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Height of the first-person perspective affects the out-of-body experience illusion

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Bodily illusions have been used to investigate one's sense of self and body ownership. This study explored the effect of the height of the first-person perspective (1PP) on out-of-body experience (OBE) illusion in which participants see their backs through a head-mounted display, receive visuo-tactile stimulation, and gradually feel as if they are sitting behind themselves, experiencing a sensation similar to an OBE. We hypothesized that increasing or decreasing the height of the 1PP would induce the OBE illusion at all heights and that participants' perceived own heights would adjust according to the 1PP height. We also predicted that the size and distance of external objects would vary according to the perceived height of one's own body. The results revealed that the OBE illusion occurred at all 1PP heights and was stronger when the 1PP height was lower or higher than usual. Meanwhile, the participants' perceived own heights, the sizes and distances of external objects did not change. These results suggest that manipulating the 1PP may affect the magnitude of the OBE illusion, but not the perception of the dimensions of the self or external objects. The height of 1PP may be one of the important factors in the bodily illusion.

KEYWORDS

bodily illusion, out-of-body experience, first-person perspective, self location, visuo-tactile integration, virtual reality

1 Introduction

Bodily illusions are employed to determine the components of the sense of self and body ownership. These illusions have been traditionally studied using the rubber hand illusion (Botvinick and Cohen, 1998). In this illusion, when participants see a fake rubber hand being stroked by paintbrushes while their real hand—which is hidden from view—is simultaneously stroked synchronously, they gradually feel the brushes stroking their real hand, perceiving the rubber hand as their own.

Two types of illusion paradigms involve the entire body. The first is the full-body illusion (Lenggenhager et al., 2007), in which participants, through a head-mounted display (HMD), see the back of a fake body being touched with a rod, while also being touched synchronously at the same point on their own back. As the visuo-tactile stimulation continues, the fake body is gradually perceived as the participant's own, and the self-location is perceived as biased toward the front where the fake body is located. The second illusion paradigm is the out-of-body experience (OBE) illusion (Ehrsson, 2007; Guterstam and Ehrsson, 2012), wherein participants see their backs through HMDs. In contrast to Lenggenhager et al.'s (2007) paradigm, participants are touched on their right shoulder by a rod hidden by the experimenter's body, while another rod approaches the right bottom of the camera. They gradually feel as if they are sitting behind themselves, experiencing a sensation akin to an OBE.

Three components contribute to the occurrence of these bodily illusions. The first is the multisensory (e.g., visuo-tactile) integration of sensory inputs from and to a body. The abovementioned bodily illusions are induced when a tactile stimulation from a rod and its visual information are spatio-temporally congruent. The second component is a human-like appearance. The fake body for which participants experience an illusion have to look like a human body (Tsakiris and Haggard, 2005; Lenggenhager et al., 2007). For example, participants can feel the rubber hand illusion when using a human-like fake hand but not a wooden stick (Tsakiris and Haggard, 2005). The third component is the first-person perspective (1PP), which is the experience from where 'I' perceive the world (Blanke, 2012). Perspectives can be manipulated using devices such as HMDs and video cameras to investigate the effect of perspective on bodily illusions involving the whole body. The OBE illusion occurs more frequently in the 1PP than in the third-person perspective (Petkova et al., 2011; Bergouignan et al., 2014). However, whether other components of the 1PP, such as its height, affect the OBE illusion remains unclear. We defined 1PP as the position of one's eyes observing the external world and the starting point of the body. We examined whether and to what extent participants felt the OBE illusion when the height of the 1PP was manipulated to be taller or shorter.

