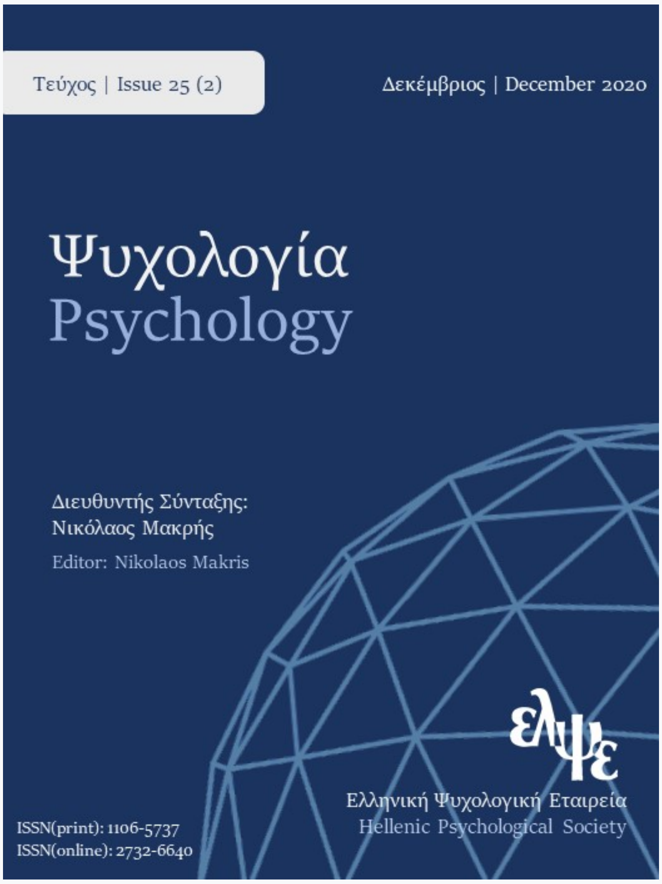
Psychology: the Journal of the Hellenic Psychological Society

Vol 25, No 2 (2020)

Special Section: Contemporary Issues in Neuropsychology



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doi: [10.12681/psy_hps.25576](https://doi.org/10.12681/psy_hps.25576)

ΨΥΧΟΛΟΓΙΑ | PSYCHOLOGY, 25 (2), 13-33

Ελληνική Ψυχολογική Εταιρεία
Hellenic Psychological Society

ΕΜΠΕΙΡΙΚΗ ΕΡΓΑΣΙΑ | RESEARCH PAPER

Out-of-body experience favors emotional memory consolidation

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KEYWORDS

body ownership,
emotion,
experience,
memory consolidation,
out-of-body skin temperature

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ABSTRACT

Body ownership reflects our ability to recognise our body at a certain location, enabling us to interact with the world. Emotion has a strong impact on memory and body ownership; interestingly, skin temperature may at least in part mediate this impact. Previous studies have found that out-of-body experiences (OBE) impair memory encoding and cause skin temperature to drop. In the present study a new method for inducing OBE was designed and their impact on a different stage and type of memory processing (emotional memory consolidation) and on skin temperature was investigated. In our experiment, we presented three types of emotional pictures (neutral, pleasant, unpleasant) before inducing OBE and testing our participants' recognition memory in a retrieval session. Throughout the whole experiment, both neck and hand skin temperature were measured using iButtons. Participants' performance was calculated using d-prime and statistical analyses included one-way ANOVA, probing the relationship between the score on the OBE questionnaire, performance and skin temperature; we also compared the differences between the experimental and a control group. Results showed that OBE favour emotional memory consolidation and cause a temperature increase, supporting the embodied cognition theory as proposed by Anderson (2003). Future studies should expand our findings, to rule out that participants experiencing OBE could have a better memory at baseline or that temperature could be increased due to other reasons.

Body ownership and Out-of-Body Experience

Experiencing fearful stimuli and feeling warm because of excitement implies a bodily state that is driven by perception. Perception is based on body ownership (Tsakiris et al., 2007), which refers to the conscious experience of identifying the body (self-identification), the experience of the actual spatial position (self-location), and the experience of the position from where one perceives the world (first-person perspective) (Blanke, 2012). In other words, body ownership reflects the relationship between the body and one's "self" by classifying the internal and the external objects as parts of one's body and other people's body respectively. This classification is based on an interaction between the internal representation of the body and multisensory input and is developed in three separate stages. First, a pre-existing ability of the body to distinguish between objects that may or may not be part of one's body. Second, the representation of the body that influences the integration of multisensory input and leads to modification of perceptual systems (usually visual and tactile). Third, the formed perception which results in a subjective experience of body-ownership (Tsakiris, 2010). Depending on whether body ownership refers to distinct body-parts or the body as a whole, is divided into two categories: partial and global ownership (Blanke & Metzinger, 2009). Global ownership which is the main focus of the present study can be tested by inducing an out-of-body experience.

An out-of-body experience (OBE) is defined as one's experience of seeing his body from a location outside the physical body (Ehrsson, 2007) and reflects global ownership in which people always identify an illusory body as their own (Blanke & Metzinger, 2009). In general, OBE has been shown to alter participants' perception about their own body in a series of experiments (Petkova & Ehrsson, 2008) causing a sense of disembodiment, by perceiving the world from a third-person perspective (3PP), which enabled participants to take the viewpoint of someone else. This sense of disembodiment could be so robust in changing the visual perspective, that participants discarded their own body and no longer perceived it as part of themselves (Guterstam & Ehrsson, 2012). Based on the above and in accordance with Blanke and Metzinger (2009) OBE influences three general properties: 1) a globalized form of identification with the body as a whole, 2) spatiotemporal self-location and 3) a first-person perspective (1PP). These properties indicate that OBE not only can change the perception of one's body locus but also reveal the interactions between the representation of self-location in its local environment and the multisensory representation of one's own body.

Body ownership and cognition

Previous studies show that OBE can manipulate first-person perspective (1PP) which affects a series of cognitive processes as presented below. A first-person perspective is needed for forming self-consciousness with respect to the location. In more detail, in an underlying representational or cognitive level, these operations are processed in a frame, from another person's (3PP) or one's own perspective (1PP) (Vogeley et al., 2004). These authors investigated the difference in perception between 3PP and 1PP, by asking participants to count objects as seen either from an avatar's perspective (3PP) or one's own perspective (1PP). Results demonstrated that participants were slower and less accurate in the 3PP condition as opposed to 1PP. In addition, data showed that visuospatial processing and decision making were altered in the 3PP, thus OBE can modify cognitive processes as well. Overall, it has been shown that OBE is adequately robust in alternating perception by causing a sensation of complete disembodiment and in influencing cognition.

Memory

Memory is a scientific area of great importance and is divided in long- term and short-term memory. Long-term memory is the capacity to store large amounts of knowledge for a long time, while short-term memory allows keeping a limited amount of information in a very accessible state (Cowan, 2008). Long-term memory, which is the primary concern of the present study is segregated in episodic and semantic memory (Tulving, 1972). Episodic memory reflects the recollection of particular personal incidents and semantic which refers to the world's knowledge. Both of these long-term memory types can be assessed through recognition (deciding whether a stimulus occurred before; was this picture presented previously?) and recall tasks (remembering particular characteristics of a previously presented stimulus; what did the third presented picture depict?) (Baddeley, 1999). The main distinction apart from the type of memory trace to be assessed is also the number of cues used for successful recognition and recall (fewer cues are needed for recall than recognition) (Tulving, 1972).

Memory formation is segregated into different stages, named encoding, consolidation, and retrieval. First, during the encoding stage, information drawn from attention and filtered with working memory is ready to be stored (Hayes, 2000). Afterwards, the consolidation process starts to formulate. This process reflects the stabilization of memory traces after their initial encoding (McGaugh, 2000). Lastly, these memory traces after being stored, they can be retrieved from storage (Ratcliff, 1978) and it is poorly understood whether retrieval involves a search process in different memory traces or a memory trace is automatically activated (Atkinson et al., 2000). Overall, memory as a complex system is dependent on many other biological processes. One of them is emotion, which can have an impact on memory consolidation.

In general, emotions are driven by two opposing motivational systems, called appetitive (pleasant) and aversive (unpleasant) (Lang, 1995). The activation of these systems can evoke different effects, for instance, initiation of startling reflexes during unpleasant emotions and their inhibition during pleasant emotions (Lang, 1995). Either of these two systems can contribute to emotional memory enhancement, on the grounds that the information to be stored is arousing (Kensinger & Corkin, 2003; LeDoux, 2000). Stronger arousal induces greater attention during the encoding phase, regardless of which motivational system is active (Bradley et al., 1992). However, it has also been found (LeDoux, 2000) that even stimuli that automatically trigger response can initiate memory formation if they are sufficiently arousing. Lastly, the contribution of arousal can be regardless of the context (Hamann, 2001; McGaugh, 2000). Thus, arousal can be an important emotional factor for successful memory formation.

Even though arousal is an important factor, valence can also influence memory performance and produce differential responses but this is more dependent on the stage of memory processing. More specifically, valence influences primarily the consolidation of memory traces (LaBar & Cabeza, 2006). Memory consolidation comprises distinct stages starting with initial training. During this period, learning develops which can lead to significant improvements in performance. This is illustrated in the studies of Hamann (2001) and McGaugh (2000) who showed that emotional stimuli can deploy attentional sources and eventually modulate memory consolidation, which occurs between 10 minutes and 6 hours later. In this first phase of stabilizing consolidation (without any external intervening factors like sleep) no further improvements take place (Walker et al., 2002). As proof, the study of Quevedo et al. (2003) demonstrated differential effects of valence only in certain aspects of memory. In more detail, by using neutral and emotional stories the authors showed that valence influenced memory consolidation for only the high emotional-scored and not for the low-emotional scored stories, regardless of their arousal. These contradictory results for arousal and valence in influencing memory performance might be due to the type of memory that was tested and not due to the properties of emotion per se.

