INFLUENCES OF FOCAL LENGTH ON SPACE PERCEPTION IN A VIRTUAL REALITY ENVIRONMENT

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ABSTRACT: In recent years, VR techniques have been applied in various fields, and communication in VR spaces has become increasingly common across a variety of situations. Moreover, it has been reported that personal space plays an important role in VR environments as well. The size of personal space varies between individuals depending on various factors, such as gender, personality, and others. In other words, even if one person feels that the communication distance with another person is "favorable," the other person may perceive this distance as "unfavorable". Based on this fact, we have proposed a communication environment in VR space that satisfies the personal space requirements of both individuals without altering the physical distance between them. Specifically, we developed a screen display method that changes a user's perceived distance to others by adjusting the focal length of the camera in the VR environment. In this study, we investigate the effects of the proposed method on information transmission within VR space. The experimental results indicate that when a user's personal space is large, it is desirable to adjust the camera's focal length to a shorter value (thus making the apparent distance appear longer). Conversely, when a user's personal space is small, it is preferable to adjust the camera's focal length to a longer value (making the apparent distance appear shorter). Furthermore, the results showed that, in terms of information transmission and distance perception,

participants in the large personal space group tended to give higher ratings for a focal length of 15 mm, while participants in the small personal space group tended to give higher ratings for a focal length of 75 mm.

KEYWORDS: *Virtual Reality; Avatar Communication; Personal Space; Degree of Transmission and Feeling of Transmission*

1.0 INTRODUCTION

In recent years, Kansei has been applied to various fields of engineering [1-2]. In particular, VR technologies have been utilized across various domains, such as avatar communication in virtual spaces. Moreover, avatar communication in VR environments has also been adopted in manufacturing and engineering fields. In manufacturing and engineering workspaces, multiple workers often collaborate and communicate to perform tasks within VR spaces [3-8]. Therefore, it is desirable to improve the communication environment in VR settings.

In real-world environments, one important factor influencing communication is personal space (P.S.). P.S. refers to the spatial area surrounding an individual's body, serving as a boundary that others are generally discouraged from crossing [9-11]. Furthermore, it has been reported that P.S. also plays a significant role in communication within VR spaces [12-14]. Notably, the size of P.S. varies from person to person depending on various factors, such as gender and personality [15-16]. In other words, even if one interlocutor feels that the interpersonal distance is comfortable during communication, the other may not necessarily share the same perception. Consequently, maintaining a conversational distance that both parties find comfortable is challenging, and realizing a communication environment that fully considers both individuals' P.S. is particularly difficult, especially in real-world settings.

With this background, we have been aiming to realize a communication environment that reflects the P.S. of both interlocutors by changing the perception of distance without altering the physical distance between them in a VR space. Specifically, we proposed a screen display method that changes the perception of distance without changing the physical distance between interlocutors by adjusting the focal length of the viewpoint camera in a VR space [17]. In other words, by applying different focal lengths to the viewpoint cameras of each interlocutor, it becomes possible to achieve communication at a

distance that both parties feel comfortable with, taking into account the size of each interlocutor's P.S.

In addition, as a pilot study in our previous research, we verified the effect of changing the focal length of the viewpoint camera on the perception of distance between interlocutors. As a result of the experiment, it was revealed that the perception of distance between interlocutors changes depending on the focal length of the viewpoint camera, and the basic technology of the proposed method was established.

Based on the results of this previous study, this study examines the effect of the proposed method of changing the focal length of the viewpoint camera on information transmission in communication in VR space. In particular, we focus on one-way communication from an avatar to a user, that is, situations in which the user is the recipient of information, and examine the effect of changing the focal length of the viewpoint camera on information transmission.

2.0 METHODOLOGY

2.1 Distance perception by controlling focal length

In avatar communication, many methods have been proposed to adapt to a user's personal space by controlling the distance between avatars [18]. However, changing the actual distance in a VR space can cause discomfort in spatial perception and lead to errors in various tasks. Therefore, we propose a method to control distance perception by adjusting the focal length, a parameter unique to VR environments. In addition, by using focal length, users with different personal spaces can communicate with each other while maintaining a comfortable perception of distance.

