Effects of Modifying the Length of a Virtual Arm on the Interpersonal Distance in Boxing

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概要：The objective of this study is to provide insights into the application of virtual reality (VR) technologies to sports, specifically in boxing. In particular, we investigate the distance between the opponents that enables one of them to hit the other using a fully extended arm to the midpoint of the chest (referred to as the "interpersonal distance"). Initially, a baseline measurement of the interpersonal distance was conducted for each participant. Then, two VR avatars with long and short arms, respectively, were employed inside a VR-based boxing training. After using one of the avatars, we conducted another measurement of the interpersonal distance to investigate possible changes in the perception of the participants to punch their opponent. At a later date the other avatar would also be used. Although qualitative, the results of this study showed that long arms increased the interpersonal distance, whereas short arms did not or slightly affect this distance; additionally, the results indicated how VR can alter this distance. These findings can be useful for future use in the VR training of boxers regarding the interpersonal distance in the boxing ring.

1. Introduction

The use of VR in sports has been continuously increasing. Especially, during the last five years, VR has been effectively used for decision making and perception in sports[1], [2], [3], including the noble art of boxing; seen such VR research; for example, it was discussed how blurry vision affects the performance of elite boxers[4].

Boxers need to make continuous decisions about striking possible punches to their opponent without being punched themselves. The corresponding distance between the opponents is referred to as the "interpersonal distance," which is crucial in boxing. This is defined as distance between the opponents that enables one of them to hit the other using a fully extended arm to the midpoint of the chest.

Research on the effects of modifying the length of a boxer's VR arm has been very limited. Previous studies have investigated the effects of modifying the length of the hand/arm of a VR avatar or environment on human perception[5], [6], [7], [8], [9] in a nonsport case.

The objective of this study is to investigate the effects of modifying the length of a VR arm (either short or long) on participants' interpersonal distance after boxing-oriented interactions with fixed or a moving target in VR. In our investigation, we assumed that participants with long VR arms achieve a longer interpersonal distance in both VR and real life than that achieved by those with short VR arms, as verified by the experiments; this is because their long arms made them believe they could punch their opponent from a longer distance, as reported in previous related studies[5], [6], [7]. Based on this, we can assume the opposite for participants with short VR arms.

2. Method

The experiments were conducted with the approval of the Ethics Committee at the Graduate School of Engineering Science in the University of Osaka (R7-16). A head-mounted display (HMD) (Quest 3 Meta Platforms, Inc.) and an application (app) developed in Unity (Unity Technologies) using OpenVR were used to perform hand tracking. Additionally, we developed an avatar with an easily modified upper-limb size[9]; the app was based on

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this avatar. Initially, 10 participants (7 males and 3 females; age 25.7 ± 2.8 years) attended a lecture about boxing. This lecture was beginner-friendly because most (if not all) participants had zero boxing experience. The theme of the lecture was about maintaining maximum distance (interpersonal distance) while still being able to punch the opponent or target in the case of a virtual environment. The lecture is given by a licensed amateur boxer (registration number: 201424176) officially recognized by the World Boxing Association and NOC*NSF.

Next, by employing the app and the HMD, the participants were assigned to two different avatars, where both their arm lengths (left and right) could be modified by the same amount multiplier. Thus, one of the avatars had a short arm (participant's arm length × 0.8), and the other had a long arm (participant's arm length × 1.2). Initially, each participant used one of the avatars, starting at a random order; at a later date, each participant used the other avatar. Next, each participant was given instructions for using the app and punching the target. Upon punching a target, a short sound was created; additionally, a small change in the color of the target (turning green) indicated that the target was properly punched. Each target was punched alternately via a jab or a straight boxing punch, as these are known range finder punches in boxing, where the arm is fully extended [10], [11], [12]. Ideally, when using these punches, the arms should be fully extended, as taught in the lecture before the experiment.

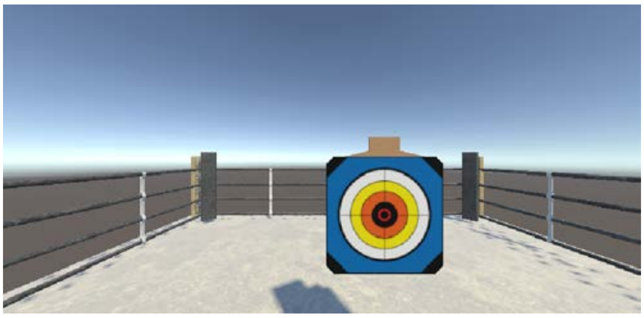

図 1 A target in the virtual environment.

