valuable addition to self-reports and are used to capture emotional responses (Ciuk et al. 2015). Fear responses can cause emotions that are associated with physiological discharges. These emotions can then be measured by physiological changes in skin conductance response and heart rate (Menard et al., 2015). A meta-analysis showed that there was a greater acceleration in heart rate when participants experienced fear than when participants were in the control condition (Cacioppo et al. 1997). Thus far, the OBI paradigm has only used skin conductance response as a physiological marker. Using only one physiological marker is a limitation of previous research, and the OBI paradigm requires further physiological exploration and validation. Therefore, the current study used heart rate as an additional objective marker of the startle response.

The identification of objective markers in the context of dissociation and OBEs is relevant as recent developments in research have allowed experimenters to induce OBEs and dissociative states. Clinical psychology studies have emphasized the discrepancy between self-reports and affective states since the Freud (Cacioppo et al. 2000; Davidson, 1998). Research has shown that self-reports of dissociative phenomena may lead to an underreporting or overreporting of syndromes (Merckelbach et al. 2017). Objective physiological assessments could reduce the overreporting and underreporting that might arise due to careless and random reactions, failure to identify feelings, or malingering (Merckelbach et al. 2017; Meade & Craig, 2012). While most OBE research has been based on self-reports several months or years after the occurrence of the OBEs (Bunning and Blanke, 2005), the OBI experimental setup enabled experimenters to examine OBEs using a physiological marker. This allowed for the investigation of the underlying mechanisms of OBEs. Consequently, Nakul and Lopez (2017) have proposed future researchers to study psychological factors, specifically depersonalization and derealization, along with the multisensory integration based OBI Paradigm. Taken together, the OBI setup allowed researchers to investigate OBEs in a laboratory setting with less confounding factors and a stable environment.

Study Aims

The first aim of this study is to test the validity of the experimentally induced OBI with a threat-evoked heart rate as a physiological marker. The respective hypotheses for this aim are as follows:

Hypothesis 1: Synchronous tapping leads to a significantly higher threat-evoked heart rate than asynchronous tapping.

Hypothesis 2: The attack to the illusory body leads to a significantly higher startle response than the attack to the real body.

We expect a three-way interaction between tapping condition, attack condition, and time. This would mean that the startle response between synchronous and asynchronous tapping differs for the real and illusory body attack and that this interaction changes by the time order. The hypothesis for this is as follows:

Hypothesis 4: There is an interaction effect between tapping condition and attack condition, and this interaction depends on the trial sequence.

Although the main goal of this study was to test the validity of the OBI paradigm with an objective marker, we also included a hypothesis to test whether subjective ratings of an OBI from the Out-of-Body Illusion Questionnaire (OBIQ) differ according to tapping conditions. This hypothesis is as follows:

Hypothesis 5: Synchronous tapping results in significantly higher OBIQ scores than asynchronous tapping.

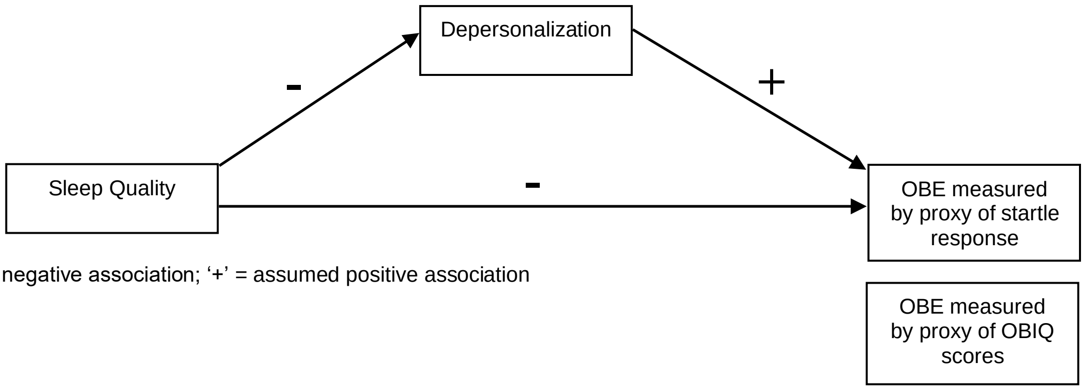
Our second aim was to investigate factors that contribute to OBEs using the mediational model with depersonalization as a mediator and sleep quality as a predictor. We employed proxy of startle response and proxy of OBIQ scores as dependent variables in different mediation analyses. This led to the following research question: *Does depersonalization mediate the relationship between sleep quality and OBEs (Figure 1)?* The hypotheses to test this are as follows:

Hypothesis 6: The relationship between sleep quality and proxy of startle response as a marker of successfully induced OBEs is partially mediated by depersonalization experiences (see Figure 1).

Hypothesis 7: There is a relationship between sleep quality and the proxy of OBIQ scores is partially mediated by depersonalization experiences (see Figure 1).

Figure 1.

Hypothesized Mediation Model



Note. '-' = assumed negative association; '+' = assumed positive association

Methods

Participants

One hundred and sixty-three first-year psychology students were recruited via an internal university system. Of these, 46% were men and 54% were women. The mean age was 21.3 (*SD*=3.12; range=18–39). Participants were compensated with points, which are an integral part of a compulsory research practicum course. This study was approved by The Dutch Ethical Committee of Psychology (ECP) at the University of Groningen.