2.2 Experimental overview

In this experiment, the avatar's story telling aloud at three focal lengths: 15mm, 35mm, and 75mm. Figure 1 shows examples of the screen presentation for each focal length condition. In addition, information transmission is examined from two perspectives: "degree of transmission" and "feeling of transmission" [19]. The degree of transmission indicates the degree to which the speaker's utterance was

accurately received by the listener, and the sense of transmission indicates the degree to which the listener felt that the information from the speaker was correctly shared. The participants in the experiment were 36 students from Doshisha University and the Graduate School.

(a) (b) (c)

Figure 1: Story telling by the avatar in each focal length: (a) 15mm (b) 35mm and (c) 75mm

2.3 Experimental procedure

Figure 2 shows the experimental procedure. In the experiment, participants answered a pre-experiment questionnaire, and then measured their P.S. in VR using the stop-distance method [20]. After that, the avatar telling a story aloud under each focal length condition, and after each story, participants were given a post-story questionnaire and a comprehension test. In addition, to take into account the order effect, the order of the focal lengths was changed for each participant. Finally, participants were asked to answer a post-experiment questionnaire.

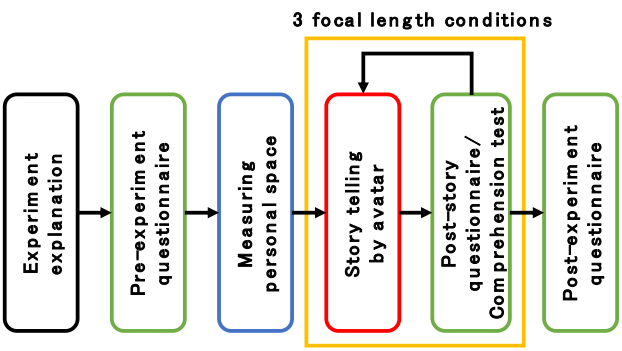

Figure 2: Experimental procedure

2.4 Contents of the comprehension test and questionnaire

The confirmation test consisted of five multiple-choice questions for each story (Table 1). The post-story questionnaire (Table 2) consisted of questions about the feeling of transmission, which were created based on the questionnaire by Iwai et al. [21], and questions about the distance perception from the avatar. Questions Q1 to Q8 were rated on a seven-point scale from "1: Strongly disagree" to "7: Strongly agree", and Q9 was rated on a five-point scale from "1: Too far" to "5: Too close".

The post-experiment questionnaire (Table 3) consisted of questions about the comfortable ranking of the three focal length conditions.

Table 1: Example of comprehension test

	Question
Q1	What was the main character's name?
Q2	After the main character got lost in the forest, who guided her?
Q3	What kind of mission did the main character receive at the lake?
…	…

Table 2: Post-story questionnaire

Question about feeling of transmission	
Q1	Did you feel that you understood the avatar's story well?
Q2	Did you feel that the story was coming from the avatar?
Q3	Did you feel that it was easy to listen and catch the avatar's story
Q4	Did you feel a sense of unity with the avatar?
Q5	Did you concentrate on listening to the avatar's story?
Q6	Was this avatar's story memorable?
Question about distance perception	
Q7	Did you feel nervous and/or pressured during the story telling?
Q8	Did you feel discomfort during the story telling?
Q9	Did you feel that the distance during the story telling was comfortable?

Table 3: Post-experiment questionnaire

	Question
Q1	Please rank the conditions that you feel comfortable during the story telling.
Q2	If you have any thoughts and/or feelings about the content of the story, please write it down.
Q3	If you have any thoughts and/or feelings about the avatar, please write it down.
Q4	If you have any opinions and/or impressions about the experiment, please write it down.

3.0 RESULTS AND DISCUSSION

3.1 Results for all participants

The results of the comprehension tests for each focal length condition showed no significant differences between conditions, and no statistically significant differences were observed.

Figure 3 shows the averages of the responses to Q1 to Q6 (questions related to a feeling of transmission) in the post-story questionnaire for each focal length condition.

