Reality Jockey: Lifting the Barrier between Alternate Realities through Audio and Haptic Feedback

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ABSTRACT

We present Reality Jockey, a system that confuses the participant's perception of the reality by mixing in a recorded past-reality. The participant will be immersed in a spatialized 3D sound environment that is a mix of sounds from the reality and from the past. The sound environment from the past is augmented with haptic feedback in cross-modality. The haptic feedback is associated with certain sounds such as the vibration in the table when stuff is placed on the table to make the illusion of it happening in live. The seamless transition between live and past creates immersive experience of past events. The blending of live and past allows interactivity. To validate our system, we conducted user studies on 1) does blending live sensations improve such experiences, and 2) how beneficial is it to provide haptic feedbacks in recorded pasts. Potential applications are suggested to illustrate the significance of Reality Jockey.

Author Keywords

Substitutional Reality; Haptic; Spatial Sound; Cross-Modality; Illusion

ACM Classification Keywords

H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

General Terms

Design; Human Factors;

INTRODUCTION

Ever since the human civilization began, we humans have sought many ways to leave traces of our lives. We have this ambition because we would like to treasure our memories that happened at a different time and place. For example, every parent would surely like to go back to the moment that the child first walked. Imagine if we can save all those cherished moments, and re-experience them any time we want as though they are happening right around us. Those moments are all realities that once happened, and yet they do not exist right here and now, therefore, we call them the "alternate realities."

Figure 1. The participant perceives the experimenter from the past is the actual reality as she talks with the experimenter.

The ambition of interacting with or re-experiencing the past may come from wanting to have a conversation with oneself from the past [11], or from wanting to see the historical view of renowned places [7]. These ambitions are best achieved with an idea popular in literatures, the time machine. With current technologies, it is not yet physically possible; however, we can create such kind of illusion that enables the users to re-experience the past with immersion, as though the past events are happening again.

Our memories from the past play an important role in our present lives and have impact on our decisions for the future. Re-experiencing the pleasant past memories could give us pleasure. As Csikszentmihalyi stated "…to remember the past is not only meaningful in order to create and maintain your personal identity, but it can also in itself

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be a very pleasurable activity." and "It makes it possible to choose and in our memory keep events that have been particularly pleasant and meaningful and thereby 'create' a past that helps us to deal with the future [5]." Therefore, we see our research goal to remove the barrier between alternate realities, which may lead to an immersive re-experiencing of the past, has a high value in our lives.

Our goal, therefore, is to develop a system that erases the barrier between "the past" and "the present", so that the participants would not regard recorded past as being simply "the past". The "past", in this case, is a recorded subset of everything that has happened up to now, and we will refer these "recorded past", which we choose to record because they are closely related to our personal lives, as "past reality" through this paper. We want to achieve that when we re-experience these recorded past reality in the future, we would perceive them to be happening again at that time and not feel awkward about the sudden emerging of the past reality. To achieve that, the users have to be tricked into losing their conviction about reality, that is, they have to lose their sense of time and space, and doubt what portion of the sensations they are experiencing is "real", so that they will perceive the past as the actual reality (Figure 1). As a result, the alternate realities could gradually fade into the present seamlessly, and users can relive their memories or other people's experiences vividly as though they are happening at the present moment. In achieving that, the illusion of the past reality happening again is presented to the participants.

The idea of being able to manipulate one's mind through the act of presenting alternate realities has already been proven by Suzuki et al. and their Substitutional Reality (SR) System, which is visual-sensation based [17]. We intend to build on their idea, and suggest that with the addition of immersive 3D spatial sound environment and haptic feedbacks, we could add great values to the whole SR experience and the participants are more likely to believe the recorded alternate realities to be happening live.