As opposed to the beneficial impact of emotions on memory performance, some other factors can cause memory storage to malfunction. Out-of-body experience can cause proprioceptive drift which massively influences aspects of memory. A recent experiment showed that induction of OBE led to memory distortion, indicating that a first-person perspective is required for successful encoding (Bergouignan et al., 2014). The above-mentioned authors tested whether perceiving the world from the perspective of one's own body is essential for successful encoding. In their experiment, participants were engaged in social interaction, while undergoing an out-of-body illusion, in which proprioceptive drift occurred from the real body to the other side of the testing room. One week after the OBE session, participants' memory of these events was assessed with results demonstrating an impaired retrieval for events encoded during an OBE compared with the control condition (in-body state). Overall, it can be concluded that for an efficient episodic memory encoding an in-body state (first-person perspective) is an essential prerequisite but more studies on this topic are required.

Even though OBE has been shown to have a negative impact on cognition, some more recent studies studying the effects of virtual reality on cognition prove otherwise. Tuena et al. (2017) have demonstrated that disrupted body ownership can favor episodic memory under certain circumstances. In their experiment, they tested embodied cognition and episodic memory, by applying a virtual reality (VR) paradigm. They created three experimental groups (full, medium, and low embodiment) and examined the episodic memory of the participants as they were virtually navigating three cities and attempting to memorize all the events that they encountered. The participants in accordance with their assigned group were either feeling in full control of their virtual body, in medium or low control respectively. Then in a recognition task, participants were asked to report about certain events that have occurred with the full embodiment group demonstrating the highest scores. These findings underline the fact that OBE might actually enhance episodic memory, as long as participants feeling in control (agency) and know the locus of their actions (location).

In the same direction, Bréchet, Mange, Herbelin, Gauthier, Serino & Blanke (2018) have found that OBE favors both memory encoding and retrieval. The authors used virtual reality (VR) system which resembled a real-life situation during both the encoding and the retrieval session. It was found that participants' scoring in the recognition memory task depended on the delay and the of the elements that were changed. Last and more important, was found that OBE as induced in the experiment using VR enhanced delayed retrieval, questing the theory that 1PP is essential for successful memory encoding and retrieval. The sense of self, body ownership, and episodic memory are linked in a different way as the embodied cognition theory suggests.

All the aforementioned contradictory results may lead to the embodied cognition theory. The embodied cognition theory as proposed by Anderson (2003) suggests that cognition might not be the manipulation of abstract symbols but a response to the environment. According to his theory, processes of thinking occur in very particular (and often very complex) environments to elicit a practical solution. This underlines the fact that cognition is highly embodied and represents a situated activity, evoked by a person's interaction with and manipulation of stimuli from the external environment. Based on this theory, might that OBE could also enhance certain cognitive tasks, such as memory, as long as the person does not feel disoriented and feels his virtual (or dummy) body as his own.

Temperature and OBE

The human body demonstrates a complex and varying temperature pattern. The external parts of the body have a lower mean temperature than the internal parts, with temperature decreasing in the extremities (Freitas, 1999). This occurs due to environmental fluctuations but not all the extremities are influenced at the same phase or the same amplitude. The areas that display the greatest variability are the fingers and toes for low temperature and the trunk and forehead for high temperatures. Many studies have reported different skin temperatures, depending on the measured area. Freitas (1999) reports that mean skin temperature is 32-35°C, Bierman (1936) measured the exact temperature of the trunk and found that it usually varies between 33.5°C and 36.9°C and Sessler (2008) reports that skin-surface temperatures are considerably lower than core temperature and for example, forehead skin temperature is typically around 34.5°C, 2°C cooler than the core.

The skin temperature can be influenced by emotions as shown in the study of McFarland (1983), where undergraduate students performed tasks that caused their skin temperatures to either decrease or rise. Their skin temperature was between 29°C and 33.9°C, with the lowest reflecting unpleasant feelings and the highest associated with positive emotions. Based on the above and according to a number of studies (Bugental & Cortez, 1988; Levenson et al., 1990; Stemmler, 1989) emotions and skin temperature may be linked, causing temperature rise or fall, depending on the stimuli presented, especially in the face and hand (Rimm-Kaufman & Kagan, 1996).

Body ownership is another factor that alters skin temperature (Moseley et al., 2008). In more detail, proprioceptive drift can disrupt skin temperature regulation over a single limb due to impaired partial body ownership. Moseley and his colleagues tested the above by inducing the rubber hand illusion. Rubber hand illusion can cause proprioceptive drift like the OBE but for a specific body part (hand), by synchronous stroking of the real hand (unseen from the participant) and a rubber one (seen from the participant) (Costantini & Haggard, 2007; Ehrsson et al., 2007). Results showed that the skin temperature of the real hand dropped when the ownership of an artificial hand dominated, and that was not due to tactile or visual input separately or to attentional shifts toward the rubber hand. In addition, the temperature effect was limb-specific with no temperature reduction in the other real hand or other parts on the same side of the stimulated hand. Based on the above, some conclusions can be made. First, proprioceptive drift towards a fake limb can influence a real body part. Second, body ownership and physiological regulation of body ownership are closely linked in a top-down manner. Lastly, neurocognitive processes that disrupt the sense of body ownership may in turn disrupt temperature. Based on the above it can be concluded that is likely that an OBE can lower a participant's skin temperature in general based on the fact that global body ownership is influenced.

The present study uses a multidisciplinary approach by combining the findings from memory, emotion, and embodiment and tested them in an OBE experiment. More specifically, our study in contrast to previous relevant studies tested the OBE effects on memory consolidation, rather than on encoding or retrieval and introduced a novel approach in inducing OBE (visual/ auditory rather than visual/ tactile); our focus is theoretically novel and important because it examined new potential connections between stages of memory formation and body ownership, using visual and auditory modalities for testing body ownership. Our main hypothesis was that due to the experimentally induced out-of-body illusion, participants would show worse recall for unpleasant pictures, while performance for both pleasant and neutral would be the same as the control group. This was expected due to the sense of disembodiment that participants would experience could lead to a decreased sense of fear or unpleasantness and thus unpleasant stimuli would be perceived as less alarming. By inducing OBE after encoding session with non-experimental manipulation we wanted to investigate whether the underlying processes for forming emotional memories could be impaired during consolidation, expanding the findings by Bergounian et al (2014) or enhanced as Bréchet et al. (2018) and Tuena et al. (2017) demonstrated. With respect to temperature measurement, we anticipated that the temperature of the OBE group would be lower as compared to the control group because of the decreased sensation of their body. In addition, it was expected that skin temperature in the experimental group would be lower over the neck muscle and further lower on the wrist, as opposed to the control group, based on the observations of Bierman (1936) and attempting to expand the observations by Costantini & Haggard (2007) and Ehrsson et al. (2007) and test whether the decreased temperature in the real hand during a rubber hand illusion can influence proportionally the whole body during OBE.

Materials and Methods

Participants

Forty-four healthy volunteers (30 women, mean age 22 years, *SD* = 4.3 years) participated in the experiment and received monetary compensation. The study was conducted in accordance with the Declaration of Helsinki and was approved by the Ethical Committee of the University of Amsterdam. Written informed consent was obtained. All volunteers were healthy. They were unaware of the specific aim of the study and reported remaining awake and alert throughout the whole procedure. From the original sample, we excluded 20 volunteers according to the inclusion criteria. These involved alertness, throughout the whole experimental procedure, unchanged posture during the stroking session (see below) and high rating in the OBE questionnaire (see below). Finally, twenty healthy volunteers (14 women, mean age 23 years, *SD* = 3.8 years) remained for the analysis.

Stimuli

To begin, we selected pleasant, neutral, and unpleasant pictures from the International Affective Picture System (IAPS; Lang et al., 2008). The exclusion criteria for the pictures were: values from 4.5-5.5 for valence (neither pleasant nor unpleasant), values below 4.0 for arousal (pictures not causing arousal to the participants), and lower than 1024 X 768 resolution. After filtering out the pictures which fulfilled the above-mentioned criteria, we created a pool of 300 pictures, categorized them as pleasant, unpleasant, and neutral (see figure 1). These groups were selected such that there was no overlap in IAPS normative affective valence ratings, i.e. the three stimulus contents were distinct and representative of affect type: pleasant: 7.0 (valence) and unpleasant: 2.05 (valence). All neutral pictures had lower standard emotional arousal ratings (mean-3.44). The distributions of arousal ratings for pleasant and unpleasant pictures overlapped. Both contents were anchored at the high end by similar high arousal exemplars (pleasant: 5.92, unpleasant: 6.27); because of the natural picture distribution of the IAPS, the low arousal end of the unpleasant pictures range was somewhat less extended than for pleasant pictures. From the pool of the 300 pictures, 150 were selected for the encoding session and all of them for the retrieval. In the encoding phase, the 150 pictures were divided as 50 neutral, 50 pleasant, and 50 unpleasant. In the retrieval phase, the previously seen 150 pictures were presented amongst 150 new pictures from the same pool. Each participant was viewing a unique set of picture selection and order for both the encoding and retrieval session that was created beforehand[1].