For Q4 "sense of unity," the evaluation tended to be higher as the focal length became longer, and there was a statistically significant trend between the conditions. In addition, the average sense of transmission was higher for the 35mm focal length, and there was a statistically significant trend between the 15mm and the 35mm focal length.

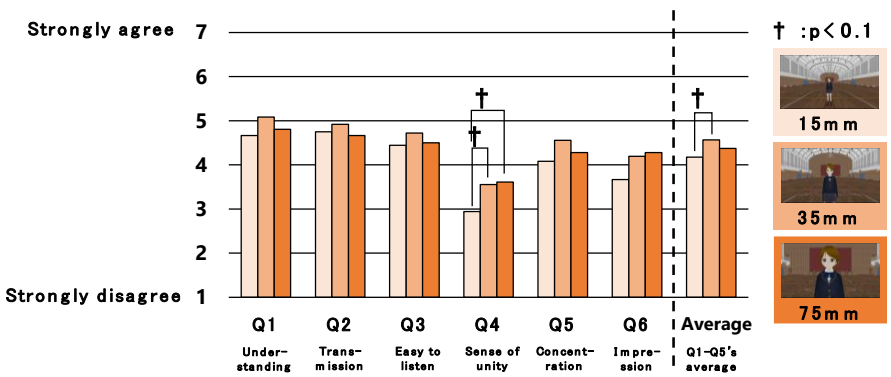

Figure 3: Results of questionnaire regarding feeling of transmission for each focal length condition

Figures 4 and 5 show the average of the answers about the distance perception for each focal length condition. For both Q7 "Nervousness/Pressure" and Q8 "Discomfort", the longer the focal length, the stronger the sense of nervousness/discomfort with the avatar, and there was a statistically significant difference between the conditions. For Q9 "Distance perception", the focal length of 35mm was rated as the most comfortable distance perception, the focal length of 15mm was rated as far away, and the focal length of 75mm was rated as close, and there was a statistically significant difference between the conditions.

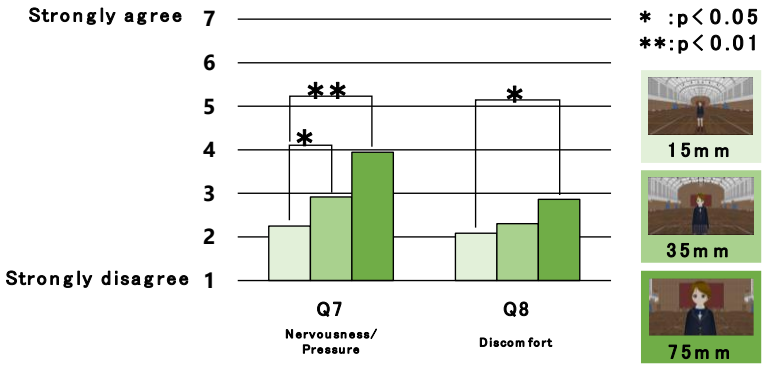

Figure 4: Results of Q7 and Q8 for each focal length condition

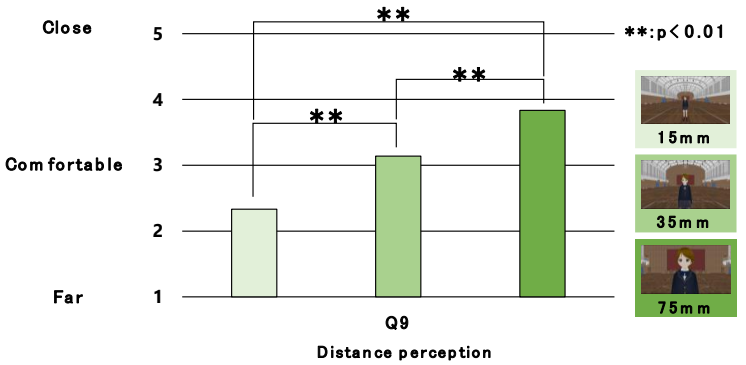

Figure 5: Results of Q9 (distance perception)
for each focal length condition

3.2 Results of classification by P.S.

The relationship between the human's personality and the size of P.S. has been indicated [15-16]. Therefore, in this study, we will investigate the relationship between the size of P.S. and the comfortable distance perception. In addition, in order to realize a communication environment that takes into account the size of the P.S., participants were classified based on the average P.S. measurement value of 6.18m. As a result, 11 participants were classified into the group with a large P.S. and 25 participants were classified into the group with a small P.S. in the VR space.