The system we have developed is called "Reality Jockey." It is a lightweight, mobile, immersive VR system that blends or alternately presents the sounds from the past and the sounds from the present to the participant. Sounds from the past scene are augmented with haptic feedbacks to further strengthen the sense of they happening in the reality such as the vibration on the table associated with recorded sounds of something being placed on the table. We mix the live scene and the past scene so the whole experience can be interactive. For example, during experiencing the past the user might ask a question, then the user would get appropriate response because live events are also presented.

Reality Jockey consists of a noise-cancelling headphone, a motion sensor, a USB audio interface, an equalizer, an amplifier, a tactile sound transducer, a binaural microphone embedded dummy head, and a contact microphone. The equalizer and amplifier are needed to power and play the desired frequency range of conduction sound in the tactile sound transducer that generates the haptic feedback.

Our system has intentionally left out the visual component in the VR experience. The reason is that we humans rely on our visual sensation the most, and yet we can form vivid images of our surroundings in our mind with our eyes closed when stimulated by other sensations such as hearing, touch, taste, and smell. Researches have shown that audio sensation alone can provide a self-motion illusion to the participant [9]. Riecke et al. further stated that audio along with haptic feedback in cross-modality can strengthen the sense of such illusions [15]. This proves that audio and touching sensation are important factors in how humans perceive the events that are happening around them and they can fabricate images and experiences in their head even when visual sensation is not available to them.

In essence, our system has to be an immersive virtual reality system for the users to believe in their presence both in the live and in the past. Tachi stated three fundamental elements of virtual reality: 3D space, real-time interaction, and self projection [18]. These elements make a virtual experience immersive. In our system, we address each of these elements accordingly. The user constructs the vivid 3D space from imagination; real-time interaction is achieved by blending the live feedbacks; self projection is intuitive because the user thinks everything is happening in live.

We conducted user studies to validate our system on 1) does blending live sensations make participants to perceive the past reality to be live more easily, and 2) how beneficial is it to provide haptic feedbacks in the recorded alternate realities.

Our work to develop a system that erases the barrier in time and space pays tribute to the Turing Test [21]. We aim to create an immersive experience to the participants so they would believe every interaction they make with the system is indeed real, even though it may be computer-generated past realities. Our research has the following significances.

- A system that lifts the barrier between alternate realities has been developed. The approach is to blend sensations from alternate realities and transition between them seamlessly.
- We suggest that having realistic audio and haptic sensations in the alternate realities can make a better illusion of them happening in live.
- Our user studies revealed how humans can believe something that is not happening to be real.
- Potential applications that can be achieved with our system were conceptualized.

RELATED WORK

Our research builds on the following research areas. They are 1) confusing the conviction about reality, 2)

substitutional reality, 3) HCI communication systems, and 4) audio and haptic sensations in VR systems.

Conviction about Reality

There are many researches regarding how human perceives the reality and how they act when they lose their conviction about reality. The rubber hand illusion phenomenon suggests that people can actually believe a rubber hand to be their own hand when stimulated long enough with visual and haptic sensations [2]. Roediger et al. states that people can remember things that never happened [16].

The participants have to be first confused in their conviction about reality in order for the alternate reality, be it from the past or from remote venues, to sink in and seem happening right here and now. Reality Jockey implements a similar method suggested by Suzuki et al. and their SR System, which aims to aid the researches in neuroscience by alternately presenting the past scene and the live scene to the participants [17]. The SR system focuses on the visual perception and uses panoramic videos recorded in the past. Therefore, it has the pitfall of having to restrict the exact place of where the system is used; otherwise the live scene and recorded scene would look completely different. Also the participants are prohibited in certain movements such as looking at themselves because they would not see their own body in the recorded scenes. Our system, on the other hand, can be installed anywhere and permits full movement to the participants' head with the help of motion sensing.

Substitutional Reality

Superimposing an alternate reality from the past on the live reality has been a popular topic for performance arts. The Mirage project superimposes images of the dancer from the past in the real world where the live dancer dances [13]. Iwai designed a performance that captures live video images of the attendees, and then manipulate them to create time-lapse, slow motion effects [8]. Inspired by the above work, Takeuchi et al. created PRIMA, a system that provides interaction between the participant in the present time and the people in the past time in the same place [19].