We also focused on the anatomical dimensions of bodily illusions. Previous studies have shown that participants can feel the illusion of an unrealistically long arm (Kilteni et al., 2012) and a third arm (Guterstam et al., 2011) using the rubber hand illusion paradigm in a virtual environment. In the Barbie-doll illusion paradigm (van der Hoort et al., 2011; van der Hoort and Ehrsson, 2014), participants lie on their backs and see, through HMDs, a large, normal, or Barbie-doll-sized fake body touched by a rod, while they are touched simultaneously by another rod at the consistent position of their hidden bodies. Because of the synchronous touching of fake and real bodies, participants gradually began to feel the illusion of their bodies becoming large, normal, or Barbie-doll-sized, suggesting that multisensory integration generated by the synchronous touching could cause the illusion regardless of the anatomical limitations of the components of the real body, such as length, number, and size. Therefore, we hypothesized that the OBE illusion can occur at the anatomically implausible height of 1PP.

Hiromitsu and Midorikawa (2016) investigated whether the OBE illusion occurred when the camera height was set to parallel perspectives at the same height as the actual 1PP of participants sitting on a chair and downward perspectives looking down on the seated participants 50 cm higher than the parallel perspectives. Note that the values of camera height in parallel perspectives were not reported. The study revealed that synchronous touching caused higher illusion scores compared to asynchronous touching, regardless of perspective. The researchers focused on experimentally inducing pathological OBE, which often occurs from a downward perspective, such as looking down on the self-body, and thus included only two levels of 1PP height. Since both parallel and downward perspectives in their study represented heights commonly experienced when sitting or standing in daily life, it is unclear whether taller and shorter 1PP heights than those experienced in daily life would affect the intensity of the OBE illusion.

Therefore, the present study investigated whether the OBE illusion occurred at taller and shorter 1PP heights than those used in the study by Hiromitsu and Midorikawa (2016). We hypothesized that regardless of the height of 1PP, the illusion occurs at a comparable degree. To test this, three camera heights were used in the OBE illusion paradigm: normal (110 cm from the floor), short (27 cm), and tall (180 cm). The normal height was comparable to the actual height of participants' viewpoint when sitting in a chair, whereas the short and tall heights were heights that participants could not experience while standing or sitting in a chair.

Furthermore, we focused on the effects of perceptual changes in body size and external objects caused by bodily illusions. In the Barbie-doll illusion (van der Hoort and Ehrsson, 2014), when participants experienced the illusion with fake bodies, they estimated the size of a box presented in front of the camera based on the illusory-biased size of their own bodies. For example, when experiencing the illusion of large bodies, they estimated the box to be smaller, and when experiencing the illusion with Barbie-doll-sized bodies rather than with normal bodies, they estimated the box to be larger. This suggests that when participants experienced the illusion, they felt as if they had transferred to the fake bodies and began rescaling the perceptual size of the external world by using the size of the fake bodies as a reference. Additionally, participants could estimate the size of objects based on the length of their virtual hands (Linkenauger et al., 2013). These studies suggest that perceptual size estimation can change depending on the size of the fake or virtual bodies. However, unlike these studies, the OBE illusion does not use observed fake bodies.

Therefore, we investigated whether manipulating the height of the camera in the OBE illusion alters the perception of the height of the participants' own bodies. Assuming that body height increases with body size, we also examined whether the participants misperceive the size of the box according to the 1PP height, even without fake bodies. We also hypothesized that if the perceived dimensions of the external world change depending on the height and size of one's own body, the perceived distance to an external object would also change according to the 1PP height during the OBE illusion. To test our hypotheses, in addition to the OBE illusion questionnaire we conducted an experiment employing a height perception questionnaire, size estimation task, and distance estimation task.

2 Materials and methods

2.1 Participants

Fifteen healthy female Japanese students participated (mean age: 19.20 years, standard deviation: 0.86; mean height: 157.38 cm, standard deviation: 6.22). The sample size was determined in accordance with that in Hiromitsu and Midorikawa (2016)'s experiment. One of the participants was 175 cm tall, a considerable deviation from the mean height. Since the exclusion of this participant did not change statistical significance of effects in repeated measure analyses of variance (rmANOVAs) (see Results section), rmANOVAs including this participant are reported in this

FIGURE 1
Experimental setup.

paper. This study was approved by the Humanities and Social Sciences Research Ethics Committee of Ochanomizu University (approval number: 2017-131). All participants provided written informed consent for participation before the experiment.

