

# Study on multiple-virtual body perception: Effects of different spatial presentation and command input methods

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## Abstract

The development of a system enabling a single operator to manipulate multiple remote proxy bodies holds considerable social significance due to its potential to enhance time efficiency. This research involved a user study aimed at exploring the characteristics of multiple-body perception, influenced by the method of spatial presentation (simultaneous, switching, transparent) and the command input method to the proxy bodies (buttons, voice). A subjective evaluation through questionnaires assessed the embodiment experiences associated with multiple bodies. The data analysis from this evaluation highlighted that the transparent presentation method notably improved the sensation of occupying multiple spaces simultaneously.

## CCS Concepts

• **Human-centered computing** → Human computer interaction (HCI);

## 1. Introduction

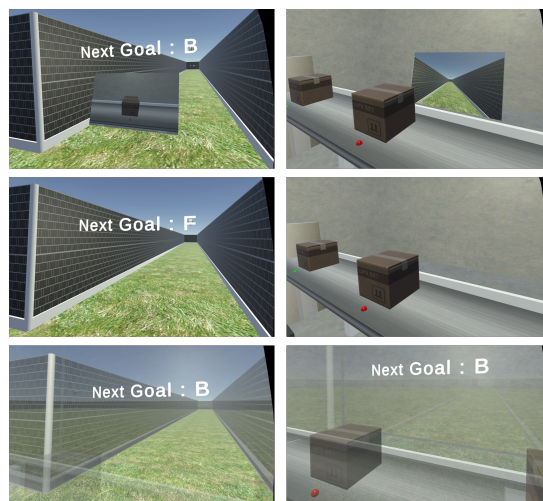
The adoption of 5G technology has enabled proxy bodies that let operators control perception and movement across multiple remote spaces, enhancing time efficiency. Understanding how operators manage perception and control of multiple avatars is crucial. Study by Kikuchi et al. [YYR\*22] and Miura et al. [RSM\*21] has addressed multi-body control, with Kikuchi focusing on dual-space experience and Miura exploring control of up to four synchronized avatars. While these studies highlight both challenges, like switching delays, and benefits in efficiency, methods for presenting multiple spaces and inputting commands remain underexplored.

This study aims to clarify how different spatial presentation methods and command input techniques affect multiple-body perception. Two remote spaces were set up with specific spatial presentation and command input conditions for the avatars. A user study was conducted to examine multiple-body perception under these conditions.

## 2. User study to evaluate multiple-body perception

### 2.1. Spatial presentation conditions

Three spatial presentation conditions were employed: simultaneous, switching, and transparent presentations (Figure 1). The simultaneous presentation displayed an immersive space involving a non-immersive small window of the other space. The switching presentation alternated between showing one immersive, visible



**Figure 1:** User views in three spatial presentation conditions (upper: simultaneous, middle: switching, lower: transparent)

space. The transparent presentation overlaid both spaces, setting varying transparency levels for two views.

### 2.2. Operation conditions

The control operation conditions pertained to different input interfaces used to initiate movement of the walking task. Three condi-

tions were tested: button input, first-person voice command (1-VC), and third-person voice command (3-VC). In the button input condition, movement was activated by pressing a button on the controller. The voice command conditions allowed movement initiation through speech, with two variations: in the first-person condition, participants speak that they initiate the behavior themselves, whereas in the third-person condition, they requested the action to start by addressing the system.

### 2.3. Experiment procedure

First, participants provided informed consent and were briefed about the experimental procedures and the questionnaire. They then donned the head-mounted display and were trained on task execution. Participants undertook one of the nine experimental conditions per session, completing a task followed by a questionnaire rated on a 5-point Likert scale (1: never, 5: always), emphasizing agency and spatial perceptions.

- Q1. The avatar's hand felt like my own during the walking task.
- Q2. The avatar's hand felt like my own during the sorting task.
- Q3. I felt in control of the avatar's hand in the walking task.
- Q4. I felt in control of the avatar's hand in the sorting task.
- Q5. I perceived my body as existing in two spaces at once.
- Q6. It felt like my body was shifting between the two spaces.
- Q7. I perceived my distributed body in two spaces simultaneously.
- Q8. I felt as if I existed in a single, unified space combining both tasks.

## 3. Result

### 3.1. Sense of agency

Questions Q3 and Q4, addressing the sense of agency, varied only by task. A three-way within-subjects ANOVA, with two experimental conditions and a task factor, showed no significant interaction but revealed a main effect of the task factor ( $F(1,19) = 19.558, p < .01$ ) (Figure 2). The walking task received lower ratings than the sorting task ( $p < .05$ ). According to Wegner's theory [Weg03], agency arises from alignment between intentions and outcomes, thought-action coherence, and absence of alternative causes. As experimental conditions had no significant impact on these factors, they did not affect agency; however, the task type did. Higher engagement in the sorting task likely contributed to its higher ratings.

### 3.2. Sense of self-location (Q5)

Items Q5 to Q8 addressed the sense of self-location. Figure 3 shows the results of sensation of coexistence. A two-way within-subjects ANOVA was conducted with spatial presentation and operation condition as the two experimental factors. The result revealed no significant interaction but showed a main effect for spatial presentation condition ( $F(2,38) = 12.2226, p < .01$ ). Post-hoc comparisons by Holm method indicated that the transparent presentation yielded significantly higher evaluations than both simultaneous and switching presentations ( $p < .05$ ). It indicated that spatial presentation strongly influences immersion and visual perception. Specifically, the transparent presentation, allowing simultaneous immersion in

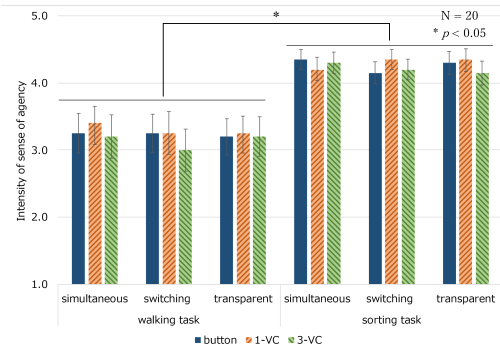


Figure 2: Ratings of sense of agency

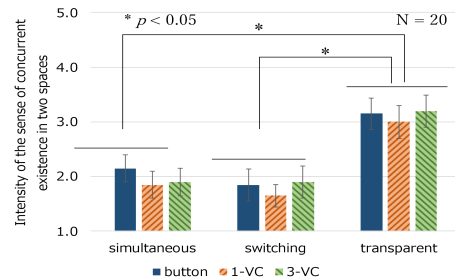


Figure 3: Ratings of the sense of being in two spaces simultaneously

both spaces, proved more effective, enhancing the perception of occupying dual spaces within the same field of view.

## 4. Conclusion

The aim of this study was to explore the characteristics of multiple-body perception in VR spaces, focusing on three visual presentations and button/voice control operations. The findings confirmed that the transparent presentation of the VR spaces has a significant effect on the participant's sensation of coexistence of two spaces. Future research will focus on extending the number of spaces.

## 5. Acknowledgment

This work was partially supported by the Local-5G Project at TMU, the Telecommunications Advancement Foundation, and JSPS KAKENHI 18H04118, 21K19785.

## References

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