The goal of our research is similar in concept. We aim to create the illusion that the past events are happening vividly again through substitutional reality. Our work addresses an issue that the previous works lack by constructing an immersive audio environment and providing haptic feedback, a key component in realism.

HCI Communication Systems

The Turing Test suggests a method to measure if a computer can imitate a real human being and thus demonstrating machine intelligence [21]. Weizenbaum developed ELIZA, a computer program that acts the role of a psychotherapist and responds to the user's typing to provide the illusion that it is a human being [22]. Colby et al. also created a similar system, PARRY, that takes the role of a paranoid patient [4].

Both ELIZA and PARRY aim to demonstrate that when humans interact with a computer, it is possible for them to be immersed in an illusion that they are chatting with a real person. Our system takes a similar concept of aiming to create an illusion during the communication and interaction of the participants and the system that everything is the reality. Whereas the previous works used text-based communications, our focus is on verbal and tactile communications.

Audio and Haptic Sensation

Up until now, VR systems have mainly focused on one out of the human's five senses, the visual. It has been the tradeoff between interactivity and realism. However, realism of a VR system can be greatly increased if we have at least two sensation feedbacks in cross-modality [3]. Law et al. have developed a multi-modal interactive floor that includes visual, audio, and haptic sensations [10]. However, their focus is only on the interactive floor as all the sensations come from it. Our system addresses the whole environment surrounding the participant.

3D sound has been proven to be an important factor in virtual environments [1]. Naef et al. developed a spatialized audio rendering system that utilizes many speakers [14]. Our system aims for compactness by using a headphone, and we add haptic feedback.

It has been proven that realistic haptic feedbacks can be generated from sound. Minamizawa et al. have developed TECHTILE toolkit, an easy-to-use haptic device that can generate realistic haptic feedbacks through either playing recorded sounds or streaming live sounds to the haptic reactor [12]. We therefore use a similar concept in generating haptic feedbacks in real-time from recorded sounds.

In Reality Jockey, we construct a spatialized sound environment and add haptic feedback in cross-modal effect. For example, the participants would feel the realistic vibrations on the table when they hear something is placed on the table.

THE REALITY JOCKEY SYSTEM

Reality Jockey is a VR system that erases the barrier between the reality and the alternate reality that happened at a different time and space. We do so by immersing the participants in an environment with audio and haptic

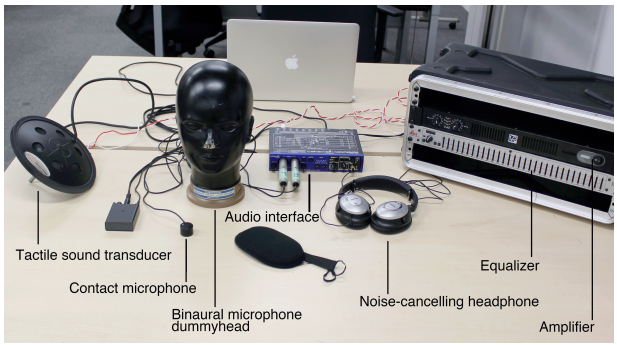

Figure 2. The Reality Jockey system.

feedbacks. The audio feedback consists of a spatialized 3D sound system that plays back a recording of the past sounds such as conversations between people and environment sounds. The 3D sound system mimics the source where the sounds would be actually coming from if the participant were placed in the same environment as to provide an immersive audio component in our VR system. The audio component is augmented with haptic feedback associated with certain sounds. The key point in providing a sense of "being there" in the past is the seamless transition between the live reality and the past reality. We continuously blend or alternate between the realities to confuse the participants in their conviction of true reality.