2.2 Apparatus and stimuli

An HMD (Oculus Rift CV1, Oculus VR, United States) with a resolution of 1,080 × 1,200 pixels per eye, refresh rate of 90 frames per second, and 110° field of view, as well as a web camera (Logicool C920t, Logitech, United States) with a resolution of 1,920 × 1,080 pixels and sampling rate of 60 Hz were connected to a Windows 7 computer (CELSIUS W510, FUJITSU, Japan) and controlled by Unity (Unity Technologies, United States). Participants sat on a chair 2 m in front of the camera. Their backs were recorded with a camera, and they viewed the HMDs in real time. Two 20-cm long rods were used as tactile stimuli. During visuo-tactile stimulation, white noise was presented through headphones equipped with HMDs.

2.3 Procedure

We included three conditions for the camera height. In the normal condition, the camera was positioned at a height of 110 cm from the floor, approximately matching the typical eye level of an average adult Japanese woman when seated in a chair. The camera height was determined based on our pilot study where mean eye level of 15 Japanese women sitting on the chair was 110.10 cm (standard deviation of 3.35). In the short condition, the camera was positioned at a height of 27 cm from the floor, much lower than the view when squatting down. In the tall condition, the camera was positioned at a height of 180 cm from the floor, much higher than the view when either sitting in a chair or standing.

Before the experiment, to familiarize the participants with the experimental apparatus, the experimenter asked them to wave their hands and explained that they were watching their own backs through the HMD in real time. The experimenter ensured that the participants did not experience virtual reality sickness before starting the experimental session. Following Guterstam and Ehrsson (2012), the experimenter touched the participants' right breast and the right lower space of the camera lens synchronously or asynchronously (i.e., synchronous or asynchronous condition) at a rate of approximately 60 times per minute for 60 s (Figure 1). Participants were asked not to move their heads during the stimulation.

After the stimulation, the size- and distance-estimation tasks were performed. The experimenter presented a white box (20 × 20 × 20 cm) 50 cm in front of the camera and asked the participants to observe the box. After presenting the box for 10 s, a black screen was displayed on the HMDs. Participants were asked to estimate the width of the box by creating an interval between their hands. These intervals were measured for analysis. They then reproduced the distance to the box by extending their dominant hand forward. The distance from the edge of the HMDs to their extended hand, which was equivalent to the distance between them and the box, was measured. Finally, they removed the HMDs and completed the questionnaires. The trial was performed once for each of the six conditions (camera: short, normal, and tall; synchrony: synchronous and asynchronous) in a randomized order. The inter-trial interval was approximately 2 minutes.

2.4 Questionnaire

For this study, we used the OBE illusion questionnaire (Guterstam and Ehrsson, 2012), which we translated into

Japanese. This questionnaire included two illusion statements (Q1 "I experienced that the hand I was seeing approaching the cameras was directly touching my chest [with the rod]"; Q2 "It felt as if my head and eyes were located at the same place as the cameras, and my body just below the cameras") and two control statements (Q3 "The visual image of me started to change appearance so that I became [partly] transparent"; Q4 "I felt as if my head and body were at different locations, almost as if I had been 'decapitated'"). These statements were rated on a seven-point Likert scale ranging from −3 ("I do not agree at all") to +3 ("I agree completely"). Additionally, we used a self-location questionnaire to assess the change in perceived self-location (Guterstam and Ehrsson, 2012). A proportional map of the experiment room, which contained key landmarks (i.e., camera, chair, experimenter, entrance door, and walls), was presented to the participants. They rated how strongly they experienced themselves to be located at their real and illusory locations in the chair and camera, respectively, on a visual analog scale ranging from 0 ("I did not experience being located here at all") to 100 ("I had a very strong experience of being located here"). Finally, we asked participants to rate their height perception during the trial ("How tall did you feel your own height during this experiment [compared to your usual height]?") by providing a number relative to their normal height, considering their normal height to be 1.0.