Study Design

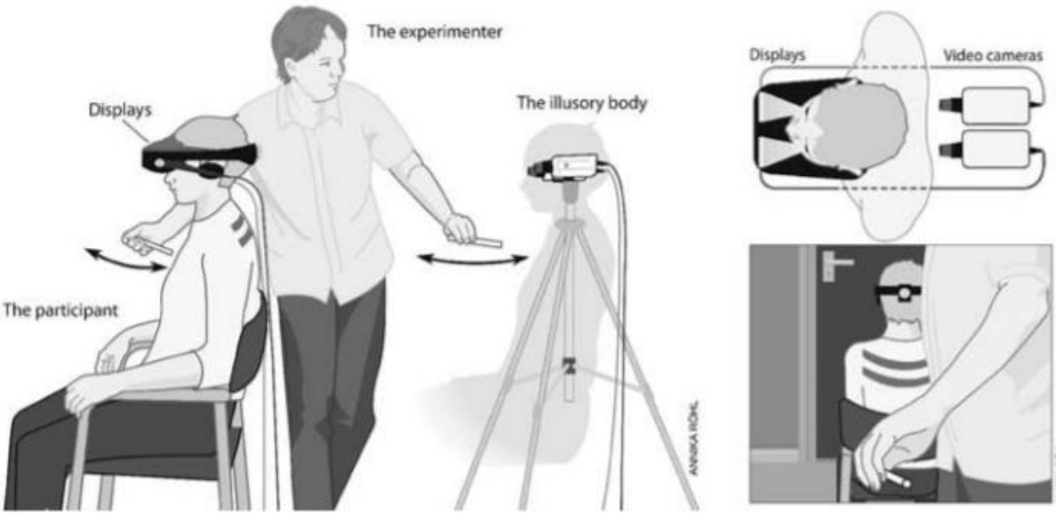
This study used a randomized laboratory study to test experimentally induced OBEs. For the first part of the study, a 2x2x3 factorial study design was used in the experiment. Participants were randomly assigned to groups by subject factor, with one group assigned to the synchronous tapping condition and the other to the asynchronous tapping condition. Additionally, there were two within-subjects factors. The first within-subjects factor was the threat condition (illusory body threat and real body threat). The second within-subjects factor was time (see experimental setup and procedure for further detail). The threat condition was counterbalanced, and participants experienced the attacks with a pre-determined pseudo-randomized order, including order A (Real, Illusory, Illusory, Real, Real, Illusory) or order B (Illusory, Real, Real, Illusory, Illusory, Real).

Experimental Setup and Procedure

After signing the informed consent, the participants answered a set of baseline questionnaires. Following that, participants attached the Cortrium C3 (Version B8, Cortrium, 2016) device to the midsternal line of their chests to measure heart rate. The Cortrium C3 (referred to as the "C3" from here on) is a wireless Holter monitor with three ECG electrodes. The C3 was found to be compatible with the wired ECG machines in a controlled laboratory environment (Kunkels et al. 2021). Heart rate and respiration signals were recorded by the C3 and sent to an iPad application called Cortrium via Bluetooth. The application allowed us to flag a timestamp for the attack in the behavioral task. During the experimental procedure, the participants sat on a chair and wore a head-mounted display (Oculus Rift CV1, Oculus VR, LLC., Irvine, California, USA; Display Resolution=1080 x 1200 per eye at 90 Hertz) connected to a pair of cameras mounted side-by-side 1.2 meters behind the participants. This allowed the participants to see their backs as if they were looking at themselves from someone else's point of view (Figure 2). The experimenter stood between the participant and the camera. Then, the experimenter started to tap the chest of the participant's real and illusory body (cameras) with rods synchronously or asynchronously depending on the participant's group. The illusory body tap was implemented by tapping below the cameras corresponding to the upper-right chest line. The experimenters tapped the participants' chests for 60 sec at a rate of 1 tap per second. This corresponded to the rate of the rod movements below the camera in the synchronous group. In the asynchronous group, the rod movements below the camera preceded the chest tapping with a 0.5-sec delay. After two minutes of tapping, a fake threat stimulus was applied by swinging a plastic hammer towards the real or illusory body. The illusory body threat stimulus was presented at a point slightly below the cameras, and the real body threat stimulus was presented at a point on the back of the participant's head. Throughout the experiment, the participants' illusion experiences were verbally assessed using the OBIQ (Ehrsson, 2007) after the behavioral tasks (e.g., tapping procedure) finished. The procedure was repeated six times (three times with the illusory body threat and three times with the real body threat).

Figure 1

The Experimental Setup that is designed to induce the out-of-body illusion and what the participants see.



Adapted from 'The Concept of Body Ownership and Its Relation to Multisensory Integration' by H. Ehrsson, 2012.

Self-Report Measures

The Pittsburgh Sleep Quality Index (PSQI; Buysse et al. 1989) is a self-administered 19-item questionnaire to assess sleep quality. The PSQI includes 7 components that produce a global score, and high global scores indicate greater sleep disturbances. Internal consistency in the current sample was poor for the PSQI (Cronbach's α= .52). This finding was not in consonant with previous studies (Beaudreau et al. 2012; Gomes et al. 2018)

The Cambridge Depersonalization Scale (CDS; Sierra and Berrios, 2000) is a self-administered 29-item questionnaire that measures frequency (0-4 scale) and duration (0-6 scale) of depersonalizations symptoms. A composite score is calculated by summing all item scores and higher scores show the severity of depersonalization. The scale showed high internal consistency with Cronbach's alpha value 0.95, respectively. The finding was in line with previous studies (Sierra and David, 2011; Kontoangelos et al. 2016)

Out-of-Body Illusion Questionnaire (OBIQ; Ehrsson, 2007) is a 10-item questionnaire that includes three statements correspond to illusion and seven control statements, which were unrelated to illusion. It includes a seven-point scale and on this scale -3 meant (‘absolutely certain that it did not apply’, 0 meant ‘uncertain whether or not it applied’, +3 meant ‘absolutely certain that it did apply’. The illusion statements in questionnaire showed poor internal consistency with Cronbach’s alpha value 0.48.

Heart Rate

For the calculation of threat-evoked heart rate, R-R intervals, also referred to as interbeat intervals (IBI/RR) were employed. The R-R interval is the time period in milliseconds between two consecutive R peaks in the QRS (e.g., a waveform that indicates the electrical activity of the heart) signal on the electrocardiogram (Lanfranchi and Somers, 2010). R-R intervals are used to calculate heart rate in beats per minute. Previous studies showed that a startle response leads to a faster heart rate (Cacioppo et al., 1997) and fewer milliseconds between successive R-R intervals.

