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Investigation of Factors Producing a Sense of Virtual Reality Using Substitutional Reality

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Abstract: Substitutional Reality (SR) is a technology that can render the boundary between the real and the virtual unclear by switching between live and recorded footage. In this research, we examined factors not yet investigated by SR and conducted experiments to investigate their effectiveness in an SR context.As existing research has, in order to standardize conditions, used recorded footage only, we conducted a comparative experiment in order to investigate the effectiveness of existing research, and to investigate whether there was any discrepancy between live and recorded footage. Since the existence of inconsistencies makes it trivial to identify footage as live, and since the human element makes the introduction of inconsistencies inevitable, we also conducted an experiment to investigate the extent of the combined effect communication (which has already been recognized as effective by prior research), inconsistencies, and other factors would have. Finally, as a non-human factor, we conducted an experiment investigating the effect of being made aware of the passage of time.We found that there was not a major discrepancy between live and recorded footage, but the existence of inconsistencies did enable users to recognize live footage. We also found that communication had a comparative larger impact on the user's sense of reality than did inconsistencies or posture. We found that the sensation of the passage of time, conveyed to the subject by "resuming" the footage, has the potential to make the distinctions between live and recorded footage less clear.

Keywords: *substitional reality, virtual reality, head mounted display, communication*

1. INTRODUCTION

Substitutional Reality (SR) is a technology that can render the boundary between the real and the virtual unclear by exchanging live footage and previously-recorded past footage. While VR awaits further developments in video technology to eliminate the discrepancy between the real and the virtual, SR has garnered attention as an alternate method of conveying a sense of reality and presence that does not require advanced video technology.

Prior research shows that cooperative behavior such as deliberately praising one's partner's actions closes the psychological and social distance between people, strengthening the impact of information such as one's partner's movements [1]. Research has also shown that a subject in an SR experience can be made to become accustomed to the "reality" delivered through the HMD by a person repeatedly moving in and out of their personal space between 1.2 and 2 meters from the subject [2]. It is also understood that a backward-leaning posture is read as an "inattentive manner," a forward-leaning posture as an "attentive manner," and standing straight up as a "neutral manner" [3]. As such, in this research, we aimed to investigate the practical value of these factors with regard to their usefulness in SR.

2. DEVELOPMENT ENVIRONMENT

For the VR footage, we used Unity 5 to apply panoramic footage to the inside wall of an orb. Viewing this footage from the center of the orb provided a realistic 360-degree view. The HTC Corporation's VIVE Pro HMD VR headset was used to display the VR image, while the 360-degree panoramic footage was photographed using the Ricoh Theta S camera.
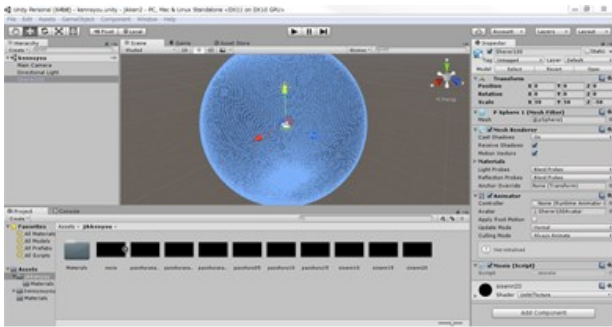
Figure 1: Screen of the development environment

3. COMPARATIVE EXPERIMENT OF LIVE AND RECORDED FOOTAGE

3.1 Experiment overview

Prior research indicates that the closing of psychological/social distance due to cooperative behavior has low potential to convey a sense of reality. It also indicates that the feeling of eye contact, as well as entering a subject's personal space, up to a distance of 0.5m away, while waving, has the potential to convey a sense of reality. Finally, we understand that adding communication enables us to convey a greater sense of reality [4]. However, since this research, in order to standardize the participants' conditions, only tested with recorded footage, and since SR technology involves switching between live and recorded footage, it is necessary to investigate the combination of both types of footage. We thus conducted this comparative experiment to investigate whether any discrepancy existed in the effectiveness of factors shown to be effective by prior experiments when used in our research environment, with both live and recorded footage.

3.2 Eye contact preliminary experiment

We conducted a preliminary experiment investigating the impact of the movement of the eyes and other factors on the feeling of eye contact, as well as what would constitute an appropriate distance for our experiment environment. We found that the action that created the sensation of eye contact was moving the face and eyes in the same direction simultaneously, while a distance of under 1m would allow for the movement of the eyes alone to suffice.

3.3 Methodology

The participant wore the HMD and headphones, and judged whether the footage was live or recorded. White noise was played into the headphones, so that the participant could not judge from the presence of absence

of footsteps or other sounds.

The people appearing in the footage were both men and women. The actions they performed were holding eye contact, conducted at a distance of 1m (the distance judged to be effective by prior research), and repeatedly (either 3 or 5 times) entering and retreating from the participant's personal space, at a distance of 0.5m. So that participants could not judge from the number of repetitions, all possible permutations were carried out for both live and past footage, resulting in a total of 18 combinations.

Figure 2. Image of the HMD being worn

3.4 Results and considerations

Of 18 trials, in 11 trials the difference in number of participants who believed the footage to be live vs. those who believed it to be recorded was less than 10%. Among those, in 6 trials over 50% of participants responded "don't know." This result indicates that there were no major discrepancies between live and recorded footage.