Overview

The Reality Jockey system (Figure 2) consists of a noise-cancelling headphone (Bose QuietComfort 15), a motion sensor (ATR-Promotions TSND121), a USB audio interface (Cakewalk UA-101), an equalizer (DBX Graphics Equalizer 131), an amplifier (Classic Pro DCP800), a tactile sound transducer (Clark Synthesis TST239), a binaural microphone embedded dummy head (Kenwood DH-67), and a contact microphone (Sun Mechatronics MW-22). The USB audio interface expands the number of inputs and outputs to the PC's sound interface, and the microphones, headphone, and transducer connect to it. The equalizer cuts off the sound in the high frequency range and only sends low frequency sounds (<400 Hz) that symbolize the conduction sounds of the vibration recorded with the contact microphone. The amplifier powers and amplifies the sounds sent from the equalizer and sends them to the tactile sound transducer, as it needs external power. The tactile sound transducer is fixed on a wooden table, and it generates haptic feedback to the participant's hands. The dummy head, with binaural microphone embedded, can record and also stream live spatialized sound; the participants then hear the 3D spatialized environment sound from the headphone. To compensate for the possible movement of the participant during the usage of the system, we use the motion sensor so that when, for example, the participants turn their heads the sound sources would stay in their original places as to provide a realistic real-world sound environment.

Design

Reality Jockey aims to lift the barrier in time and space. Our method to do so is to present both the reality and the past to the participants and continuously alternates between the two. The switching is intended to be done seamlessly so the participants would then begin to lose track of which is the live reality, and therefore would believe that the past is actually happening right here and now.

Our approach is to only consider audio and haptic sensations and investigate the cross-modal effect. Since our goal is to mix live and past realities, and gradually fade into the past, we have to reduce the presence of the live reality, and increase the presence of the past reality. The easiest and most intuitive way of doing so is to simply close our eyes. Without visual sensation, our minds are free to create images of the surroundings that may not be the actual reality. For example, people tend to close their eyes while listening to fantasy stories to imagine actually being in those virtual worlds. Therefore, we have excluded the visual component.

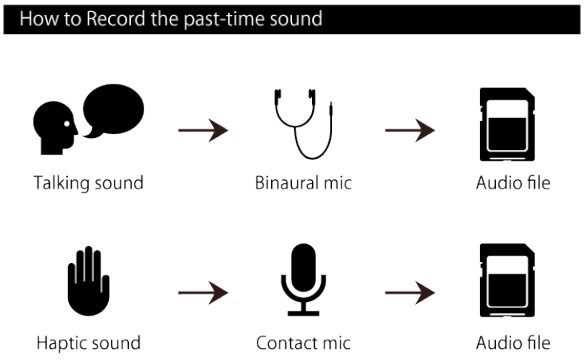

Figure 3. Recording is divided into two tracks.

The haptic sensations involved in our system are implicit. We consider these implicit haptic sensations, such as the vibration in the table when stuff is put on it, because these sensations are natural. They are regarded as part of our everyday lives so having them greatly increases the realism of virtual experiences.

We will separate the design of the system into the recording phase, where we discuss how we record the past scene contents to be experienced by the system, and the experiencing phase, where we discuss how we blend and substitute realities and present them to the participant.

Recording phase

Reality Jockey substitutes in an alternate reality from the past. Therefore, it is crucial how we do the recording of the sounds in the past. Since we would like to provide audio and haptic sensations in cross-modal effect, we have to record the sounds in two different tracks: one for the general environment sound that we humans realize in everyday life, and one for the conduction sound associated with the vibration in materials (Figure 3).

We humans can perceive sounds coming from particular point source or direction thanks to how our heads and ears are shaped. The acoustic signals are modified and received at each ear differently according to the head-related transfer function (HRTF). To simulate how a human head receives sound signals and thus recording it, we use a dummy head that has one microphone embedded in each of the ears. The two sound channels recorded using such a method, when played together, will produce realistic binaural sounds that are the same as though we are hearing it with our ears in real time, and thus we can identify where the sound is coming from.