The heart rate data were exported via MatLab Cortrium GUI to prepare the R-R intervals for analysis. The electrocardiographic artifacts and connection losses were visually checked and the participants with electrocardiographic artifacts were excluded from the analyses. Any huge fluctuations in QRS complexes and respiratory rates were considered to be artifacts and long flat lines were viewed as connection losses (see Appendix). The participants with fluctuating QRS complexes but steady respiratory rates were included in the analysis (see Appendix). Furthermore, two consecutive R-R peaks that were longer than 2500 ms or two consecutive R-R peaks that were shorter than 300 ms were not included in the analysis if the visual inspection revealed long flatlines or fluctuations. One participant was excluded due to their data containing two consecutive R-R peaks longer than 2500 ms and connection losses during crucial periods. Eleven participants were excluded because they had two consecutive R-R peaks shorter than 300 ms and there were connectivity failures during critical periods. In addition to these participants, 78 participants were removed from the data analysis after the visual inspection because of long flat lines or fluctuated QRS complexes. In total, 90 participants were removed from the analyses that used heart rate data.

The mean difference scores of three post- and pre-event IBI/RR were calculated and operationalized as the threat-evoked heart rate in this study. The IBI/RR in which the threat stimulus presented was considered to be the event IBI/RR. The event IBI/RR was not used in the analyses in order to enhance the contrast between post- and pre-event IBI/RRs. As such, a positive score (i.e., smaller IBI/RRs in the pre-event condition compared to the post-event condition) indicated a decrease in heart rate following the threat attack whereas a negative value (i.e., smaller IBI/RRs in the post-event condition compared to pre-event condition) corresponded with an increase in heart rate. The threat-evoked heart rate was used for the dependent variable in the three-way mixed ANOVA analysis.

For the calculation of the proxy of startle response, the mean of the mean differences of three post- and pre-event IBI/RRs in synchronous tapping and illusory body attack (Synchoronous/Illusory) conditions is employed. This analysis only used the physiological data collected during the Synchronous/Illusory conditions because of the precedent set forth in Ehrsson (2007). Though there were important differences between the experiments (e.g., the inclusion of the body attack condition as a within-subjects variable in this study), the Synchronous/Illusory conditions were expected to lead to an OBI. The proxy of startle response was used as the dependent variable in the mediation analysis.

Data Analysis

The data were analyzed with SPSS (version 26.0.0) using an alpha level of 5% to test for significance. The three-way mixed ANOVA, the independent samples t-test, and mediation and correlation analyses were used to test the hypotheses.

Three-way mixed ANOVA

A three-way mixed ANOVA was used to determine whether the tapping (synchronous and asynchronous), the attack (real body and illusory body), or the time (1st block, 2nd block, and 3rd block) had an effect on the threat-evoked heart rate. Based on our hypothesis, a three-way interaction was expected. Heart rate data were based on $n = 24$ participants in the synchronous tapping group and $n = 12$ participants in the asynchronous tapping group. There were 37 outliers whose data were excluded based on the inspection of a boxplot. Linear transformations did not lead to noteworthy improvements (Field, 2018). Therefore, the outliers were removed from the data. After removing the outliers, the homogeneity of variances was tested with Levene's test. The equality of variances was violated as well ($p < .05$). For the three-way interaction effect, there was no evidence that the sphericity assumption was violated, $\chi2(2) = 2.446$, $p = .294$. This means that variances of the differences between all combinations of related groups were equal.

Independent Samples T-Test

There were 96 participants in the synchronous tapping group and 63 participants in the asynchronous tapping group. Each participant experienced the illusory body attack as it was a within-subjects factor. An independent-samples t-test was run to determine whether there were differences between the participants in the synchronous and asynchronous groups in relation to the illusory body attack condition reported in the OBIQ scores. The OBIQ scores for each tapping condition were normally distributed, as shown by normal Q-Q plots. In addition, the assumption of homogeneity of variance was met as shown by Levene's test for equality of variances (p=.70).

Correlation Analyses

There were 44 participants included in the correlation analysis between sleep quality (evaluated with the PSQI), depersonalization (evaluated with the CDS), and OBE (proxy of startle response). The preliminary visual inspections showed that the linearity and normality assumptions were not met. Due to the violation of the normality assumption, one outlier was removed. However, removing the outlier did not lead to better results. For this reason, the outlier was included in the Pearson correlation analysis.

Ninety-two participants were recruited for the correlation analysis between sleep quality (evaluated with the PSQI), depersonalization (evaluated with the CDS), and OBE (Proxy of OBIQ Scores; Mean of OBIQ scores in Synchronous/Illusory conditions). The initial visual inspections suggested that the linearity and normality assumptions were not met. A Pearson correlation analysis was conducted.

Mediation Analyses

After a check indicating that the assumptions of normality and homoscedasticity had not been violated. We further conduct two mediation analyses to estimate the paths of casual influence from sleep quality to OBE through the mediator of depersonalization. In order to calculate the direct and indirect effect of the mediation, Model 4 in the PROCESS macro of Hayes (2018) was used in both analyses. The equations for the path diagram of the mediation models are as follows: (X: Sleep Quality, M: Depersonalization, Y: Proxy of Startle Response) and (X: Sleep Quality, M: Depersonalization, Y: Proxy of OBIQ Scores). The statistical significance of the indirect effect was measured using 95% bias-corrected bootstrapped confidence intervals with 10,000 draws.

Results

Descriptive Statistics

The startle responses of the tapping and attack conditions in each block were averaged across the participants. These scores are summarized in Table 1. There was no trend across time, body attack conditions, and tapping conditions. Furthermore, the overall mean was positive in all conditions, which indicated a decrease in heart rate following the attack.

Table 1

Means and standard deviations of startle responses (3 POST-PRE Event IBIs) obtained from OBI Paradigm.