Among the trials using live footage, in 3 trials there was a major bias towards evaluating the footage as live. Reasons given included "the distance is close" and "they seem used to doing this," indicating that the cause was slight variations in movements in each trial, resulting in inconsistencies.

4. EXPERIMENT INVESTIGATING THE PRESENCE/ABSENCE OF COMMUNICATION AND INCONSISTENCIES

4.1 Experiment overview

We understand that the occurrence of inconsistencies makes it easy to identify live footage, thus making this a component of differentiating between live and recorded footage. However, the human element makes a certain

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amount of inconsistency unavoidable. We therefore conducted an experiment to investigate to what the extent of the combined effects of communication (judged to be effective by prior experiments) and inconsistencies would be.

4.2 Experiment Methodology

The experiment was conducted in the same manner as the preceding experiment. Trials were divided into three. In the first, "Presence/absence of communication," images of a person walking in front of the participant were shown, either making eye contact or not, and waving or not. In the second, the new factor of good/bad posture was introduced, with participants shown images of a person sitting in a chair in front of them, demonstrating either good or bad posture. In the third, we deliberately introduced inconsistencies by showing the participant three sets of footage of a person waving their hand, in which the start of the wave was delayed each time. Each trial was conducted 3 times in different permutations of live/recorded footage, resulting in a total of 27 different combinations.

4.3 Results and considerations

Participants were asked to evaluate their impressions on a 5-point scale where 1 represented "Recorded" and 5 "Live." Among the Communication group, 7 trials showed a small difference of 10% between the proportion of those who evaluated the image as live vs. those who evaluated it as a recorded image, a smaller difference than the other groups. The average value was 3.04, tending towards "Live," indicating that most participants felt the images were live.

Among the Posture group, 3 trials showed a difference of over 30%, while among the Inconsistency group, 7 trials showed a difference over 30%; a major difference. Both the Posture and Inconsistency groups also showed a bias in favor of participants being able to recognize whether an image was live or recorded, with the majority of participants able to do so. Accordingly, this indicates that communication is more effective factor than either posture or inconsistency in conveying a sense of reality.

5. EXPERIMENT INVESTIGATING AWARENESS OF TIME

5.1 Experiment overview

Our previous experiments investigated factors relating to the human element. However, since participants also pay attention to surrounding factors other than humans, we turned our attention to non-human factors, investigating the effectiveness of factors which convey an awareness of the passage of time.

5.2 Experiment Methodology

We used an hourglass, a stopwatch, and a display as objects to stimulate an awareness of time. The footage was divided into a first and second half, divided by a momentary blackout. In the same manner as the previous experiments, participants were asked to determine whether both the first and second halves of the video were live or recorded.

The contents of the footage showed a video being displayed on the display, and the hourglass and the stopwatch being started. When the stopwatch had ran for one minute, the video and the stopwatch were paused. The latter half of the footage was the same, except that the video on the display was adjusted to appear as if it had just been unpaused. We also conducted trials in which the stopwatch and hourglass were started without dividing the video in half. In order to check if personal space had an effect, we carried out the experiment from distances of both 0.5m and 1m. Four permutations of live and recorded footage for the first and second half, plus both live and recorded undivided footage, and two different distances produced a total of 12 combinations.

5.3 Results and considerations

Participants were asked to evaluate their impressions on a 5-point scale where 1 represented "Recorded" and 5 "Live." The average values were 3.005 for the 0.5m group and 3.060 for the 1m group; both close to 3. In the trials in which the footage was not divided into halves, participants correctly identified whether a footage was live or recorded in 40% of cases; a low number. These results indicate that it was difficult to differentiate between live and recorded footage.

When giving reasons for their judgements, some participants felt that the first half of the video had been recorded, while the second half was a live video manipulated to appear as if the video on the screen had just been unpaused. Some participants also felt the reverse. We also received responses stating that the repetition of the action of pausing the stopwatch as the hourglass ran out, as well as the video on the display appearing to continue from the first half, conveyed a sense of the footage being live. These results indicate that by conveying an impression of the passage of time to the participant by using a video that appears to "resume" its playback, the boundary between live and recorded

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footage can be obscured.

Table 1: Average value of 5 grades for each distance

distances	average (SD)
0.5m	3.005(1.190)
1.0m	3.060(1.325)

6. CONCLUSIONS AND FUTURE ISSUES

6.1 Experiment overview

In this research, we searched for factors which could cause a virtual world to appear real in SR, and conducted experiments to investigate their practicality. We found that there was not a major discrepancy between live and recorded footage, but that the presence of inconsistencies did aid in determining that footage was live. We also found that communication was a more powerful factor than either posture or inconsistencies in conveying a sense of reality. Finally, we found that conveying an impression of the passage of time to the participant by using video that appears to "resume" its playback has the potential to obscure the boundary between live and recorded images.

Owing to the involvement of a number of factors not dealt with by this study, such as the impact of the video quality and sounds of the testing environment, the impact of the degree of intimacy between the person appearing in the video and the participant caused by differences in personal space, etc., there is a need to conduct experiments that eliminate these factors, and to test the extent of these factors' influence themselves. It is also necessary to devise new experimental methods in order to investigate whether this technology can be adapted to concepts that do not exist in reality (e.g. cartoon characters, etc.).

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