Induction of OBE

For the induction of OBE, participants wore a pair of head-mount displays that were connected to a 3D video-camera (Full HD 3D Handycam® Camcorder, Model # HDR-TD10, Sony Corporation), placed 2 m in front of the participant. The images from the 3D camera were presented through the head-mount display (field of view: 45-degree, Resolution: 1280x720, Wearable HDTV, 2D/3D, Virtual 7.1 Surround Sound, Sony Corporation) on both eyes imitating real vision. Thus, the participant was only viewing his or her front side of the body from a second-person perspective (180o) as sitting in front of him or her. The experimenter was standing in view just in front of the participant and was using two paintbrushes to stroke the 3D binaural microphone (The Free Space - Binaural Microphone, 3Dio) by moving one paintbrush toward a location just below the cameras, where the 3D microphone was placed, to create the illusion that the experimenter was stroking the ears of the subject. Participants heard the stroking of the microphone through headphones with a clear distinction if the stroking was on the left or the right side (see fig. 2.a, 2.b, and 2.c). The stroking was repeated on each side in succession every 3 seconds for both the experimental and the control condition. In this way, we controlled the number of movements in each condition. For the experimental group, there was no noticeable delay (less than 150 msec) between the visual and the hearing stroking (synchronous). In the control group, we used the Radiodelay program (Daan Systems, www.daansystems.com/ radio delay) to induce the asynchronous stroking with 3 seconds delay with the experimenter wearing headphones in order to listen to the delayed stroking. Thus, there was no overlap of the stroking sound with the movement of the brush towards the location of the illusory "ear". The binaural microphone was connected to a Dell-laptop and also the two pairs of headphones. The experimenter was also wearing headphones in the experimental condition but they were not connected to any jack, to maintain identical settings for both conditions. The reason why a visual/ auditory stimulation was used instead of visual/ tactile like in previous studies was to test whether an alternative sensory integration could also induce OBE experiences, based on the findings of a recent study, linking the auditory system to somatosensory system (connections between the primary auditory cortex and the primary and secondary somatosensory region) (Ro et al., 2012). Thus, we hypothesized that inducing OBE while stimulating the acoustic system and not the somatosensory (tactile stimuli) could evoke similar results.

Fig.2.a. *Experimenter during the stroking phase*

Fig. 2.b. Participant during the stroking phase

Fig. 2.c *Participant's view during the stroking phase*

Questionnaire

Directly after the stroking phase, the participants from both experimental and control groups were required to complete a questionnaire, based on Ehrsson (2007) with small modifications to correspond to our method of stroking. Ten questions were designed which required a rating of the strength of agreement or disagreement with ten suggested perceptual experiences. Three statements were designed to correspond to the illusion (see fig. 3, questions 3, 6, and 10). The seven other statements, which were unrelated to the illusion, served as control statements for suggestibility and compliance with task demands (see fig. 3, questions 1, 2, 5, 7- 9). The participants used a seven-point visual analogue scale to rate the extent to which these statements did or did not apply. On this scale, -3 meant 'absolutely certain that it did not apply', 0 meant 'uncertain whether or not it applied', and +3 meant 'absolutely certain that it applied'. Thus, a score of ≥ +1 meant that the participants affirmed the statement, a score of ≤ -1 meant that they denied it, and a score of 0 meant that they were uncertain if the statement applied (see fig. 3). In order to obtain the score for the illusion questions, we averaged for each participant separately questions 3, 6, and 10 while for the control questions, we averaged the remaining questions. Based on this averaging, we could determine whether participants actually felt the illusion or not.

Temperature measurement

For temperature measurement, a wireless temperature system for human skin temperature measurements was used, the iButton® (Thermochron, Dallas Semiconductors, Maxim Integrated Products, Inc., Sunnyvale, CA) (model DS1921G; ± 0.5 °C). The iButton is a small (16× 6 mm2), robust self-sufficient system that measures temperature and records the results in a protected memory section. Afterwards time and temperature data can be transferred to a computer for data analysis. Two iButtons were used and they were placed one on the wrist and the other on the neck (see fig. 4.a and 4.b for exact location) and the skin temperature was recorded every second during the whole experiment.

Please indicate for the following statements:

-3 ... -2 ... -1 ... 0 ... 1 ... 2 ... 3

it did not appy — uncertain — it did apply

1. I felt the touch at some distance in space in front of me and not on my body.
2. I experienced that my (felt) body was located at two locations at the same time.
3. I felt as if my head and eyes were located at the same place as the cameras, and my body just below the cameras.
4. I could no longer feel my body, it was almost as if it had disappeared.
5. The visual image of me started to change appearance so that I became (partly) transparent.
6. I experienced that I was located at some distance in front of the visual image of myself, almost as if I was looking at someone else.
7. I felt as if my head and body was at different locations, almost as if I had been 'decapitated'.
8. I experienced a movement-sensation that I was floating from my real body to the location of the camera.
9. I felt that I had two bodies.
10. I experienced that the hand I was seeing approaching the cameras was directly touching my ears (with the brushes).

Fig. 3. *The questionnaire for reporting the OBE*

Fig. 4.a. *The neck iButton*

Fig. 4.b. *The hand iButton*

Procedure

The experiment took place in a testing room with some furniture. After arrival at the room, participants read and signed an informed consent form and they were informed about the experimental procedure. Participants were then seated in a comfortable chair in a small, normally lit room. Afterwards, the encoding session started with participants viewing a series of images, each presented for 3s. Participants were instructed beforehand that they should attend to each picture the entire time it appeared on the screen because at the end of the experiment they will be asked to recognize them. For each participant, a unique sequence for the pictures' presentation was created beforehand. After the encoding session, participants were seated two meters in front of the camera in a relaxed position, put on the HMD, and the headphones with one of the experimenter's help, and instructed not to move. Then the experimental induction of the OBE occurred. The stroking session lasted 3 min and was repeated 7 times with a break of 1 min in between the stroking phases. The paintbrushes were moved either synchronously (illusion condition) or asynchronously (control condition). Participants were instructed to remain as still as possible and pay attention to the images projecting in the HMD and not looking up or down. Afterwards, they filled out a questionnaire reporting OBE containing 10 multiple choice questions, based on Ehrsson (2007) and answer 5 open-ended questions reporting their feelings about the pictures, the experimental procedure, the stroking, and the presence of the experimenter. Lastly, during the retrieval session, participants were first asked if they can recognize the image or not and then judge their confidence regarding their answer using a visual scale from 0 to 5 (0-5 confidence scale, in which 0 mean no confidence at all and 5 certain) while viewing the picture during the whole process. The task used in the present study was a recognition task investigating visual long-term memory, as in the relevant literature investigating OBE experiences, primarily visual recognition tasks were employed.

Analysis

Questionnaire

Prior to the analysis, a normality test (Shapiro-Wilk) was conducted in order to test if the assumptions of normality were met. In addition, an independent t-test, two-tailed, was performed to compare OBE and IBE answers.

Performance in memory task

We computed the d-prime score from measurements of the hit rate and false alarm rate using the participant's scores from four categories that were computed based on their performance during the retrieval session: 1) the participant correctly identified that the picture was previously presented (true positive), 2) the participant incorrectly identified that the picture was previously presented, while it was not (false positive), 3) the participant correctly identified the picture as not previously presented (true negative) and 4) the participant failed to identify that the picture which was previously presented (false negative). Afterwards, d-prime was calculated as: $d' = Z(\text{hit rate}) - Z(\text{false alarm rate})$ (Macmillan & Creelman, 2005), where hit rate = true positive / (true positive + false negative) and false alarm = false positive / (false positive + true negative). Separate repeated-measures ANOVAs were conducted comparing participants' performance within-group (OBE - IBE) and the d-prime in three picture types (neutral, pleasant and unpleasant pictures), an independent t-test, two-tailed comparing both groups (between subjects' design) and linear regression between scores in the OBE questionnaire and performance. The effect size was also calculated, using Cohen's d.

Skin Temperature

The temperature was averaged for each of the two locations on both hand and neck for every stroking round (1-8) and across all stroking rounds. The change in temperature for each point in each round was quantified as the temperature difference between the average of each stroking round for both hand and neck and the baseline (as calculated thirty seconds before the stroking phase started). We compared each location (hand, neck) between groups using an independent t-test, two-tailed. We also performed a correlation analysis for each stroking round (1-8) between groups (OBE – IBE) and a repeated-measures ANOVA with the stroking rounds (1-8) as within-subjects' factor and group (OBE-IBE) as between-subjects' factor. Also, the baseline temperature was observed in order to safely make assumptions about the temperature change as induced by OBE. Temperature data from one participant was lost due to a recording error.

Results

OBE questionnaire

Participants in the OBE group scored higher in the illusion statements than the IBE group with significant difference [$t(42)= 3.184$, $p<.003$], while for the control questions the difference was non-significant [$t(42)= -0.174$, $p=.863$] (see fig. 6). Thus, the participants in the OBE group reported the experience of sitting in front of their physical bodies and looking at them from this location. However, because we wanted to include only those with the strongest illusion (score: >1) and the strongest control condition (score: <-1), we discarded 24 participants, as already mentioned in the materials and methods section. The differences between groups were maximized for the illusion questions [($t(18)= 13.207$, $p<.001$(see fig. 7)], while ratings for the control questions remain non-significant. For this reason, all the analyses described in the below sections carried out on the illusion questions.