	Tapping Condition			
	Synchronous Tapping		Asynchronous Tapping	
	Attack Condition			
Time	M (*SD*) Real Body	M (*SD*) Illusory Body	M (*SD*) Real Body	M (*SD*) Illusory Body
1st Block	(*42.607*) 2.666	(*55.681*) 25.889.	(*55.735*) 2.778	(*32.160*) 0.056
2nd Block	(*54.810*) -3.722	(*16.777*) 0.500	(*43.024*) 7.778	(*25.218*) 18.111
3rd Block	(*59.570*) 6.667	(*59.763*) -3.833	(*20.265*) 1.222	(*40.523*) 19.556

Note. Negative value is considered as an acceleration in the heart rate that indicates the OBI.

Three-Way Mixed ANOVA

The three-way mixed ANOVA analysis did not yield any significant findings. There was no significant simple main effect of the tapping condition, indicating that the startle response of the participants in the synchronous and asynchronous tapping groups was generally the same $F(1, 34)=.374$, $p=.545$, partial $\eta^2=.011$. There was not a statistically significant simple main effect of time, meaning that the startle response of the participants did not differ significantly between blocks $F(2, 68)=1.996$, $p=.287$, partial $\eta^2=.036$. There was not a statistically significant simple main effect of attack $F(1, 34)=1.080$, $p=.306$, partial $\eta^2=.031$. This indicated that the threat stimuli to conditions of the illusory and real body did not yield any difference in startle responses. There was no significant interaction effect between tapping and attack conditions $F(1, 34)=0.48$, $p=.829$, partial $\eta^2=.001$. This revealed that startle responses of attacking the real or illusory body did not depend on whether participants were in the synchronous or asynchronous group. There was no significant interaction effect between the tapping and time conditions $F(2, 68)=1.486$, $p=.234$, partial $\eta^2=.042$. Thus, tapping participants synchronously or asynchronously did not lead to a different startle response over time. There was also no significant interaction effect between attack and time conditions $F(2, 68)=0.68$, $p=.935$, partial $\eta^2=.002$. This suggested that the startle responses of the illusory and real body attacks did not differ over time. There was no statistically significant three-way interaction between tapping, attack, and time $F(2, 68)=1.996$, $p=.287$, partial $\eta^2=.036$. This means that participants did not experience different startle responses in any levels of tapping, attack, and time conditions.

Independent Samples T-Test

The participants in the synchronous tapping condition experienced the illusion more ($M=0.72$, $SD=1.51$) than those in the asynchronous tapping condition ($M=0.55$, $SD=1.59$), a statistically non-significant difference, where $M=0.16$, 95% CI [-.33, 0.66], $t(157)=.66$, $p=.51$, $d=.11$. This revealed that there was no difference between the OBI scores of the synchronous and asynchronous groups.

Correlational Analyses

There was no statistically significant correlation between sleep quality and both the proxy of the startle response ($r=0.28$, $p=.852$) and depersonalization ($r=0.78$, p=.620; see Table 1). Moreover, the association between depersonalization and the proxy of the startle response (Pro_Heart) was not significant (*r*=-.213, *p*=.155). Meanwhile, there was a statistically significant, moderate positive correlation between sleep deprivation and depersonalization (*r*=0.319, *p*=.002). However, the association between Proxy of OBIQ scores and both sleep quality (r=0.12, *p*=.914) and depersonalization was not significant (*r*=0.53, *p*=.614; Table 2). Although the dependent variables did not correlate with sleep quality and depersonalization scores, the correlation is not a necessary condition for mediation analysis (Hayes, 2018). Thus, the mediation analyses were conducted as hypothesized.

Table 2

Table of Correlations for PSQI, CDS, and Pro_Heart (n=44)

	1	2	3
1. PSQI	--		
2. CDS	,077	--	
3. Pro_Heart	,028	-,213	--

Note. PSQI = Pittsburgh Sleep Quality Index Global Scores;
CDS = Cambridge Depersonalization Scale Total Scores;
Pro_Heart = Proxy of Startle Response
*p < .05

Table 3

Table of Correlations for Main PSQI, CDS, and OBIQ (n=92)

	1	2	3
1. PSQI	--		
2. CDS	,32*	--	
3. OBIQ	,012	,053	--

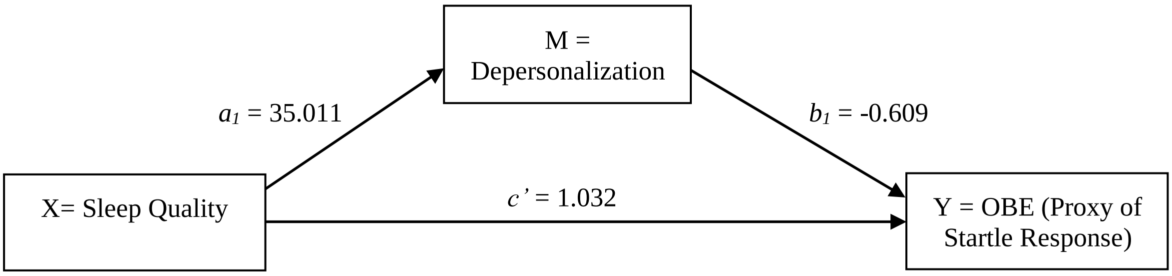
Note. PSQI = Pittsburgh Sleep Quality Index Global Scores;
CDS = Cambridge Depersonalization Scale Total Scores;
OBIQ = Proxy of OBIQ Scores
*p < .05
**p <.001

Mediation Analysis with Proxy of Startle Response

Sleep quality was not significantly associated with depersonalization (a=35.011, p=0.62). Furthermore, depersonalization was not significantly associated with the proxy of the startle response (b=-0.609, p=0.17). The parameter estimates of the indirect effect of sleep quality (ab) using 10,000 bootstrap samples were b=-0.432; 95% CI [-3.689; 1.530], meaning that there was no evidence of an indirect effect of sleep quality on the proxy of startle response through depersonalization. The direct effect of sleep quality on the proxy of startle response of c′=1.032 was not statistically significant (p=0.80).

Figure 3.