2.5 Data analysis

The data were not normally distributed based on the Shapiro-Wilk test; therefore, correlations were assessed using the Spearman's rank correlation coefficient. Significant correlations were observed between Q1 and Q2 scores (rho = 0.473, $p < 0.001$) and between Q3 and Q4 scores (rho = 0.533, $p < 0.001$). The scores of the two items were averaged as the illusion and control statement scores, respectively. A negative correlation was observed between the self-location scores for the camera and chair positions (rho = −0.828, $p < 0.001$); the self-location score was calculated by averaging the score for the camera and the reversed score for the chair positions (i.e., subtracted from 100).

Several observed variables were not normally distributed according to Shapiro-Wilk test. However, as type I error and power of *F*-statistic are not altered by violation of normality (Blanca et al., 2023), we employed rmANOVA. An rmANOVA was conducted on the scores of the OBE illusion questionnaire, with the statement (illusion, control), synchrony (synchronous, asynchronous), and camera (short, normal, tall) as within-participant factors. We also performed an rmANOVA with the synchrony and camera as within-participant factors on the self-location score, height-perception score, estimated size of the box, and estimated distance to the box. When the sphericity assumption was violated, as determined by Mauchly's test, the degrees of freedom were corrected using the Greenhouse-Geisser method. Post-hoc comparisons were performed using the Holm correction method. Statistical analyses were performed using JASP 0.18.3 (JASP Team, 2024).

3 Results

For the OBE illusion questionnaire, the main effects of the statement, synchrony, and camera were significant (Figure 2; Table 1). The interaction between the statement and synchrony was also significant, although other interactions were not. Post-hoc comparisons for the statement–synchrony interaction revealed significant differences between the illusion and control statement scores in the synchronous condition ($p < 0.001$, Cohen's $d = 2.19$) and between the illusion statement scores in the synchronous and asynchronous conditions ($p < 0.001$, $d = 1.53$). No significant difference was observed in the control statement scores between the synchronous and asynchronous conditions ($p = 0.922$, $d = -0.02$). Post-hoc comparisons for the main effect of the camera revealed that the OBE illusion questionnaire score was higher in the tall condition than in the normal condition ($p = 0.032$, $d = -0.32$). No significant difference was found between the short and normal conditions ($p = 0.077$, $d = 0.26$) and the short and tall conditions ($p = 0.574$, $d = -0.07$). These results suggest that participants experienced the OBE illusion regardless of camera height and that it was stronger when the 1PP height was much higher than usual.

For the self-location questionnaire, significant main effects of the synchrony and camera were observed without a significant interaction between them (Figure 3A; Table 1). Post-hoc comparisons revealed that the self-location score was higher in the short ($p = 0.003$, $d = 0.91$) and tall conditions ($p < 0.001$, $d = 1.16$) than in the normal condition. No significant difference between the short and tall conditions was observed ($p = 0.336$, $d = -0.25$). Participants felt more strongly that their location was displaced from the actual chair position to that of the camera behind them in the synchronous condition than in the asynchronous condition and in the short and tall conditions than in the normal condition.

No significant main or interactive effects on the height-perception questionnaire or the size- or distance-estimation task (Figures 3B–D; Table 1) were observed, suggesting that participants did not perceive changes in height in any condition; moreover, no changes in perceived box size or distance to the box were observed.

4 Discussion

4.1 OBE illusion and self-location perception

Consistent with previous findings (Guterstam and Ehrsson, 2012; Hiromitsu and Midorikawa, 2016), the results of the OBE illusion and self-location questionnaires revealed that the OBE illusion was observed regardless of camera height. Participants felt more strongly that they were located at the position of the camera during the synchronous visuo-tactile stimulation than during asynchronous stimulation. As no significant difference in the control statement of the OBE illusion questionnaire between the synchronous and asynchronous conditions was observed, we could rule out a response bias confounding the OBE illusion questionnaire. These results suggest that the OBE illusion occurs regardless of whether the 1PP height is equivalent to the normal viewpoint.