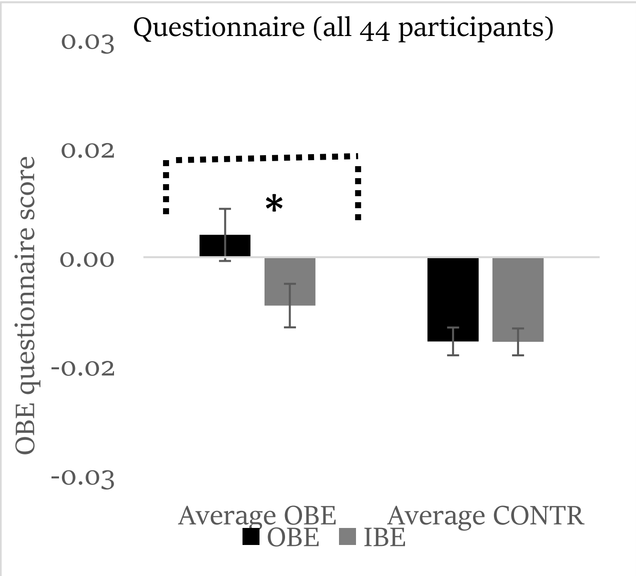

Fig.6. *Questionnaire scores for all 44 participants. The asterisk indicates significance at level a=0.05. Error bars indicate range* (highest- lowest value)

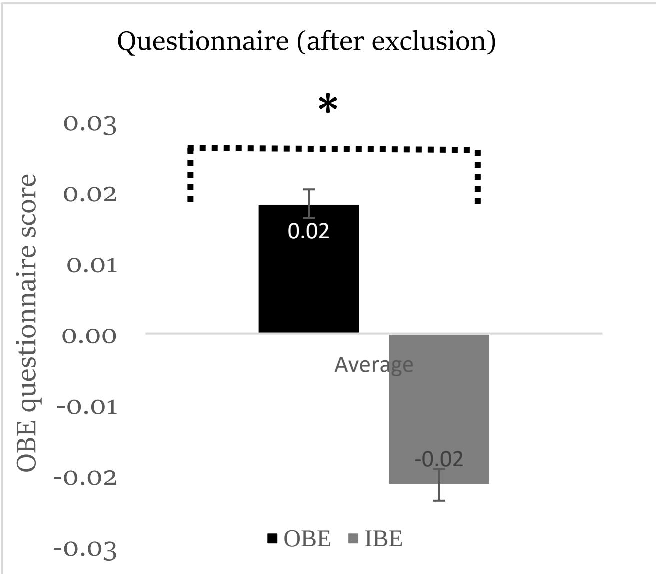

Fig.7. *Questionnaire scores for 20 participants (24 excluded). Only the illusion questions are shown, because the control questions differences between groups remained non-significant. The asterisk indicates significance at level a=0.05. Error bars indicate range (highest- lowest value)*

Performance (d-prime)

A repeated measures ANOVA with a Greenhouse-Geisser correction determined that performance (as measured by d-prime) did not differ statistically significantly in the three picture types [$F(1.629, 29.327) = 0.274$, $p = .717$]. However, between groups, the difference was significant regardless of picture type [$F(1, 18) = 7.335$, $p=.014$]. Therefore, we can conclude that even though participants' performance remained relatively unchanged across conditions, the out-of-body state elicits a statistically significant improvement as opposed to the control group which did not undergo the illusion (see fig.8).

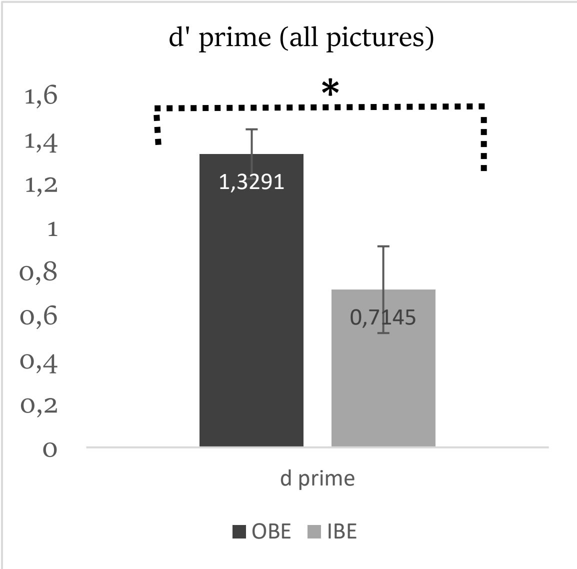

Figure 8. *The difference in performance between OBE and IBE group. In particular, figure 8b demonstrates that reporting stronger OBE (based on the questionnaire) improves performance with strong correlation r=.46. The asterisk indicates significance at level a=0.05. Error bars indicate range (highest- lowest value)*

Based on the significance that ANOVA showed, we further investigated whether the intervention also affects performance differently for the separate picture types. An independent-samples t-test was conducted to compare performance (d-prime) in the retrieval session in OBE and IBE groups. Performance differed between conditions for all picture types but significantly only for the pleasant picture types. There was a significant difference in the scores for the OBE (M=1.29, SD=1.12) and IBE (M=.065, SD=0.95) groups in the pleasant picture condition; [$t(18)= 2.723$, $p=.014$ (see fig. 9)]. This difference was maintained after correcting for multiple comparisons. These results suggest that out- or in-body state affects participant's performance, especially for pleasant pictures.

Also, a correlation analysis was conducted to compare performance (as measured by d-prime) in the retrieval session in OBE and IBE groups. It was found that performance and score in the OBE questionnaire are relatively strong correlated [$r(20) = .46$, $p = .04$]. Furthermore, the effect size was tested (Cohen's d) was calculating regarding the performance in pleasant pictures between OBE and IBE groups. Results showed that the effect size for this analysis ($d = 1.24$) was found to exceed Cohen's (1988) convention for a large effect ($d = .80$). These results suggest that the out- or in-body state really affects participant's performance. Specifically, our results suggest that when people experience a strong out-of-body illusion, their performance for retrieving emotional stimuli increases.

Lastly, three linear regressions were performed between OBE questionnaire scores and conditions. OBE questionnaire did not significantly predict d prime for neutral images [$b = .126$, $t(18) = 1.876$, $p = .077$] nor d prime for unpleasant images [$b = .124$, $t(18) = 1.683$, $p = .110$]. Nevertheless, for the pleasant pictures the results were found significant [$b = .141$, $t(18) = 2.723$, $p = .014$], even after Bonferroni correction.

Confidence rating

An independent-samples t-test was conducted to compare performance scores between OBE and IBE groups in neutral, unpleasant, and pleasant conditions. There was non-significant difference between the scores for the OBE (M=3.68, SD=0.67) and IBE (M=3.5, SD=0.84) in neutral picture type; $t(18)= 0.523$, $p=.607$. Also, there was non-significant difference between the scores for the OBE (M=3.56, SD=0.48) and IBE (M=3.61, SD=0.53) in unpleasant picture type; $t(18)= -0.241$, $p=.812$. Last, there was non-significant difference between the scores for the OBE (M=3.52, SD=0.47) and IBE (M=3.68, SD=0.53) in pleasant picture type; $t(18)= -0.745$, $p=.466$. These results suggest that out- or in-body state does not have an impact on participants' confidence (see fig.11). In addition, a paired-samples t-test was conducted to compare confidence ratings across conditions within groups. There was no significant difference in the scores for neutral (M=3.59 SD=0.75) and unpleasant (M=3.58, SD=0.49) [$t(19)= -0.014$, $p=.989$], between neutral and pleasant (M=3.60, SD=0.48) [$t(19)= -0.084$, $p=.934$] and between unpleasant and pleasant [$t(19)= 0.360$, $p=.723$]. These results suggest that the type of emotional stimuli does not have an impact on participants' confidence (see fig. 11).

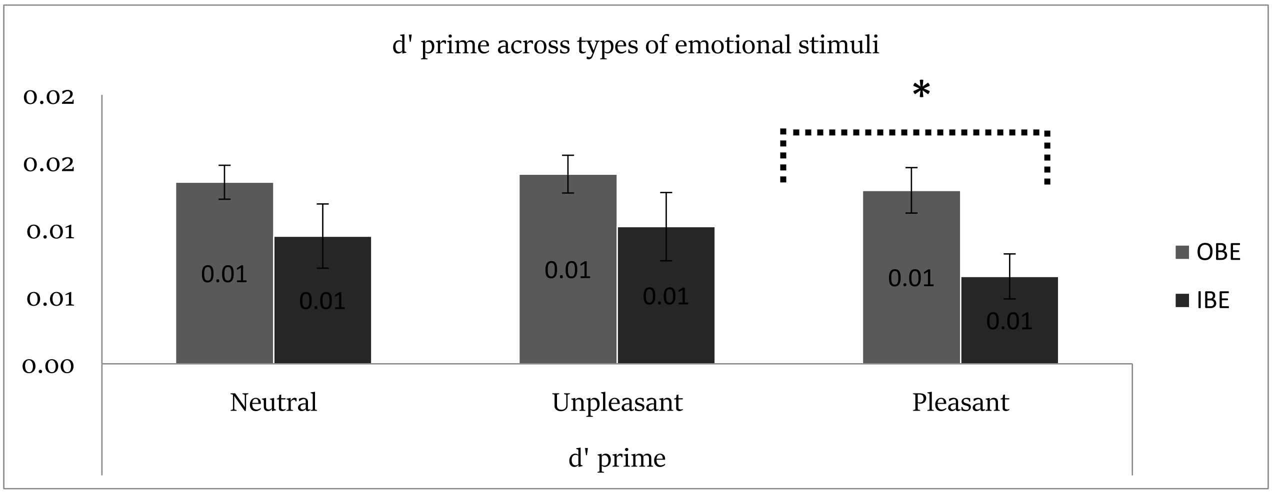

Figure 9. *The d-prime differences across conditions. Post-hoc test showed that the difference between groups was found to be significant only in the pleasant condition. The asterisk indicates significance at level a=0.05. Error bars indicate range (highest- lowest value)*