Mediation model of Proxy of Startle Response



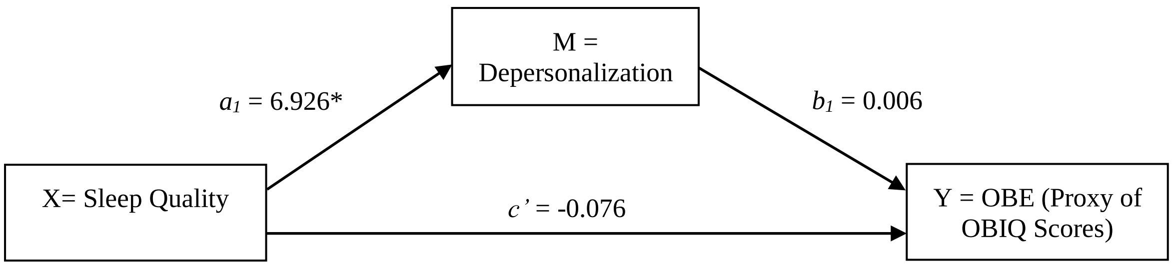
Note: X= independent variable; M= mediator; Y= dependent variable. Standard errors are reported in parenthesis.
$*p < 0.05$.
$**p < 0.001$

Mediation Analysis with Proxy of OBIQ Scores

Participants who were sleep-deprived were more likely to experience depersonalization (a=6.926, p=0.02), and participants who had OBEs were not more likely to be influenced by depersonalization and related disembodiment experiences (b=0.006, p=0.46). A bootstrap confidence interval for the indirect effect (ab=0.021) based on 10,000 bootstrap samples was within zero (-.109 to .156). There was no evidence that lowered sleep quality influenced the occurrence of OBEs (c'=-0.076 p=.71).

Figure 4.

Mediation model of Proxy of OBIQ Scores



Note: X= independent variable; M= mediator; Y= dependent variable. Standard errors are reported in parenthesis.
*$p < 0.005$.
**$p < 0.01$

Table 4.

Depersonalization as a Mediator of the Effect of Sleep Quality on Out-of-Body Illusion Measures Proxy of Startle Response and the Proxy of OBIQ Scores

	Raw Parameter Estimate	Standard Error	95% Bias-Corrected Confidence Interval (CI)	
			Lower	Upper
Proxy of Startle Response				
Total Effect	0.600	4.035	-7.544	8.744
Direct Effect	1.032	4.001	-7.048	9.113
Indirect Effect	-0.432	1.230	-3.689	1.510
Proxy of OBIQ Scores				
Total Effect	-0.055	0.203	-0.459	0.350
Direct Effect	-0.076	0.216	-0.505	0.353
Indirect Effect	0.021	0.065	-0.109	0.156

Note. Results are based on 10,000 bias-corrected bootstrap samples.
* 95% CI does not include zero.

Discussion

This study employed the OBI paradigm developed by Ehrsson (2007) in order to experimentally induce OBEs in healthy participants and test the startle response using heart rate as an objective marker of the paradigm. As such, a three-way mixed ANOVA was employed to test if synchronous (vs. asynchronous) visuotactile stimulation and a body attack on the illusory (vs. real) body resulted in an elevated threat-induced startle response and whether this effect differed across trials. We further conducted a mediation analysis by using depersonalization as a mediator, sleep quality as a predictor, and proxy of startle response as a dependent variable. To investigate whether objective physiological responses correspond with subjective self-reported experiences, and independent samples t-test was conducted with the OBIQ scores gathered after the synchronous and asynchronous tapping in illusory body attack conditions, and the aforementioned mediation analysis was repeated with the proxy of OBIQ scores. Unfortunately, the overall results did not support current hypotheses regarding the validity of the paradigm to induce OBEs and a mediating effect. A closer inspection of the findings revealed a noteworthy implication that will be discussed in the following sections.

Validity of OBI Paradigm

The first aim of this study was to test the validity of the OBI paradigm using heart rate. The synchronous visuotactile stimulation was expected to induce an OBI. The present study did not find a significant difference in startle response between the synchronous and asynchronous groups. This suggests that synchronous visuotactile stimulation does not lead to a person locating their sense of self in another place. This was not in line with our paradigm-based hypothesis that congruent visuotactile correlation can induce an aberrant sensation such as an OBE (Ehrsson, 2007). Furthermore, we hypothesized that there is an interaction effect between tapping condition and attack condition and that this interaction depends on time. There was not enough evidence to support this hypothesis. Meanwhile, the overall mean of the tapping condition, body attack condition, and time was positive. A positive value indicates greater heart rate deceleration, which means the illusion did not work on the participants and they felt calmer after the threat stimuli across conditions. We also tested the OBI paradigm with self-reports of participants using the OBIQ. There was not any significant difference between the illusory attack group's synchronous and asynchronous tapping conditions. The overall mean of the tapping condition was between 0 and 1, indicating that participants were uncertain about their experience with a positive tendency toward the affirmation of the illusion.

The results of the overall means in heart rate and OBIQ analyses may have been caused by several factors. The participants might have experienced the illusion in both the synchronous and asynchronous conditions, while their unpleasantness and stress levels were increased during the behavioral task (e.g., the tapping). Then, the participants might have felt more comfortable as the task finished. Additionally, the threat stimuli may not have been perceived as scary enough to cause any physiological responses in the participants. Thus, these factors might have caused an overall deceleration of heart rate after the tapping, whereas the self-reports indicated a trend of an OBI occurring.