The results of the OBE illusion and self-location questionnaires also revealed that participants felt more strongly that they were located behind themselves in the short and tall conditions than in the normal condition, regardless of the synchrony of visuo-tactile stimulation. These results aligned with the hypothesis of Hiromitsu

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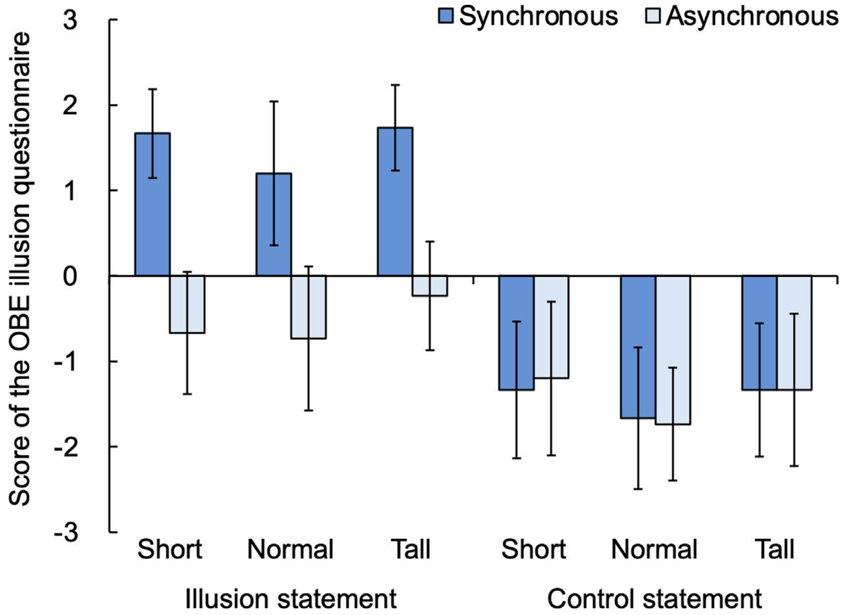

FIGURE 2
Results of the OBE illusion questionnaire. Error bars denote 95% confidence intervals.

TABLE 1 Results of repeated measure analysis of variance.

Dependent variable	Effect	*df*	*F*	*p*	η_p^2
OBE illusion questionnaire	**Statement**	1, 14	38.62	**< 0.001**	0.734
	Synchrony	1, 14	57.94	**< 0.001**	0.805
	Camera	1.43, 20.00	4.18	**0.042**	0.230
	Statement * synchrony	1, 14	34.46	**< 0.001**	0.711
	Statement * camera	2, 28	0.39	0.679	0.027
	Synchrony * camera	2, 28	0.17	0.844	0.012
	Statement * synchrony * camera	2, 28	1.10	0.348	0.073
Self-location questionnaire	**Synchrony**	1, 14	7.51	**0.016**	0.349
	Camera	2, 28	11.30	**< 0.001**	0.447
	Synchrony * camera	2, 28	0.28	0.760	0.019
Height perception questionnaire	Synchrony	1, 14	0.41	0.533	0.028
	Camera	1.20, 16.82	2.39	0.137	0.146
	Synchrony * camera	1.28, 17.89	0.01	0.961	<0.001
Size estimation	Synchrony	1, 14	0.01	0.911	<0.001
	Camera	2, 28	2.89	0.073	0.171
	Synchrony * camera	1.30, 18.25	3.77	0.059	0.212
Distance estimation	Synchrony	1, 14	2.76	0.119	0.165
	Camera	2, 28	0.64	0.534	0.044
	Synchrony * camera	2, 28	0.82	0.452	0.055

Note: Significant effects ($p < 0.05$) are bolded.