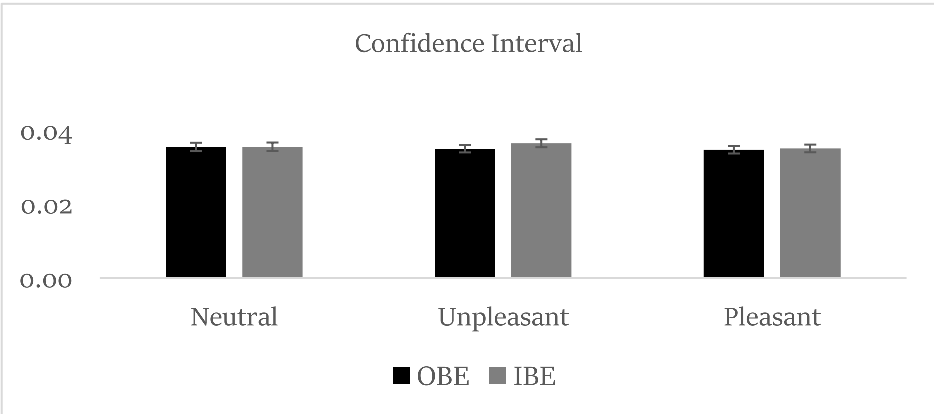

Fig. 11. *Confidence rating for each picture type. No significant difference was found between groups or within picture type. Error bars indicate range (highest- lowest value)*

Temperature

To begin with, it is important that all the graphs are corrected to baseline, computed by subtracting the average of 30 seconds prior to stroking session from the average temperature in each stroking phase. A repeated measures ANOVA with a Greenhouse-Geisser correction determined that mean group (OBE – IBE) differed statistically significantly between stroking phases [$F(1.554, 26.413) = 25.623$, $p < 0.001$]. Therefore, we can conclude that OBE elicits a statistically significant increase in temperature.

Furthermore, analysis with one way ANOVA demonstrated significant differences between groups for the second stroking phase in neck temperature; [$F(1,18) = 14.947$, $p<.001$ (fig.6)]. With a paired samples t-test we compared hand and neck temperature in all stroking phases. All comparisons showed that hand and neck temperature are significantly different during the whole stroking session. Overall, we can notice that for both hand and neck sites, skin temperature is raising much more for the hand, while the neck shows a smaller change with more significant results. Both hand and neck are demonstrating a steady increase (see fig. 12a and 12b).

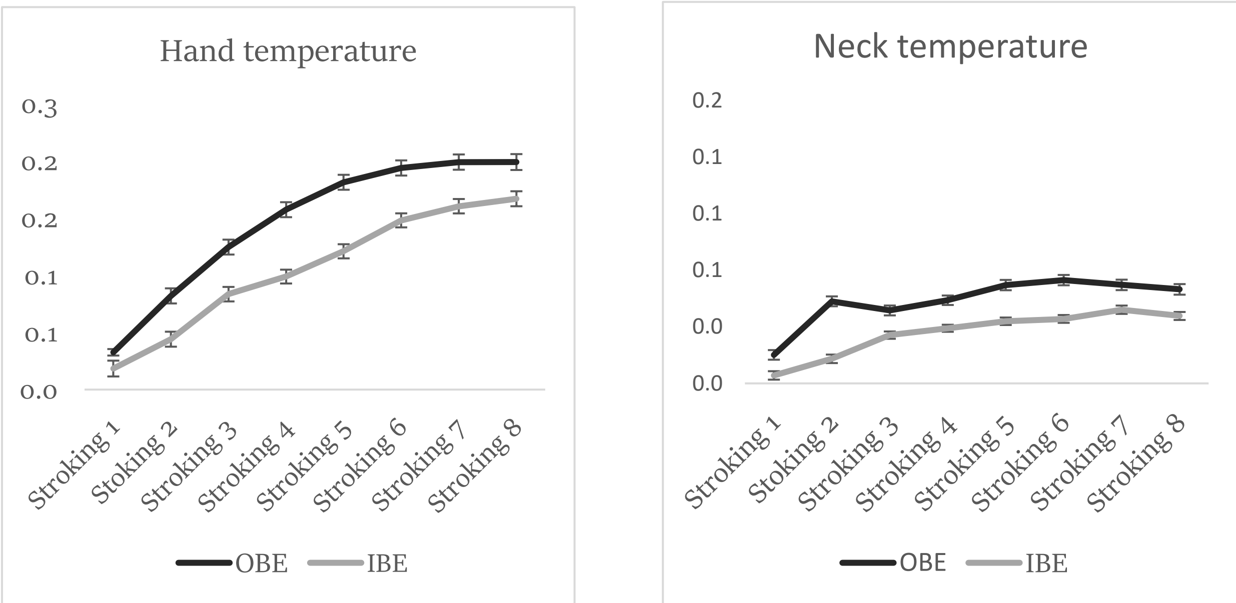

Fig.12a and 12b. *Differences in temperature between groups for hand (12a) and neck (12b) measurement sites. Error bars indicate the range (highest- lowest value)*

Linear regression was performed to test whether skin temperature can predict scores in OBE questionnaire and thus an out-of-body state. Results showed that hand temperature did not significantly predict answers to questionnaire [$b = .238$, $t(18) = -1.048$, $p = .321$] and did not explain variance in OBE questionnaire scores [$R^2 = .214$, $F(1, 17) = 1.044$, $p = .321$. On the other hand, neck temperature significantly predicted answers to questionnaire [$b = 1.310$, $t(18) = 2.833$, $p = .011$] and explained a significant proportion of variance in OBE questionnaire scores [$R^2 = .321$, $F(1, 17) = 8.028$, $p = .011$.

Discussion

Out-of-body experience is characterized by the perceived location of the self, outside one's body. This results in perceiving the world from an extracorporeal visual angle and in seeing one's own body from this perspective. This phenomenon is quite striking, because it challenges the experienced spatial unity of self and body and influences self-consciousness (Blanke, 2012). On the other hand, emotion and body perception are in close interaction and memory is strongly influenced by emotion. In the present study, we attempted to test emotional memory consolidation with respect to body ownership, as induced by OBE, and determine if the latter can benefit or distort emotional memory consolidation after successful encoding.

It has been suggested that OBE impairs encoding (Bergouignan, et al., 2014), and distorted partial body ownership causes the decrease of skin temperature (Moseley, et al., 2008). We tested if OBE could also impair consolidation for emotional pictures after non-experimentally manipulated encoding and cause skin temperature decline. In order to test that we designed a sound-based technique by stroking participants' illusory ears (3D microphone), based on the methodology and procedure by Ehrsson (2007), and placed two iButtons for measuring neck and hand temperature. This technique proved to efficiently induce OBE even for the participants who reported a weak effect (based on the OBE questionnaire). Our study demonstrated that participants who strongly felt the illusion had a better performance in emotional pictures recognition tasks and higher neck temperature. With respect to performance results, d-prime across picture types was found to be non-significant, except for pleasant emotional pictures, perhaps due to an underpowered sample.

In contrast to the encoding that has been found to be impaired during OBE, consolidation seems to be strengthened, as the studies by Bréchet et al. (2018) and Tuena et al. (2017) demonstrated. OBE enhances memory consolidation perhaps by evoking active retention of memory over its simple maintenance (Walker & Stickgold, 2004). Apart from that, it also likely that the instructions given at the beginning of the experiment influenced performance. Participants were instructed to pay as close attention to the images as possible because later they will be asked to remember them. Participants perhaps actively recalled the memorized images and tried to bind together the most important memory traces in order to constitute a complete memory (Alvarez & Squire, 1994). Our experimental induction of OBE further aided these processes by causing a sense of disembodiment (but still maintain their sense of sense -agency- and location) which eliminated interference. This interference could include external environmental stimuli such as noises, observing the laboratory equipment, or internal stimuli such as decreased motivation or feelings of boredom. By inducing OBE, participants due to a sense of disembodiment attempted to gain -perhaps unconsciously- full control (maintain agency) in a shifted location. Thus, they could be more focused on the task, by eliminating irrelevant stimuli (disturbances).

On the other hand, Moseley and his colleagues (2008) found impaired memory after OBE. This could be explained by the fact that they tested partial ownership using the rubber hand illusion, while we tested global body ownership with OBE. Their experimental manipulation perhaps resulted in distorted body ownership which interfered in the encoding process, changing the way of forming the memory traces. Based on the above, it is demonstrated that encoding and consolidation are two different processes and OBE improves memory only after successful encoding. Also, OBE could imitate sleep with respect to memory consolidation's improvement as will be further described in the next paragraphs.

Literature reports that any improvement in performance after the initial training during memory consolidation occurs only in sleep (Walker, 2009; Walker et al., 2002). In this perspective, OBE can imitate sleep (and perhaps REM) characteristics for enhancing emotional memory consolidation (Stickgold, 2005). In addition, there are some neural correlates between OBE and sleep. Some brain areas like the precuneus and supramarginal gyrus (De Ridder et al., 2007; Cavanna & Trimble, 2006; Maquet, et al., 1996) show similar activation patterns in OBE and sleep. In the following paragraphs, we will elaborate more on this topic.