It is useful to discuss the overall mean to affirm the illusion and reduced heart rate in synchronous and asynchronous tapping conditions via OBIQ. The combination of the potential delay in VR setup and fast asynchronous tapping might have caused participants to feel the asynchronous tapping just like the synchronous tapping. The metronome was used at a rate of 2 taps per second to keep the number of the shoulder taps consistent in across conditions. Furthermore, several researchers discussed the inconsistencies in the delay between taps in the asynchronous condition in RHI experiments, where the delays ranged from 300 ms to 2 s (Riemer et al. 2019). In this study, the delay between taps in the asynchronous condition was 500 ms. Several researchers found that delays less than or equal to 300 ms in the asynchronous tapping condition induced the proprioceptive drift and the strong sensation of RHI (Shimada et al. 2009). Assuming that OBI manipulation is based on a similar behavioral task and concepts like multisensory integration and body awareness, one can argue that the results of the RHI under 300 ms can be applied to the OBI. If there was a delay greater than or equal to 200 ms due to the technical setup, participants might experience the asynchronous tapping as synchronous. In order to assess the average asynchrony, the latency due to the connections between the camera, the VR setup, and the computer should have been included in the calculation. However, the latency of these components was not measured in this experiment. Therefore, the contribution of technical setup to the delay in the asynchronous tapping is unknown in this study. The combination of the latency in the HMD and the fast-paced asynchronous tapping might have increased the congruency of the asynchronous visuotactile stimulation, causing the increased sensation of OBI.

Another factor to consider is that the visual input of the third-person perspective might have been too strong to induce shifts in self-localization. This can be explained by the dominance of visual perception in multisensory integration (Colavita, 1974). Colavita (1974) showed that when participants experienced simultaneous visual and audio inputs, the participants reacted more to visual input (Colavita, 1974). This implied that the vision could dominate multisensory integration and awareness (Spence et al. 2012). Several researchers extended the findings of the Colavita visual dominance effect to the sensory input of touch in the RHI paradigm (Hartcher O'Brien et al. 2010). They found that when visual stimuli were presented away from the participants' physical bodies, the dominance of vision over touch was significantly reduced. In this study, the distance between the camera and the real body was only 1.2 m, whereas in the other experiments, it was 2 m (Ehrsson, 2007; Guterstam and Ehrsson, 2012). Therefore, the greater distance between the camera and the real body in the original experiment could modulate the visuotactile stimuli in the same way that the intensity of visual dominance can be reduced during the multisensory integration of the sense of self. The diminished vision potency may have led to an optimal visuotactile integration, thus inducing an OBI in the original experiment. Therefore, the underlying visual dominance could explain the overall positive mean in the self-reports, which means that participants might have already experienced their sense of self in the illusory body by seeing themselves via the VR goggles, independent of the tactile manipulation and time. Furthermore, several researchers reported that individuals experienced OBEs in relatively relaxed conditions (Blackmore, 1984a; Gabbard et al., 1982). In addition to the subjective reports of the sense of comfort in previous research, our study showed that heart rate as a physiological account also indicated a relaxed condition.

There were other differences between this study and the original OBI experiment that might have contributed to the inconsistency of the results between the two experiments. For example, we employed heart rate as a physiological marker while the original experiment used skin conductance response. Although heart rate and skin conductance response were comparable in terms of capturing the fear response (Menard et al. 2015), the startle response measured with heart rate was not significantly different between synchronous and asynchronous groups. Thus, heart rate may not be sensitive enough to capture the short-term emotional responses. Furthermore, it is worth noting that there were methodological differences in that the original study did not test both body attack conditions and did not use the same analyses. Overall, this study was unable to find evidence to support the occurrence of OBIs, which could be due to these experimental differences

Sleep Quality, Depersonalization, and Out-of-Body Experiences

Our only significant finding was a negative correlation between sleep quality and depersonalization in the mediation analysis using the Proxy of OBIQ Scores. This finding is in line with the previous research (Selvi et al. 2015; Arora et al. 2020; van Heugten-van der

Kloet et al. 2018). Besides this finding, our study was unable to find support for the relationship between sleep quality, depersonalization and OBEs using the proxy of startle response and proxy of OBIQ scores.

Though we did not find evidence to support the occurrence of OBIs, our findings related to the relationship between depersonalization and OBEs warrant further discussion. These findings may be because the participants' experiences of the OBI were not at significant levels based on the validation analyses that were conducted with the Threat-Evoked Heart Rate and the OBIQ data.

Further, the overall mean score of the OBIQ and reduced heart rate may indicate that OBEs can occur in relaxed conditions. While this finding is in line with other studies (Blackmore, 1984a; Gabbard, 1982), several researchers argued that OBEs occur during stressful and traumatic experiences (Rabeyron and Caussie, 2016). Rabeyron and Caussie (2016) argued that OBEs can function as a protective mechanism for traumatic experiences. In addition, depersonalization occurs under stressful circumstances (Gabbard, 1982) and is connected to traumatic experiences (Shilony and Grossman, 1993). To conclude, the circumstances that lead the occurrence of OBEs may range from relaxed to stressful and traumatic. Meanwhile, depersonalization components may be actively involved in OBEs when the stress levels are elevated.

Several researchers argued that there might be a confusion of nosological categorization over the term depersonalization and its relationship with OBEs (Braithwaite et al., 2013). Braithwaite et al. (2013) contrasted depersonalization and OBEs. They pointed out that while depersonalization refers to flattened affect, loss of emotional coloring (Braithwaite et al. 2013), and occurs under stressful conditions (Gabbard, 1982), those who have OBEs report vivid experiences (Blackmore, 1984a), a heightened sense of awareness (Murray and Fox, 2005). Furthermore, OBEs can occur in circumstances where individuals are resting

(Blackmore, 1984a). In addition, Braithwaite et al. (2013) argued that the sense of self remains within the corporal space with depersonalization, while individuals experience their sense of self outside their bodies during an OBE. Thus, OBE and depersonalization may be two distinct phenomena that occur in different circumstances and lead to different sensations.

Limitations

There were several limitations in this study that merit mentioning. There were a number of technical shortcomings linked to the use of the C3 in the experiment. First, the C3 mobile application used to receive the Bluetooth signals was coded for newer versions of the C3. Therefore, the mismatch between the C3 and the mobile application code might have led to inconsistencies in data transfer during the experiment. Second, the Bluetooth signals coming from other devices (e.g., the Bluetooth earbud used to listen to the rhythm of tapping) might have interfered with the C3's Bluetooth signals. Third, the C3 that was used in the experiment did not have the Conformitè Europëenne (CE) mark, which assures the intended use and performance of the device. Fourth, the tactile stimulation to participants' chests during the experiment might have dislocated the ECG electrodes of the C3. Because of the experimental task (e.g., tapping the chest and interfering Bluetooth signals) and possible problems with the performance of C3 (an outdated product without CE-Mark), there were many experimental limitations. These technical shortcomings led to massive data loss, as well as unequal and low group sizes.