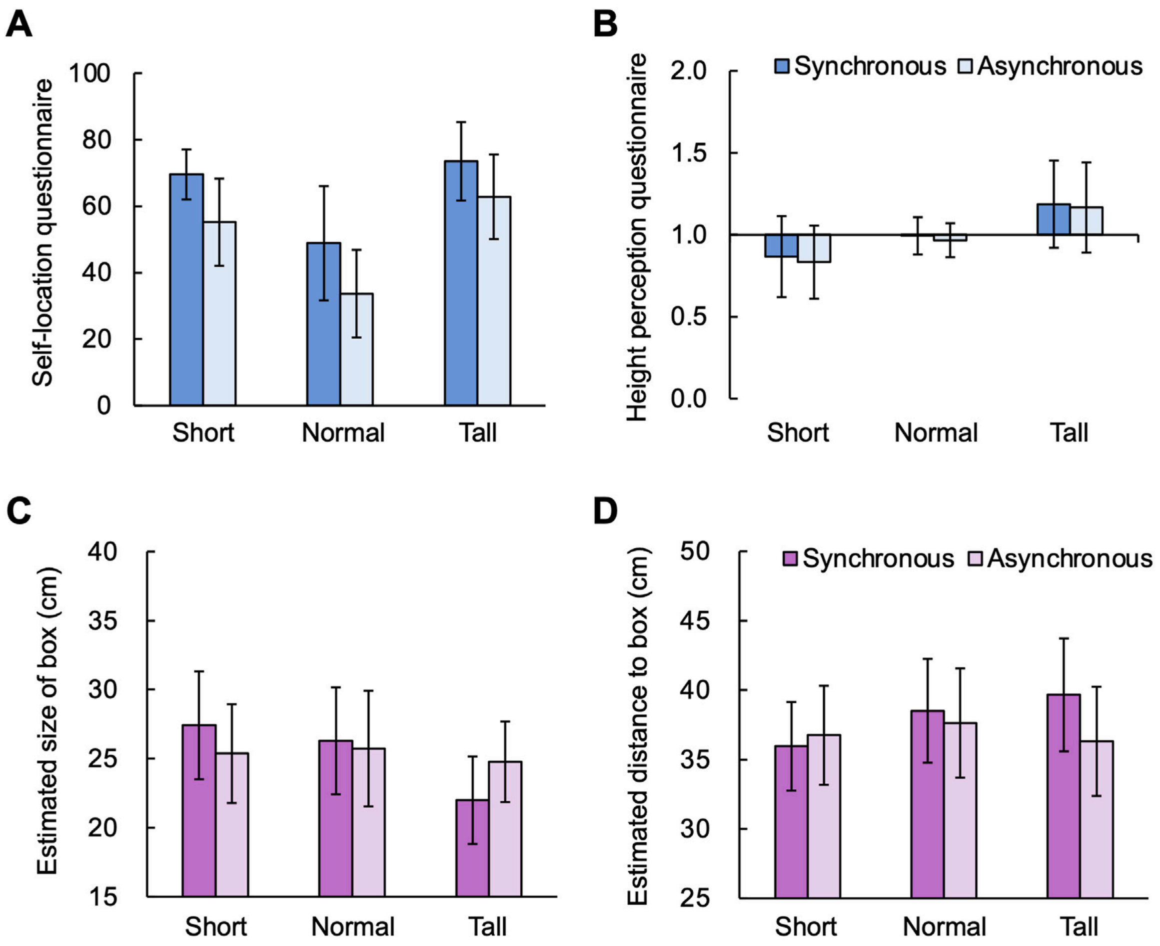

FIGURE 3
(A) Results of the self-location questionnaire, **(B)** the height-perception questionnaire, **(C)** the size-estimation task, and **(D)** the distance-estimation task. Error bars denote 95% confidence intervals.

and Midorikawa (2016) that a downward perspective would increase the OBE illusion compared to a parallel perspective. However, their hypothesis was not supported by their own experimental results, which showed non-significant effect of 1PP height on the OBE illusion (Hiromitsu and Midorikawa, 2016). Our findings demonstrated significant effects of 1PP height, which can be attributed to using camera heights much taller and shorter than ones used by Hiromitsu and Midorikawa (2016). However, the difference in the OBE illusion questionnaire between the short and normal conditions was not significant, potentially due to our underpowered sampling.