Sleep has been associated with out of body experiences (Cheyne et al., 1999; Maquet et al., 1996). More specifically, the hypnagogic and hypnopompic experiences are accompanying sleep paralysis and include supernatural nocturnal assaults and paranormal experiences and are closely associated with Rapid Eye Movement (REM) sleep. The posterior cingulate cortex (PCC) is one of the brain areas found to be involved both in sleep and body ownership. Neuroimaging studies suggest a role for the PCC and the adjacent precuneus in integrating self-referential stimuli in the context of one's own personality and is also involved in autobiographical memory (Tsakiris, et al., 2007; Northoff & Bermpohl, 2004; Braun, et al., 1997). Thus, PCC reflects a sense of body ownership. PCC also interferes in sleep even though it is one of the least active brain regions (Maquet, et al., 2005). Apart from the PCC, the adjacent precuneus, as already mentioned, is also involved in both body ownership and sleep. The precuneus has reciprocal cortico-cortical connections with the adjacent areas of the posterior cingulate and retro-splenial cortices. This interconnection occurs in both hemispheres, bridging correspondent components, and provides partly an anatomical basis for their functional coupling. The precuneus is also selectively connected with other parietal areas, such as the caudal parietal operculum, the inferior and superior parietal lobules, and the inferior parietal sulcus. In the following paragraph, the role of the parietal lobe will be further described.

The parietal lobe is greatly involved in OBE and especially the inferior parietal lobule or temporoparietal junction (Blanke & Arzy, 2005; Chaminade & Decety, 2002). The inferior parietal lobule is involved in perceiving the person who performed an action. Results demonstrated activation in the right intraparietal sulcus and in the bilateral inferior parietal lobule. Also, in the conditions where the origin of the action was confused, the activation in the left inferior parietal lobule was stronger when participants did not perform the action themselves, and in the right when they did. With respect to sleep and in accordance with Chee & Chuah (2007), the inferior parietal sulcus is also involved in sleep as a memory storage factor and in combination with the extrastriate cortex in processing visual information influencing visual short-term memory. The overall quality of sleep is changing if the activation pattern of the inferior parietal lobule alters, proving its contribution to the sleep circuit. Apart from this, it was found that during the onset of non-REM sleep, the inferior parietal lobule was deactivated and not transmitting sensory information from the periphery (Braun, 1997). All these findings suggest that the inferior parietal lobule, along with other brain areas, is greatly involved in body sensation and sleep and future studies should probe further the possible connections between OBE and sleep patterns. In addition, they could provide more insights into the underlying reasons for how performance in our emotional memory tasks was improved.

The participant's temperature in the OBE group was found to be increased. Literature reports that skin temperature and heart rate has been found that is highly and differently affected by various emotional states (Sinha et al., 1992). More specifically, neutral emotional conditions cause the least change in skin temperature and heart rate, while negative emotions evoke the largest changes and pleasant intermediate changes. These changes vary depending on the site from which temperature is recorded, but overall these different physiological responses influence cognitive and memory processes by making stimuli easier or more difficult to be memorized (Holland et al., 1985).

Skin temperature did not follow the same pattern across groups and on different body parts. More specifically, the temperature on the neck was found to be consistently higher in the OBE as opposed to hand temperature which was lower but with high fluctuations. This could be explained by the fact that extremities have always rapidly changing temperature, especially the hands which are constantly influenced by the environmental conditions (Fiala et al., 2001). Neck temperature on the other hand as being closer to the heart (core temperature) is relatively unchanged and consistent within groups and between groups was found constantly higher in the OBE group, thus it could be used as a marker for an out of body state.

This temperature increase could have contributed to the performance improvements. Studies have shown that as core body temperature increases, cognition, and especially memory consolidation, speed of reasoning, and information processing are positively affected (Coleshaw et al., 1983). All the above-mentioned findings could provide support for our temperature findings. Nevertheless, even though the temperature was found to be associated with out of body state, no relation was found with the performance, suggesting that performance and skin temperature areas both influenced by OBE but have no interconnections. In line with the above mentioned is the results by Braithwaite, Watson, and Dewe (2017) who did not find temperature decrease in upper extremities, while testing RHI, despite the fact that prior studies have found temperature fluctuations as a fear or anxiety response towards a threat (Moseley et al., 2008; Kammers et al., 2011). All these suggest that literature so far is inconclusive regarding temperature alternations as a response to distorted body ownership (partial or global).

Apart from that, the differences that have been observed between literature (Moseley, et al., 2008) and our results with respect to skin temperature could be due to a number of reasons both as experimentally induced and as influenced by external factors. As described above with respect to performance, Moseley and his colleagues investigated partial body ownership and found a temperature decline in the hand, which was replaced by the rubber hand. For isolated body parts, skin temperature could be easier lower as described in the introduction. Apart from that, an important factor was room temperature. Due to the fact that our experiment was not conducted in a lab but in an office, temperature regulation was not possible. Thus, participants' temperature maybe was influenced by the time of day (morning –afternoon) and the sunlight conditions (sunny – cloudy). Lastly, OBE is a relatively innovative technique and none of the participants was familiar with the procedure, thus temperature increase might be due to proprioceptive drift and the stroking phase, which perhaps caused anxiety and uneasiness. In this condition might have contributed to the fact that the experimenter was seen very close to the participants' view. To control for that, we recommend later experiments to use a lab at a constant temperature and make sure that participants do not feel uneasy during the experimental procedure for eliminating these effects.

Our experiment only included behavioral responses with no electrophysiological and brain imaging measurements. This is a drawback, since many brain areas, especially the temporoparietal junction (Blanke et al., 2004), are involved, and would be interesting to further probe these areas and link them if possible, with the neural substrates of sleep. In line with this, Blanke (2004) reports that OBE probably is associated with a failure of integration of proprioceptive, tactile, and visual information of one's body associated with many brain areas' dysfunction. In summary, Blanke (2004) based on the neurological evidence of his study states that out of body experiences are related to 1) a disintegration within personal space (multisensory dysfunction) and 2) a disintegration between personal space (vestibular) and extra-personal space (visual) due to interference with the temporo-parietal junction. In order to test all the above, future studies should make use of physiological measuring tools, such as electrocardiogram, neuroimaging techniques, like functional magnetic resonance imaging (fMRI), and skin conductance measurements.

Another drawback of the study was the lack of baseline emotional memory measure. Even though participants were randomly assigned to each group (experimental: OBE, control: IBE) and a similar number of participants were excluded from both groups, because they failed to meet the inclusion criteria, criteria, it is still possible that participants who were more prone to out of body experience had better emotional memory than the control group, thus compromising our findings. Albeit, there is no reason to believe that more of those participants were in the experimental group rather than the control group, participants in the experimental group on average might had a higher memory capacity baseline and performed better. This baseline measure should be performed in future studies a priori, before the induction of OBE, by segregating the pool of pictures and test half of them directly after the encoding session and before the stroking phase and half of them afterwards, interspersed with new pictures. Then by subtracting performance in the first retrieval session from the second retrieval session, it can be determined whether the consolidation process is influenced by OBE. Thus, an objective measurement will be developed to rule out the previously mentioned possibility.

In addition to the above, the type of task used (visual recognition) could also constitute a drawback. Even though OBE was found to positively affect participants' performance, it should be noted that recognition tasks are considered to be easier than recall tasks, as it is easier to employ relevant cognitive strategies for recognizing previously occurred stimuli than recalling particular characteristics of previously presented stimuli (Garrido et al., 2012). Also, it is found that particularly short-term visual memory can be held for longer and can be more accurate than auditory short-term memory (Hilton, 2001). Thus, OBE effects when a recall test is employed tapping on visual long-term memory, might not show similar results in other settings, enhancing only repetition (accuracy in successfully judging a stimulus as previously presented) rather than recalling specific memory traces, associated with a previously presented stimulus and related to only visual rather than auditory or other types of stimuli. Future studies should take into consideration the above-mentioned limitations and investigate the potential positive effects of OBE in other settings (for instance, tactile stimuli in recall tasks).

Overall, investigating OBE can be very challenging because if they are not experimentally induced, occur scarcely in a small sample of the entire population and they are rather spontaneous (Blanke et al., 2004). Based on our experiment, we propose the following explanation: Out-of-body experience (as reported in the OBE questionnaire) enhances memory consolidation (as been found from significant differences in d-prime between OBE and IBE groups) and interacts with the temperature with no conclusive data whether higher temperature predicts stronger OBE or stronger OBE causes temperature increase (see fig. 13). As already mentioned, OBE is associated with deficient multisensory and visual processing. Also, OBE is closely connected with autoscopic phenomena and with several medical conditions (Blanke, et al., 2004; Brugger et al., 1997). All these make body ownership phenomena one of the top priorities for researchers to fully describe them. Neuroimaging and behavioral techniques will provide us more information about these multisensory and cognitive processes during out-of-body experiences and related illusions, with the ultimate goal to unravel the exact underlying mechanisms of self and body awareness and design proper interventions to successfully treat associated medical conditions.