In this study, there were several generalizability issues due to our sample. First, the difference of the significant results in the mediation analyses using the proxy of OBIQ scores and the proxy of startle response might have resulted in due to different sample sizes. Second, we did not screen participants for several mental disorders and conditions. For example, we did not control for the impact their mental health (e.g., previous trauma, drug abuse) or physical health (e.g., eyesight problems) could have on the results. Third, we did not screen for cortical excitability even though one study argued that cortical excitability could be an underlying neurological cause for OBEs in healthy population (Milne, 2019). Fourth, all the participants in our sample were students and possibly too WEIRD (Western, educated, industrialized, rich, democratic). These factors may hinder the generalizability of the experiment results.

The experimental design of this study was a limitation for the mediation analysis. The independent variable and the mediator were assessed at a single time point, while the dependent variable was measured another time. Because of this, we cannot deduct causality based on the mediation analysis.

There were also several potential issues with data treatment and analysis. Some studies used independent observers to detect artifacts in human physiological data (Palmieri et al. 2014; Kurobe et al., 2014). The independent observers could be helpful for overcoming cognitive biases, including confirmatory bias. In this study, the artifacts were identified by the experimenters, and they were not blinded to the research hypotheses.

Future Research

There were several technical improvements that would be useful for future studies. Future researchers should consider using a different heart rate device or a newer version of the C3 that is compatible with the mobile application and carefully take into account the possible interferences (e.g., Bluetooth signals and artifacts). Additionally, they should ensure that the chosen device has the CE mark, which may imply a guarantee of intended use and performance. Future research could also consider monitoring the latency of the Oculus Rift CV1 and its interaction with the graphic card of the computer and the camera.

In another experiment using the same fundamental multisensory processes as the OBI paradigm, experimenters induced an illusion of owning an invisible body after a one-minute visuotactile stimulation (Guterstam et al. 2015). Then, researchers tested whether owning an invisible body illusion affected the social anxiety response. In order to test this, they employed heart rate as a physiological marker. Based on their informal pilot experiments and their aim to maintain the duration of the social stress event, they chose the specific time interval of 13 seconds of pre-event IBIs. The researchers found significantly lower heart rate in illusory body than mannequin after the synchronous brushing. Anxiety and fear are defensive emotions that help an individual to adapt and prepare for upcoming negative events (Barlow, 2000). It should be stressed that a healthy heart rate is not a metronome since its rhythms are characterized by both complexity and consistency (Shaffer et al., 2014). A fear response may take longer than three post- and pre-event IBIs to manifest itself in heart rate. Therefore, using more than three post- and pre-event IBIs can diminish the vulnerability of random measurements and increase the precision of the startle response. Taken together with our results, we recommend that future researchers may employ between three and 13 IBIs.

In addition to the experimental task, auditory cues can be used to form a coherent multisensory representation of one's own physical body (Radzium and Ehrsson, 2018). Several individuals report hearing percussive noises during an OBE such as a buzz, roar, or click (Irwin, 1989). Thus, future research on the OBI paradigm might consider using repetitive sounds aligned with tapping in order to amplify the intensity of the illusion.

Strengths

The approach this study took had a number of strengths. First, this is the first study to use heart rate as an objective marker of OBEs in the OBI paradigm. Second, it was also the first mediation analysis conducted to explore the psychological antecedents of OBEs while using the variables sleep quality and depersonalization. Third, although, the experimental process was shortened due to COVID-19, a relatively large sample size was achieved with which we were able to conduct robust statistical analyses. Fourth, the technological evolution of the Holter monitors allowed this study to use wireless, comfortable, and easy-to-attach devices.

Even though there were some problems with the heart rate monitor, the C3 helped us to eliminate the potential problems (e.g., cable-related motion artifacts) and enhance the possible illusion. One can argue that having an immersive visual and tactile experience would be hard while attached to many cables. This study created a relatively comfortable experience for the participants. Fifth, the counterbalancing was helpful for reducing the expectation bias that might arise from informing participants about the startling procedure before the experiment started. This means that participants knew beforehand that there would be a fake threat stimulus. However, they were uninformed of when the threat stimulus would occur, or which body would be threatened. Sixth, an additional body attack condition was integrated into the experimental task, or the real versus illusory body attack. To the best of our knowledge, this was the first time that both body attack conditions were tested within a single procedure. This experimental design allowed us to control whether a participant's startle response differed when the threat stimulus was presented to the illusory or real body.

Conclusion

Out-of-body experiences can manifest themselves with the sensations of being outside of corporal space and perceiving the physical body from an external point of view. Firstly, this study aimed to manipulate the sense of self and center of awareness in space using the established OBI Paradigm and measure the illusion with heart rate. Secondly, we explored the psychological factors that may contribute to the OBEs. However, our experimental task did not lead to an OBI, and we did not find evidence at significant levels to support our investigation of the psychological antecedents of OBEs with sleep quality and depersonalization. Nevertheless, our null results and overall means indicate several possibilities worthy of further investigation. First, the visual dominance effect might modulate the OBI with shorter distances between the real and illusory bodies. Second, a delay with the experimental setup could lead participants to perceive an asynchronous condition as synchronous. Third, OBEs may occur in both relaxed and stressful states. In stressful states, they may function as a protective mechanism with the depersonalization components involved. Fourth, OBEs and depersonalization experiences may be two different phenomena that occur under different circumstances. This study was unable to evidence similar to previous studies, which could also be due to problems with the heart rate monitor and different sample sizes. Ultimately, more research is warranted to explain the inconsistencies and underlying factors.