Our results further showed non-significant interaction between synchrony and camera factors, suggesting that even asynchronous visuo-tactile stimulation disrupting multisensory integration can induce the OBE illusion when viewing one's own back from an unusually high or low 1PP. The visual information from 1PP may affect the degree of the OBE illusion regardless of synchrony between visuo-tactile stimuli. Indeed, it is known that merely observing a fake body from 1PP can produce an illusory sense of body ownership over the fake body (Carey et al., 2019). In the debriefing of our experiment, some participants reported feeling a stronger sense of immersion in the short and tall conditions compared to the normal condition, regardless of the stimulation synchrony. Although speculative, it is possible that a viewpoint at a height not normally experienced may produce strong sense of immersion and facilitate the OBE illusion mainly driven by visual capture. Future studies should investigate this speculation in detail.

4.2 Own height perception and size and distance estimations

We hypothesized that changes in one's own height would occur according to the 1PP height during the OBE illusion induction. However, the results of the height-perception questionnaire suggested that participants' subjective heights did not change regardless of visuo-tactile synchrony and camera heights. This may be partly because inter-individual qualitative variations in the OBE illusion may affect or nullify the effects on one's own height perception. Based on the debriefing of this experiment, some participants felt that their height changed according to the camera height, while others felt that the position of the chair in which they were sitting changed according to the camera height. Further studies are needed to differentiate between height distortion and location displacement during the OBE illusion.

We also hypothesized that changes in the participants' subjective height would lead to changes in the perceived size and distance of an object. However, our results suggest that the synchrony of visuo-tactile stimulation and the 1PP height during the OBE illusion induction did not affect size or distance estimations. However, according to experiments with the Barbie-doll illusion (van der Hoort and Ehrsson, 2014), feeling that the self-body has become equivalent to a small doll is necessary for the alteration of object size perception. The experimental manipulations in our experiment may not have produced changes in subjective height and thus did not affect size or distance perception. Further investigation into the mediating effect of subjective height on changes in the perception of size and distance of external objects in the OBE illusion is needed.

Changes in size perception occur in the Barbie-doll illusion (van der Hoort and Ehrsson, 2014) where participants can see the fake body from their 1PP and presumably use it as a reference for visual size perception (Linkenauger et al., 2013). In contrast, the OBE illusion does not involve viewing the fake body from the 1PP. Thus, the vision of fake bodies may play a role in altering both subjective height and the size estimation of external objects. Another explanation for the lack of changes in size estimation is that participants could use their own backs during the OBE illusion induction as a reference for a veridical size estimation. To test this explanation, future experiments will need a new OBE illusion paradigm excluding the vision of participants' own bodies.

4.3 Limitations

Our sample size was small despite being based on a previous OBE illusion experiment (Hiromitsu and Midorikawa, 2016). Future replication studies with larger sample sizes are required to verify the robustness of these results. Moreover, the generalizability of our findings is limited. Only women participated in this experiment. Although our previous study suggested that the degree of the OBE illusion was comparable between sexes (Toi, 2016), further studies should confirm whether the present results could be generalized regardless of sex. In this study, we measured participants' height but not their weight as we focused on the effects of perspective height. However, as body mass index modulates the perception of one's own body size (Thaler et al., 2018), it would be beneficial to measure both height and weight in future research to investigate the influence of body mass index on the degree of the OBE illusion as well as on the effect of perspective manipulation.

4.4 Conclusion

Our results suggested that stronger OBE illusion occurs when the height of 1PP was higher or lower than the normal perspective. The subjective height and the perceived size and distance of an object did not change with the height of 1PP. Further studies are needed to investigate whether the changes in perception of external objects require subjective changes in height in the OBE illusion. We suggest the height of 1PP as one of the important factors in the OBE illusion.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary Material, further inquiries can be directed to the corresponding author.

Ethics statement

The studies involving humans were approved by the Humanities and Social Sciences Research Ethics Committee of Ochanomizu University. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

CT: Conceptualization, Data curation, Formal Analysis, Funding acquisition, Methodology, Investigation, Software, Writing–original draft. AI: Supervision, Writing–review and editing. SI: Funding acquisition, Supervision, Writing–review and editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/frvir.2024.1445725/full#supplementary-material

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