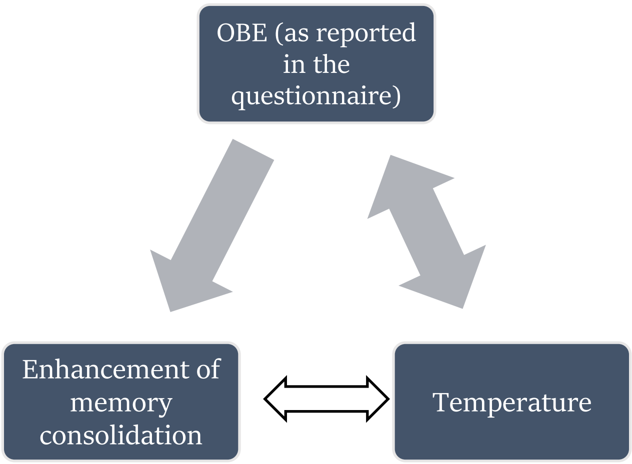

Fig. 13. *Graphical presentation of the data. Out-of-body experiences (as reported in the OBE questionnaire) enhances memory consolidation (as been found from significant differences in d-prime between OBE and IBE groups) and interacts with the temperature with no conclusive data whether higher temperature predicts stronger OBE or stronger OBE causes temperature increase*

References

Alvarez, P., & Squire, L. R. (1994). Memory consolidation and the medial temporal lobe: a simple network model. *Proceedings of the National Academy of Sciences*, *91*(15), 7041-7045. https://doi.org/10.1073/pnas.91.15.7041

Anderson, M. L. (2003). Embodied cognition: A field guide. *Artificial intelligence*, *149*(1), 91-130. https://doi.org/10.1016/S0004-3702(03)00054-7

Atkinson, R. L.; Richard C. Atkinson, Edward E. Smith, Daryl J. Bem, & Susan Nolen-Hoeksema (2000). *Hilgard's Introduction to Psychology*, *13*, 437.

Baddeley, A. D. (1999). *Essentials of Human Memory*. Psychology Press.

Bergouignan, L., Nyberg, L., & Ehrsson, H. H. (2014). Out-of-body-induced hippocampal amnesia. *Proceedings of the National Academy of Sciences of the United States of America*, *111*(12), 4421–6. https://doi.org/10.1073/pnas.1318801111

Bierman, W. (1936). The temperature of the skin surface. *Journal of the American Medical Association*, *106*(14), 1158-1162. https://doi.org/10.1001/jama.1936.02770140020007

Blanke, O. (2012). Multisensory brain mechanisms of bodily self-consciousness. Nature Reviews. *Neuroscience, 13*(8), 556–71. https://doi.org/10.1073/pnas.1318801111

Blanke, O. (2004). Out of body experiences and their neural basis. *Bmj*, *329*(7480), 1414-1415. https://doi.org/10.1136/bmj.329.7480.1414

Blanke, O., & Arzy, S. (2005). The out-of-body experience: disturbed self-processing at the temporo-parietal junction. *The Neuroscientist, 11*(1), 16-24. https://doi.org/10.1177/1073858404270885

Blanke, O., Landis, T., Spinelli, L., & Seeck, M. (2004). Out-of-body experience and autoscopy of neurological origin. *Brain*, *127*(2), 243-258. https://doi.org/10.1093/brain/awh040

Blanke, O., & Metzinger, T. (2009). Full-body illusions and minimal phenomenal selfhood. *Trends in cognitive sciences, 13*(1), 7-13. https://doi.org/10.1016/j.tics.2008.10.003

Bradley, M. M., Greenwald, M. K., Petry, M. C., & Lang, P. J. (1992). Remembering pictures: pleasure and arousal in memory. *Journal of experimental psychology: Learning, Memory, and Cognition*, *18*(2), 379. https://doi.org/10.1037//0278-7393.18.2.379

Braithwaite, J. J., Watson, D. G., & Dewe, H. (2017). Predisposition to out-of-body experience (OBE) is associated with aberrations in multisensory integration: Psychophysiological support from a "rubber hand illusion" study. *Journal of Experimental Psychology: Human Perception and Performance*, *43*(6), 1125. https://doi.org/10.1037/xhp0000406

Braun, A. R., Balkin, T. J., Wesensten, N. J., Carson, R. E., Varga, M., Baldwin, P., Selbie, S., Belenky, G., & Herscovitch, P. (1997). Regional cerebral blood flow throughout the sleep-wake cycle. *Brain*, *120*(7), 1173-97. https://doi.org/10.1093/brain/120.7.1173

Brechet, L., Mange, R., Herbelin, B., Gauthier, B., Serino, A. & Blanke, O. (2018). Viewing one's body during encoding boosts episodic memory. *bioRxiv*, Article e318956. https://doi.org/10.1101/318956

Brugger, P., Regard, M., & Landis, T. (1997). Illusory reduplication of one's own body: phenomenology and classification of autoscopic phenomena. *Cognitive Neuropsychiatry*, *2*(1), 19-38. https://doi.org/10.1080/135468097396397

Bugental, D. B., & Cortez, V. L. (1988). Physiological reactivity to responsive and unresponsive children as moderated by perceived control. *Child Development*, *59*(3), 686-693. https://doi.org/10.2307/1130568

Cavanna, A. E., & Trimble, M. R. (2006). The precuneus: a review of its functional anatomy and behavioural correlates. *Brain*, *129*(3), 564-583. https://doi.org/10.1093/brain/awl004

Chaminade, T., & Decety, J. (2002). Leader or follower? Involvement of the inferior parietal lobule in agency. *Neuroreport*, *13*(15), 1975-1978. https://doi.org/10.1097/00001756-200210280-00029

Chee, M. W., & Chuah, Y. L. (2007). Functional neuroimaging and behavioral correlates of capacity decline in visual short-term memory after sleep deprivation. *Proceedings of the National Academy of Sciences*, *104*(22), 9487-9492. https://doi.org/10.1073/pnas.0610712104

Cheyne, J. A., Rueffer, S. D., & Newby-Clark, I. R. (1999). Hypnagogic and hypnopompic hallucinations during sleep paralysis: neurological and cultural construction of the night-mare. *Consciousness and Cognition*, *8*(3), 319-337. https://doi.org/10.1006/ccog.1999.0404

Coleshaw, S. R., Van Someren, R. N., Wolff, A. H., Davis, H. M., & Keatinge, W. R. (1983). Impaired memory registration and speed of reasoning caused by low body temperature. *Journal of Applied Physiology*, *55*(1), 27-31. https://doi.org/10.1152/jappl.1983.55.1.27

Costantini, M., & Haggard, P. (2007). The rubber hand illusion: sensitivity and reference frame for body ownership. *Consciousness and cognition*, *16*(2), 229-240. https://doi.org/10.1016/j.concog.2007.01.001

Cowan, N. (2008). What are the differences between long-term, short-term, and working memory? *Progress in brain research*, *169*, 323-338. https://doi.org/10.1016/S0079-6123(07)00020-9

De Ridder, D., Van Laere, K., Dupont, P., Menovsky, T., & Van de Heyning, P. (2007). Visualizing out-of-body experience in the brain. *New England Journal of Medicine*, *357*(18), 1829-1833. Doi: 10.1056/NEJMoa070010

Ehrsson, H. H. (2007). The experimental induction of out-of-body experiences. *Science (New York, N.Y.), 317*(5841), 1048. https://doi.org/10.1126/science.1142175

Ehrsson, H. H., Wiech, K., Weiskopf, N., Dolan, R. J., & Passingham, R. E. (2007). Threatening a rubber hand that you feel is yours elicits a cortical anxiety response. *Proceedings of the National Academy of Sciences, 104*(23), 9828-9833. https://doi.org/10.1073/pnas.0610011104

Fiala, D., Lomas, K. J., & Stohrer, M. (2001). Computer prediction of human thermoregulatory and temperature responses to a wide range of environmental conditions. *International Journal of Biometeorology*, *45*(3), 143-159. https://doi.org/10.1007/s004840100099

Freitas, R. A. (1999). *Nanomedicine, volume I: basic capabilities*. Landes Bioscience.

Garrido, M. V., Garcia-Marques, L., & Hamilton, D. L. (2012). Hard to recall but easy to judge: Retrieval strategies in social information processing. *Social cognition*, *30*(1), 56-70. https://doi.org/10.1521/soco.2012.30.1.56

Guterstam, A., & Ehrsson, H. H. (2012). Disowning one's seen real body during an out-of-body illusion. *Consciousness and cognition*, *21*(2), 1037-1042. https://doi.org/10.1016/j.concog.2012.01.018

Hamann, S. (2001). Cognitive and neural mechanisms of emotional memory. *Trends in cognitive sciences*, *5*(9), 394-400. https://doi.org/10.1016/s1364-6613(00)01707-1

Hayes, N. (2000). *Foundations of psychology*. Cengage Learning EMEA.

Hilton, E. (2001). Differences in visual and auditory short-term memory. *IU South Bend Undergraduate Research Journal*, *4*, 47-50.

Holland, R. L., Sayers, J. A., Keatinge, W. R., Davis, H. M., & Peswani, R. (1985). Effects of raised body temperature on reasoning, memory, and mood. *Journal of Applied Physiology*, *59*(6), 1823-1827. https://doi.org/10.1152/jappl.1985.59.6.1823

Kammers, M. P., Rose, K., & Haggard, P. (2011). Feeling numb: Temperature, but not thermal pain, modulates feeling of body ownership. *Neuropsychologia*, *49*(5), 1316-1321. https://doi.org/10.1016/j.neuropsychologia.2011.02.039

Kensinger, E. A., & Corkin, S. (2003). Memory enhancement for emotional words: Are emotional words more vividly remembered than neutral words? *Memory & cognition, 31*(8), 1169-1180. https://doi.org/10.3758/bf03195800

LaBar, K. S., & Cabeza, R. (2006). Cognitive neuroscience of emotional memory. *Nature Reviews Neuroscience*, *7*(1), 54-64. https://doi.org/10.1038/nrn1825

Lang, P. J. (1995). The emotion probe: studies of motivation and attention. *American psychologist*, *50*(5), 372. https://doi.org/10.1037//0003-066x.50.5.372

Lang, P. J., Bradley, M. M., & Cuthbert, B. N. (2008). International affective picture system (IAPS): Affective ratings of pictures and instruction manual. *Technical report A-8*. https://doi.org/10.1007/978-3-319-28099-8_42-1

LeDoux, J. E. (2000). Emotion circuits in the brain. *Annual review of neuroscience*, *23*(1), 155-184. https://doi.org/10.1146/annurev.neuro.23.1.155

Levenson, R. W., Ekman, P., & Friesen, W. V. (1990). Voluntary facial action generates emotion-specific autonomic nervous system activity. *Psychophysiology*, *27*(4), 363-384. https://doi.org/10.1111/j.1469-8986.1990.tb02330.x

Macmillan, N. A., & Creelman, C. D. (2005). *Detection theory: A user's guide* (2nd ed.). Lawrence Erlbaum Associates Publishers.