Punching targets (Figure 1) poses two difficulties for the participants: 1) To familiarize themselves with the application environment. This can be relatively easily achieved with fixed (nonmoving) targets that randomly appear on the horizontal axis at 150 cm from the center of the VR environment. 2) To adjust their positioning when punching targets moving from left to right within a 150 cm horizontal range centered on the environment. This can be achieved by setting a random depth, ranging from 30 cm (nearest point) to 150 cm (farthest point) from the center of the VR environment. The height of the targets along the vertical axis should be aligned to the eye height of the participants, ensuring that the targets are always visible. For each target, 1.5 s was allocated before being destroyed. Additionally, participants were instructed to attempt only one punch per target. Figure 2 shows a participant punching a target. Therefore, readjusting for the same target was not intended. The total app time was set to 5 min to allow participants to fully familiarize themselves with their avatar and modified arm length[8].

図 2 Participant punching a target

The interpersonal distance was measured in the real world both before and after the VR avatar experience. The participants determined interpersonal distance without using their own arms, based solely on their perception. The measurement was performed when the participants said "stop," indicating the moment at which they perceived the distance to be the interpersonal distance, while the opponent was gradually approaching. The interpersonal distance was measured (in cm) by drawing a straight line connecting the midpoints of the participant's and opponent's chests.

3. Results

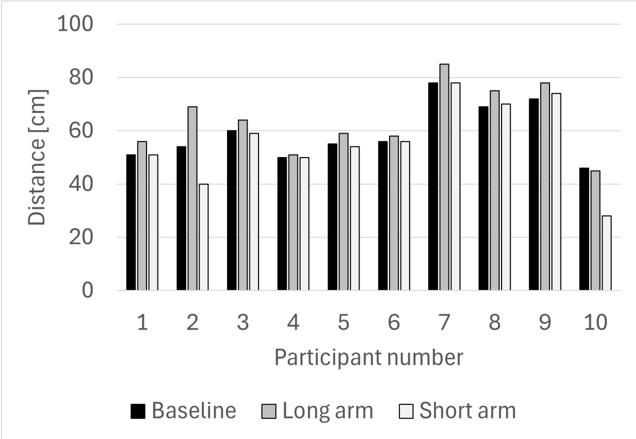

図 3 Measured Interpersonal Distance

Figure 3 shows the measured baseline interpersonal distance before and after the application experience using the two avatars. Below, we provide a qualitative interpretation of these results. The long-arm avatar mostly led to an increased interpersonal distance (compared with the measured baseline distance), making participants believe that they could still punch their opponent. However, the short-arm avatars did not lead to such results. Instead, no or a slight change in the perception of the interpersonal distance was observed in most cases.

In line with our assumption, the results showed an increase in the interpersonal distance for participants with the long-arm avatar. However, this was not the case for participants with the short-arm avatar, where the interpersonal distance was comparable to the measured baseline distance in most cases. These results indicate that the interpersonal distance could be more sensitive to increases in the arm length than to decreases.

4. Discussion

The findings of this study indicate that changing the arm length of an avatar in a virtual environment can change human perception of interpersonal distance. As seen in Figure 3, the perceived interpersonal distance increases compared with the corresponding measured baseline distance for participants with long VR arms.

Short arm avatars do not lead any changes in the interpersonal distance in most cases. This indicates that their interpersonal distance is more susceptible to increases in the arm length than to decreases.

Our results can contribute to the existing literature by demonstrating that even small and subtle changes can significantly affect the real-world interpersonal distance in specific settings such as boxing.

However, several limitations apply when interpreting these results. The number of participants was rather small, which explains why the results were mostly qualitative. In future work, we will increase the number of participants to improve the validity of the results.

5. Conclusion

In this study, we investigated the effect of changing the arm length of an avatar on the user's interpersonal distance in boxing. The results showed that virtually increasing the arm length of participants increased their interpersonal distance to their opponent, making them believe that they could punch their opponent; in contrast, virtually decreasing the arm length did not have any significant effect on the interpersonal distance. This indicates that the interpersonal distance in a boxing setting is more sensitive to increases in the arm length than to decreases. Considering that assessing the appropriate distance is important in boxing, these results could lead to new VR applications for training boxers to improve their perception of their interpersonal distance when punching their opponents. Future research should be based on a sufficient number of participants to enable quantitative and statistical evaluations.

6. Acknowledgment

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