VR-Replay: Capturing and Replaying Avatars in VR for Asynchronous 3D Collaborative Design

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ABSTRACT

Distributed teams rely on asynchronous CMC tools to complete collaborative tasks due to the difficulties and costs surrounding scheduling synchronous communications. In this paper, we present VR-Replay, a new communication tool that records and replays avatars with both nonverbal behavior and verbal communication in VR asynchronous collaboration. We describe a study comparing VR-Replay with a desktop-based CVE with audio annotation and a VR immersive CVE with audio annotation. Our results suggest that viewing the replay avatar in VR-Replay improves teamwork, causing people to view their partners as more likable, warm, and friendly. 75% of the users chose VR-Replay as the preferred communication tool in our study.

Index Terms: I.3.7 [Computer Graphics]: Three-Dimensional Graphics and Realism—Virtual reality;

1 INTRODUCTION

Temporal and geographic dispersion in distributed team can complicate communication, as the nonverbal behaviors available in face-to-face interactions are absent. Despite that fact that collaborative virtual environments (CVEs) enable distributed team members to work together synchronously or asynchronously, to date, much of the work in CVEs has been dedicated to real-time collaboration [3, 4]. Some CVEs [1, 2] do allow people to create and view text, audio or video annotations, either on desktop or in virtual reality (VR), which can aid asynchronous communication. However, these methods do not capture nonverbal information that could contextualize speech. Thus, we present VR-Replay, a new communication tool in VR that records and replays avatars with both nonverbal behavior and verbal communication.

We designed a 1x3 within-subject study with 20 dyads to investigate participants' reports of perceived outcome, performance satisfaction, quality of communication, perception of the partner and user experience. As shown in Figure 1, the task for participants was to collaborate with their partners asynchronously to place furniture in a room. In a random otder, they used three communication tools" (1) Desktop-Audio, a desktop-based CVE with audio annotations, (2) VR-Audio, a VR immersive CVE in which participants placed the furniture using embodied avatars and made audio annotations, and (3) VR-Replay, where participants' used avatars to place the furniture, and both their avatar movements and audio comments were recorded and replayed.

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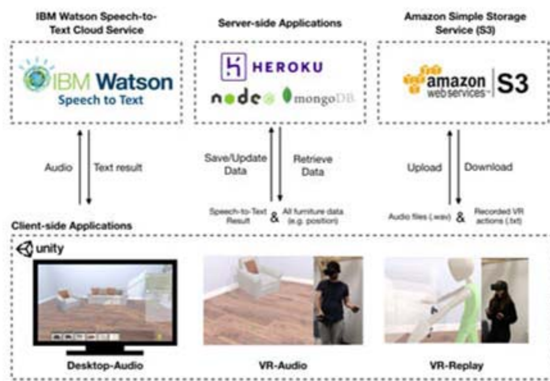

Figure 1: Prototype implementation under client-server architecture

2 PROTOTYPE IMPLEMENTATION

To support asynchronous collaboration, prototype implementation was constructed under a client-server architecture as shown in Figure 1. We developed 3 client-side applications using Unity for each study condition including Desktop-Audio, VR-Audio, and VR-Replay. The Desktop-Audio application allows users to place furniture by controlling the transform gizmo with the mouse and keyboard. Both the VR-Audio and VR-Replay applications enable users to control full body avatars, move around in the virtual rooms by teleporting, and use a grab-and-drop interaction to move furniture. All applications recorded the users voice message and upload it to the Amazon S3. In addition to audio recording, the start and the end state of the virtual room are saved in the server database. When users replay the messages through Desktop-Audio and VR-Audio applications, the application loads the saved state of the virtual room and replay the recorded audio message. In the VR-Replay application, it also captured headset and controller movement and controller button presses. When replaying the message through VR-Replay application, the application downloads the recorded VR actions data from Amazon S3 and uses it to animate an avatar in the current virtual environment. Thus, users can view every recorded action of their partners (teleporting in the virtual room, placing furniture, pointing, nodding, etc.)

3 STUDY DESIGN

We recruited 40 participants (19 female) with a mean age of 19.4 years (SD = 1.6) for a within-subject study. We explored how different conditions affected participants' reports of performance satisfaction, quality of communication, perception of others and user preference when using the three asynchronous communication tools for 3D collaborative design. During the study, participants were randomly assigned to dyads and conditon. The order of the condition and the virtual rooms used were counterbalanced. Participants had

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Table 1: Results from ANOVAs and pairwise contrasts with Bonferroni corrected for the multilevel model of each question in the survey.