The results of the comprehension tests for each focal length condition showed no significant differences between conditions, and no statistically significant differences were observed.

Figure 6 shows the average values to Q1 to Q6 (questions related to

feeling of transmission) in the post-story telling questionnaire, categorized by the size of the participant's P.S. Overall, there was a tendency for the 35mm focal length to be rated higher. On the other hand, for the average sense of transmission, Q1 "Understanding" Q2 "Transmission" and Q5 "Concentrate" the group with a big P.S. tended to rate the 15mm focal length higher than the 75mm focal length, while the group with a small P.S. tended to rate the 75mm focal length higher than the 15mm focal length.

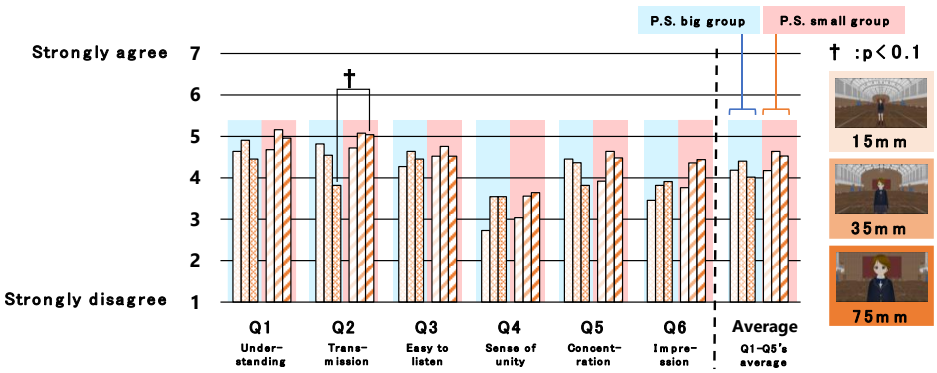

Figure 6: Results of questionnaire regarding feeling of transmission for each focal length condition categorized by the size of the participant's P.S.

Figure 7 and Figure 8 shows the average of the answers about the distance perception for each focal length condition, categorized by the size of the participant's P.S. For Q8 "Discomfort" the group with a big P.S. felt less uncomfortable at a focal length of 35 mm, but the group with a small P.S. tended to feel more uncomfortable as the focal length increased. In addition, there were statistically significant differences and significant trends between the groups at focal lengths of 15 mm and 75 mm. For Q9 "Distance perception" the group with a big P.S. prefer the focal length of 15mm, and the group with a small P.S. prefer the focal length of 35mm.

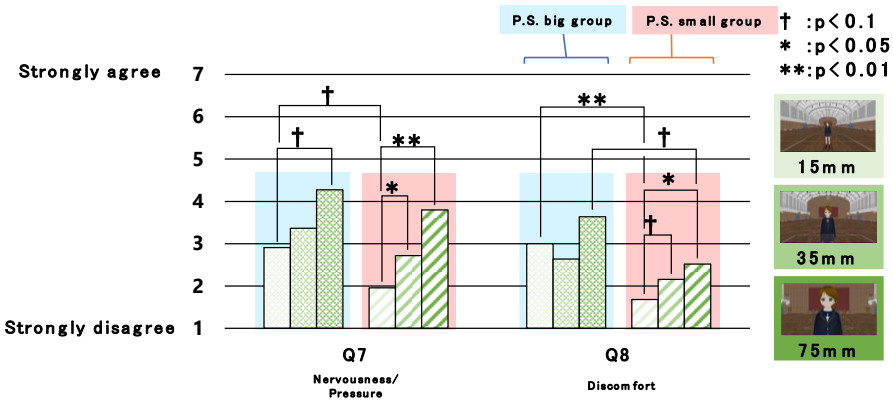

Figure 7: Results of Q7 and Q8 for each focal length condition categorized by the size of the participant's P.S.