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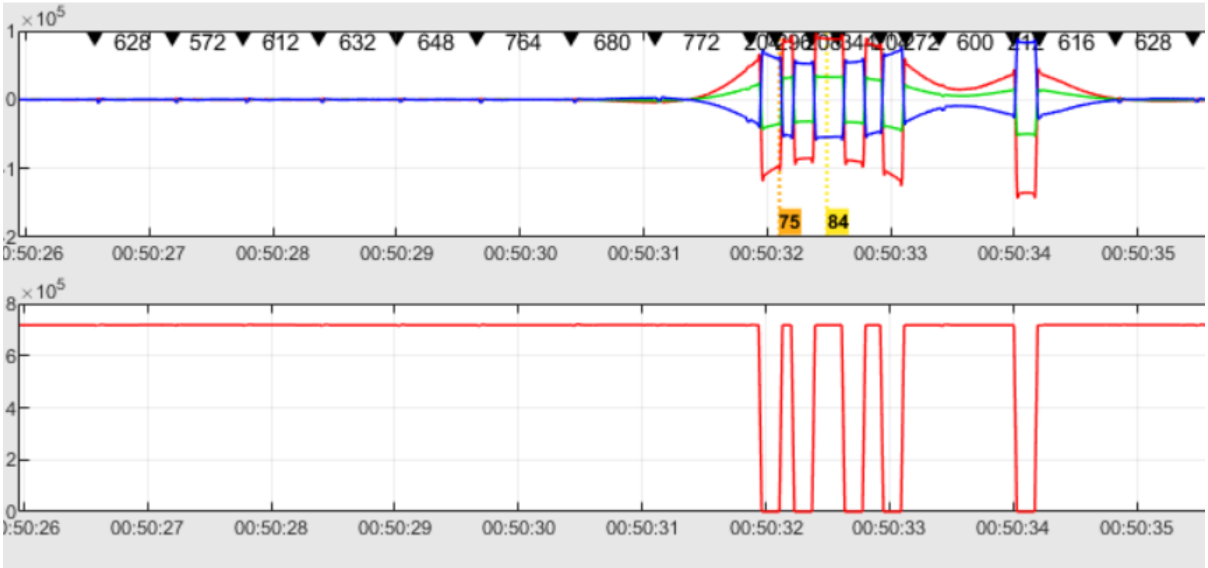
Appendix

Figure 1

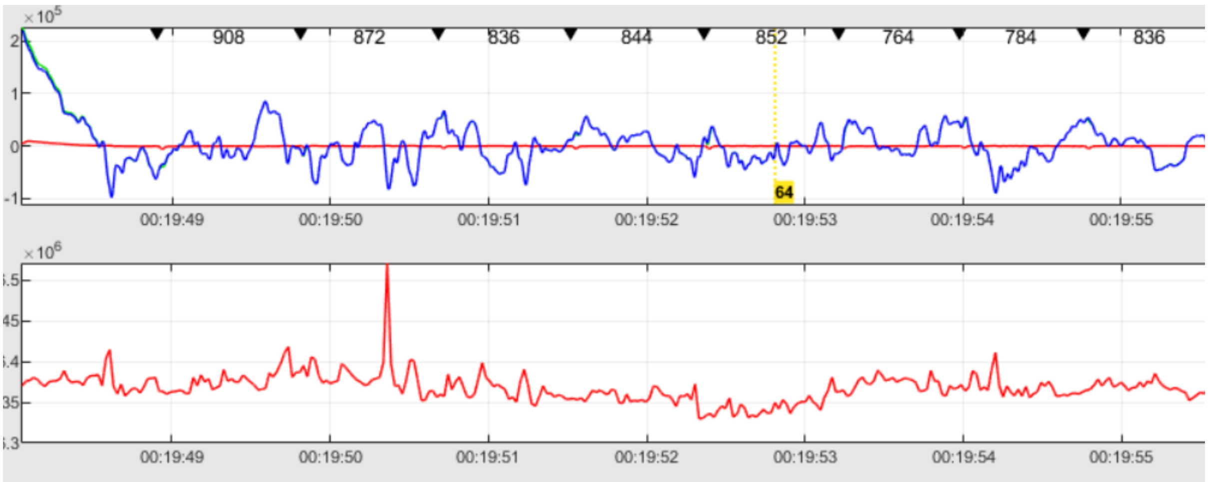
Connection Losses



Note. The channel with blue, green, and red lines shows the heart rate, and below channel with red line shows the respiratory rate

Figure 2

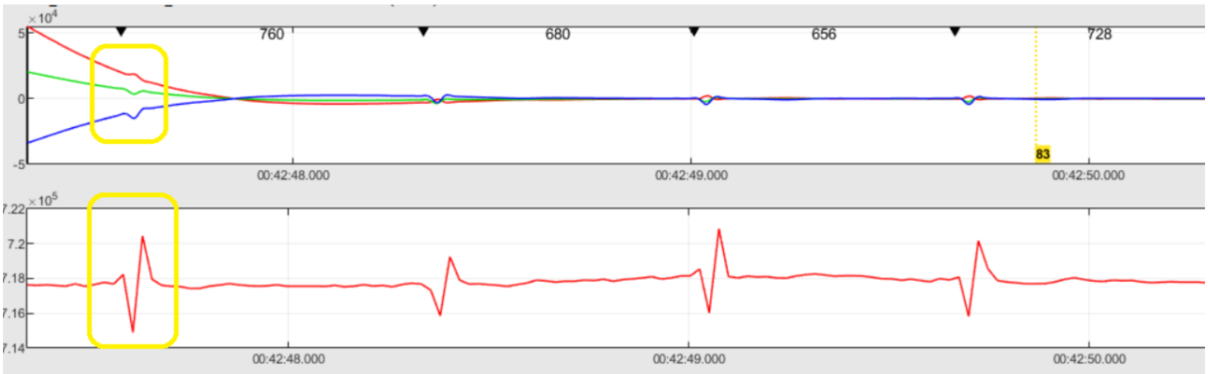
Artifacts



Note. The channel with blue lines show heart rate, and the channel with red lines show the respiratory rate

Figure 3

Fluctuating QRS complexes but steady respiratory rates



Note. The channel with blue, green, and red lines shows the heart rate, and the channel with red line shows the respiratory rate