Category	Factor	ANOVA Result	Post-hoc
Outcome Satisfaction	Satisfied with the outcome	$F_{2,78} = 1.18, p = 0.3133$	No significance
	Outcome show your own input	$F_{2,78} = 3.33, p = 0.04$	VR-Replay > Desktop-Audio
	Feel committed to the outcome	$F_{2,78} = 10.16, p < 0.001$	VR-Replay > VR-Audio, Desktop-Audio
	Outcome is the best it can be	$F_{2,78} = 0.26, p = 0.769$	No significance
	Responsible for the outcome	$F_{2,78} = 5.60, p = 0.005$	VR-Replay > Desktop-Audio
Performance Satisfaction	Efficient	$F_{2,78} = 8.31, p < 0.001$	VR-Replay > VR-Audio, Desktop-Audio
	Coordinated	$F_{2,78} = 5.96, p = 0.003$	VR-Replay > Desktop-Audio
	Fair	$F_{2,78} = 4.81, p = 0.01$	VR-Replay > Desktop-Audio
	Understandable	$F_{2,78} = 10.31, p < 0.001$	VR-Replay > VR-Audio, Desktop-Audio
	Satisfying	$F_{2,76} = 14.28, p < 0.001$	VR-Replay, VR-Audio > Desktop-Audio
Clarity of Communication	Better understand each other	$F_{2,78} = 26.58, p < 0.001$	VR-Replay > VR-Audio > Desktop-Audio
	Easier come to an agreement	$F_{2,78} = 19.37, p < 0.001$	VR-Replay > VR-Audio > Desktop-Audio
	Speed up communication	$F_{2,78} = 9.53, p < 0.001$	VR-Replay > Desktop-Audio
	Easier share your opinions	$F_{2,78} = 13.287, p < 0.001$	VR-Replay > VR-Audio, Desktop-Audio
	Easier explain things	$F_{2,78} = 11.837, p < 0.001$	VR-Replay, VR-Audio > Desktop-Audio
	Exchange communications quickly	$F_{2,78} = 4.79, p = 0.01$	VR-Replay > Desktop-Audio
Perception of partners	Likable	$F_{2,78} = 11.58, p < 0.001$	VR-Replay > VR-Audio, Desktop-Audio
	Kind	$F_{2,78} = 7.70, p < 0.001$	VR-Replay > Desktop-Audio
	Friendly	$F_{2,78} = 6.11, p = 0.003$	VR-Replay > Desktop-Audio
	Warm	$F_{2,77} = 7.37, p = 0.001$	VR-Replay > Desktop-Audio
	Fair	$F_{2,78} = 8.02, p < 0.001$	VR-Replay > Desktop-Audio
	Honest	$F_{2,78} = 4.38, p = 0.01$	VR-Replay > Desktop-Audio
	Trustworthy	$F_{2,78} = 8.66, p < 0.001$	VR-Replay > VR-Audio, Desktop-Audio
	Sincere	$F_{2,78} = 8.10, p < 0.001$	VR-Replay, VR-Audio > Desktop-Audio
	Intelligent	$F_{2,78} = 1.24, p = 0.2945$	No significance

15 minutes for the task in each condition. After completing each condition, participants filled out a survey containing questions in four categories, shown in Table 1. The researcher also performed an interview with both participants individually at the end of the experiment.

4 Discussion and Results

Using the SPSS package, multilevel modeling (MLM) was utilized to account for the nonindependence of the dyad data in each pair. ANOVA and pairwise contrasts with Bonferroni adjustments were conducted with the MLM model. These results are summarized in Table 1. These results show significant differences in all factors of performance satisfaction and clarity of communication categories. This suggests that viewing the replay avatar in VR-Replay improves participants' perceptions of teamwork over both VR-audio and Desktop. P1 stated that "(In VR-Replay) ... while she was trying to put the bed, I can know where she looked at and she explained her thoughts during the recording so it really helps me to understand her decisions." Furthermore, VR-Replay can better help participants understand each other, come to an agreement and share opinions than other 2 conditions. P10 commented, "I prefer to use the VR especially the one with the animation (VR-Replay). It encourages me to describe my thought process with my gestures so I think it can improve the communication." In terms of perception of partners, VR-Replay got the highest score which is signicantly higher than Desktop-Audio in positive perceptions including likable, kind, friendly, warm, honest, trustworthy and sincere. We interpret these results to support that people tend to have stronger positive feelings about their own actions and their partner when they're able to see each others' nonverbal cues during an asynchronous communication. Our results also shows that 75% of participants chose VR-Replay as their preferred asynchronous communication tool for 3D collaborative design, while 18% chose VR-Audio and 8% chose Desktop-Audio.

5 Conclusion and Future Work

In this paper, we present VR-Replay, a new asynchronous communication tool in VR for 3D collaborative design. With VR-Replay, a team member can record his/her voice and avatar behavior, which preserves both verbal and nonverbal cues. Then other team members can replay and view the recorded avatars perform every recorded action along with the audio messages. According to our results, compared with VR-Audio and Desktop-Audio, VR-Replay has significant differences on perceived performance satisfaction, clarity of communication and perception of the partner. However, the current prototype implementation and study has some limitations that should be addressed in the future. Our study examined a particular context in which users place furniture in a shared visual environment and we only measured participant's self-reported, subjective experience. Thus, we cannot compare actual task success between conditions. Further research which analyzes the objective effectiveness of each communication tools is needed to further explore the potential of this tool.

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