Maquet, P., Péters, J. M., Aerts, J., Delfiore, G., Degueldre, C., Luxen, A., & Franck, G. (1996). Functional neuroanatomy of human rapid-eye-movement sleep and dreaming. *Nature*, *383*(6596), 163-166. https://doi.org/10.1038/383163a0

McFarland, R. A. (1985). Relationship of skin temperature changes to the emotions accompanying music. *Biofeedback and Self-regulation*, *10*(3), 255-267. https://doi.org/10.1007/BF00999346

McGaugh, J. L. (2000). Memory--a century of consolidation. *Science*, *287*(5451), 248-251. https://doi.org/10.1126/science.287.5451.248

Moseley, G. L., Olthof, N., Venema, A., Don, S., Wijers, M., Gallace, A., & Spence, C. (2008). Psychologically induced cooling of a specific body part caused by the illusory ownership of an artificial counterpart. *Proceedings of the National Academy of Sciences, 105*(35), 13169-13173. https://doi.org/10.1073/pnas.0803768105

Northoff, G., & Bermpohl, F. (2004). Cortical midline structures and the self. *Trends in cognitive sciences*, *8*(3), 102-107. https://doi.org/10.1016/j.tics.2004.01.004

Petkova, V. I., & Ehrsson, H. H. (2008). If I were you: perceptual illusion of body swapping. *PloS One, 3*(12), 3832. https://doi.org/10.1371/journal.pone.0003832

Quevedo, J., Sant'Anna, M. K., Madruga, M., Lovato, I., de-Paris, F., Kapczinski, F., Izquierdo, I., & Cahill, L. (2003). Differential effects of emotional arousal in short-and long-term memory in healthy adults. *Neurobiology of learning and memory*, *79*(2), 132-135. https://doi.org/10.1016/S1074-7427(02)00034-5

Ratcliff, R. (1978). A theory of memory retrieval. *Psychological review*, *85*(2), 59. https://doi.org/10.1037/0033-295X.85.2.59

Rimm-Kaufman, S. E., & Kagan, J. (1996). The psychological significance of changes in skin temperature. *Motivation and Emotion*, *20*(1), 63-78. https://doi.org/10.1007/BF02251007

Ro, T., Ellmore, T. M., & Beauchamp, M. S. (2012). A neural link between feeling and hearing. *Cerebral cortex*, *23*(7), 1724-1730. https://doi.org/10.1093/cercor/bhs166

Sessler, D. I. (2008). Temperature monitoring and perioperative thermoregulation. *Anesthesiology*, *109*(2), 318.

Sinha, R., Lovallo, W. R., & Parsons, O. A. (1992). Cardiovascular differentiation of emotions. *Psychosomatic Medicine*, *54*(4), 422-435. https://doi.org/10.1097/00006842-199207000-00005

Stemmler, G. (1989). The autonomic differentiation of emotions revisited: Convergent and discriminant validation. *Psychophysiology*, *26*(6), 617-632. https://doi.org/10.1111/j.1469-8986.1989.tb03163.x

Stickgold, R. (2005). Sleep-dependent memory consolidation. *Nature*, *437*(7063), 1272-1278. https://doi.org/10.1038/nature04286

Tsakiris, M. (2010). My body in the brain: a neurocognitive model of body-ownership. *Neuropsychologia*, *48*(3), 703-712. https://doi.org/10.1016/j.neuropsychologia.2009.09.034

Tsakiris, M., Hesse, M. D., Boy, C., Haggard, P., & Fink, G. R. (2007). Neural signatures of body ownership: a sensory network for bodily self-consciousness. *Cerebral Cortex, 17*(10), 2235–44. https://doi.org/10.1093/cercor/bhl131

Tuena, C., Serino, S., Gaston-Bellegarde, A., Orriols, E., Makowski, D., Riva, G., & Piolino, P. (2017). How virtual embodiment affects episodic memory functioning: a proof-of-concept study. *Annual Review of Cybertherapy and Telemedicine 2017*, 98-103.

Tulving, E. (1972). Episodic and semantic memory. In E. Tulving & W. Donaldson, *Organization of memory*. Academic Press.

Vogeley, K., May, M., Ritzl, A., Falkai, P., Zilles, K., & Fink, G. R. (2004). Neural correlates of first-person perspective as one constituent of human self-consciousness. *Journal of cognitive neuroscience*, *16*(5), 817-827. https://doi.org/10.1162/089892904970799

Walker, M. P. (2009). The role of sleep in cognition and emotion. *Annals of the New York Academy of Sciences, 1156*(1), 168-197. https://doi.org/10.1111/j.1749-6632.2009.04416.x

Walker, M. P., Brakefield, T., Morgan, A., Hobson, J. A., & Stickgold, R. (2002). Practice with sleep makes perfect: sleep-dependent motor skill learning. *Neuron, 35*(1), 205-211. https://doi.org/10.1016/S0896-6273(02)00746-8

Walker, M. P., & Stickgold, R. (2004). Sleep-dependent learning and memory consolidation. *Neuron*, *44*(1), 121-133. https://doi.org/10.1016/j.neuron.2004.08.031

ΨΥΧΟΛΟΓΙΑ | PSYCHOLOGY, 25 (2), 13-33

Ελληνική Ψυχολογική Εταιρεία
Hellenic Psychological Society

ΕΜΠΕΙΡΙΚΗ ΕΡΓΑΣΙΑ | RESEARCH PAPER

Οι εξωσωματικές εμπειρίες ευνοούν την παγίωση της συναισθηματικής μνήμης

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ΛΕΞΕΙΣ ΚΛΕΙΔΙΑ

εξωσωματικές εμπειρίες,
θερμοκρασία δέρματος,
ιδιοδεκτικότητα,
συναισθήματα,
παγίωση της μνήμης

ΣΤΟΙΧΕΙΑ ΕΠΙΚΟΙΝΩΝΙΑΣ

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ΠΕΡΙΛΗΨΗ

Η ιδιοδεκτικότητα αντανακλά την ικανότητά μας να αναγνωρίζουμε το σώμα μας σε μια συγκεκριμένη τοποθεσία, επιτρέποντάς μας να επικοινωνούμε με τον κόσμο. Τα συναισθήματα επιφέρουν ισχυρό αντίκτυπο στη μνήμη και στην ιδιοδεκτικότητα. Παρουσιάζει ενδιαφέρον ότι η θερμοκρασία του δέρματος μπορεί τουλάχιστον εν μέρει να μεσολαβήσει σε αυτή την επίδραση. Προηγούμενες μελέτες έχουν διαπιστώσει ότι οι εξωσωματικές εμπειρίες (out-of-body experiences, OBE) έχουν αρνητικό αντίκτυπο στην κωδικοποίηση πληροφοριών και προκαλούν πτώση της θερμοκρασίας του δέρματος. Στην παρούσα μελέτη σχεδιάστηκε μια νέα μέθοδος για την πρόκληση OBE και διερευνήθηκε η επίδρασή τους σε διαφορετικό στάδιο και τύπο επεξεργασίας μνήμης (παγίωση της συναισθηματικής μνήμης) και στη θερμοκρασία του δέρματος. Στο πείραμά μας παρουσιάσαμε τρεις τύπους συναισθηματικών εικόνων (ουδέτερες, ευχάριστες, δυσάρεστες) προτού προχωρήσουμε στην πρόκληση OBE και εξετάσουμε τη μνήμη αναγνώρισης των συμμετεχόντων μας σε μια δοκιμασία ανάκτησης. Σε όλο το πείραμα, η θερμοκρασία του δέρματος τόσο στο λαιμό όσο και στο χέρι μετρήθηκε με iButtons. Οι επιδόσεις των συμμετεχόντων υπολογίστηκαν χρησιμοποιώντας d-prime και οι στατιστικές αναλύσεις περιελάμβαναν ανάλυση ANOVA, εξετάζοντας τη σχέση μεταξύ της βαθμολογίας στο ερωτηματολόγιο OBE, της απόδοσης και της θερμοκρασίας του δέρματος. Συγκρίναμε επίσης τις διαφορές μεταξύ της πειραματικής ομάδας και της ομάδας ελέγχου. Τα αποτελέσματα έδειξαν ότι το OBE ευνοεί την παγίωση της συναισθηματικής μνήμης και προκαλεί αύξηση της θερμοκρασίας. Μελλοντικές μελέτες θα πρέπει να επεκτείνουν τα ευρήματά μας, να αποκλείσουν ότι οι συμμετέχοντες που βιώνουν OBE θα μπορούσαν να έχουν εκ των προτέρων καλύτερη μνήμη ή ότι η θερμοκρασία θα μπορούσε να αυξηθεί λόγω άλλων λόγων.