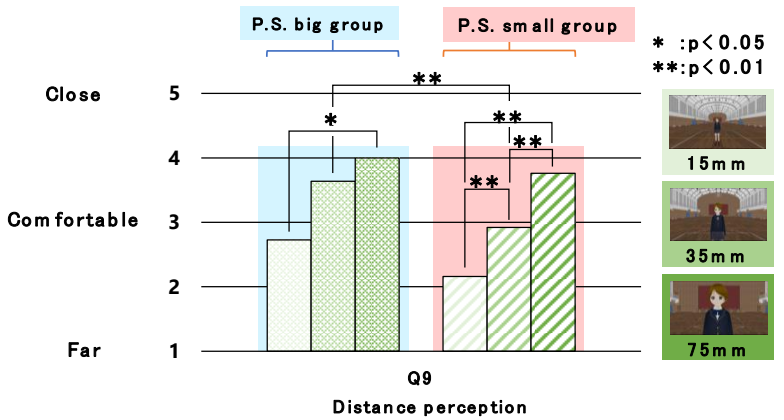

Figure 8: Results of Q9 (distance perception) for each focal length condition categorized by the size of the participant's P.S.

Figure 9 shows the comfortable ranking for each focal length condition, categorized by the size of the participant's P.S. The focal length of 35mm is highly evaluated in both groups. however, the group with a big P.S. prefer 15mm and the group with a small P.S. prefer 75mm by comparing the focal length of 75mm and 15mm.

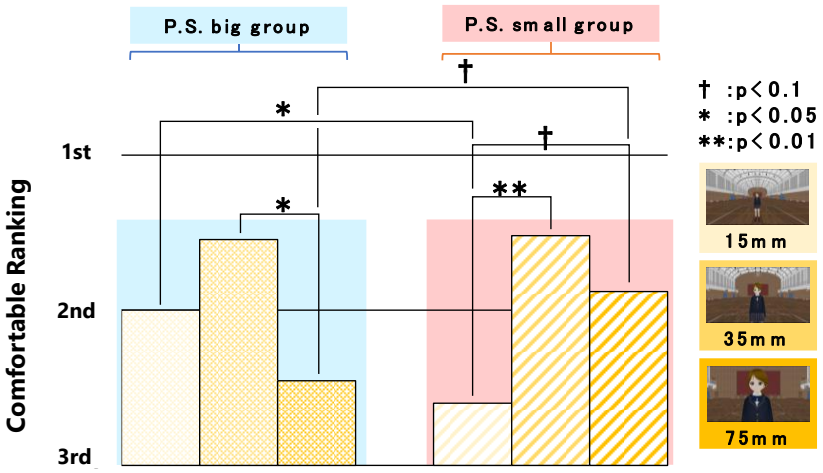

Figure 9: Comfortable ranking for each focal length condition categorized by the size of the participant's P.S.

4.0 CONCLUSION

In this study, we examined the effect of changing the focal length of the viewpoint camera in VR space on the transmission of information from the avatar.

The results of the experiment showed that, in terms of the feeling of transmission and distance perception, participants into the group with big P.S. tended to give a higher rating to a viewpoint camera with a focal length of 15 mm, i.e., a relatively small avatar size displayed on the screen. On the other hand, participants into the group with small P.S. tended to give a higher rating to a viewpoint camera with a focal length of 75 mm, i.e., a relatively large avatar size displayed on the screen.

Based on these results, in the future, in order to realize smooth and comfortable communication in VR space, we aim to introduce a mechanism that allows users to adjust the focal length themselves to achieve a distance perception that they find comfortable. Moreover, we will investigate not only in communication but also in various task situations.

AUTHOR CONTRIBUTIONS

S. Tsuji: Conceptualization, Methodology, Software, Writing- Original Draft Preparation; A. Tatsumi: Supervision, Writing-Reviewing and Editing; M. Okubo: Supervision, Writing-Reviewing and Editing.

CONFLICTS OF INTEREST

The manuscript has not been published elsewhere and is not under consideration by other journals. All authors have approved the review, agree with its submission and declare no conflict of interest on the manuscript.

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