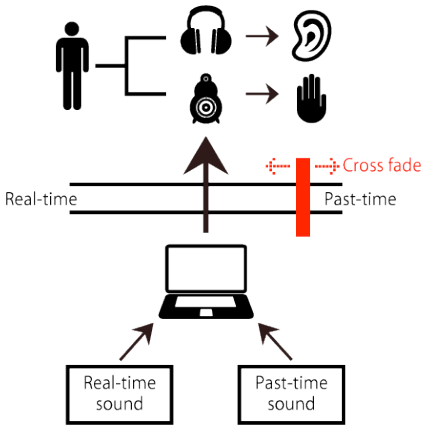

Figure 4. The participants experience the blending of real and past.

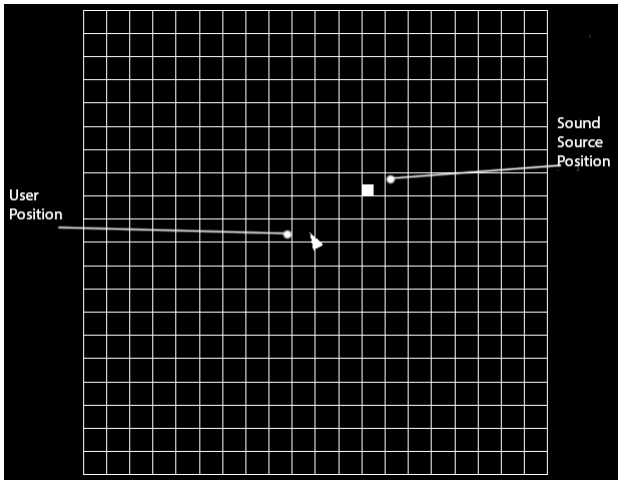

Figure 5. PC side user interface. Visualizes the participant's position (triangle) and allows real-time addition of virtual sounds sources if needed (square).

To record the vibrating conduction sounds that will later be played through the tactile sound transducer to mimic vibrations in real time, we attach the contact microphone on a table made of materials that allow easy vibration such as wood. The contact microphone will pick up conduction audios caused by the vibrations as people interact with the table.

Experiencing phase

To confuse the participants in their conviction about reality so that they begin to doubt what portion of the sensations they feel is the true reality, we blend and alternate the live reality and past reality and present them to the participants with audio and haptic feedbacks (Figure 4). The seamless transition between live scene and recorded scene is the key factor that immerses the participants in a reality that is both the present and the past.

Our system plays the recorded sound to the participants though the noise-cancelling headphone. To manipulate where the recorded sound would be coming from in a spatialized sound environment as to provide a realistic feeling, we developed a program with FMOD Ex Programmer's API [6]. The simple user interface allows us to do simple click-and-drag movements of the sound sources so they can move around the participant if the recorded audio is not binaural (Figure 5). The program also takes as an input the motion sensor readings to determine if the participants have moved their heads, and adjust the sound environment accordingly. The participant's position and head orientation is also indicated by the triangle.

The audio vibration to the feet is played in a separate track to the tactile sound transducer, which is fixed on the same type of table used in the recording phase. The recorded conduction sound first goes through the equalizer to be filtered so that only frequencies of 400 Hz and less are transmitted to the tactile sound transducer. This step is necessary because during the recording phase, the contact microphone does not only record the low frequency conduction sounds, but will also record high frequency environment sounds. Once the desired frequency range is filtered, the sound signal is sent to the amplifier to be amplified so that when the tactile transducer plays the sound, the vibration is a close approximation to what the participants would feel if a real person actually touches the table or something is placed on the table. The audio vibration is played in sync with the environment sound played in the headphone to make the transducer generate vibrations at the exact timing to mimic as if the interaction with the table happens in real time and not in the past.

Aside from playing sounds from the recorded scene, we blend in the sounds from the live scene. The same dummy head used in the recording phase is placed in close proximity to the participant's head and captures the live sounds. The FMOD program corrects the offset in the initial difference in distance between the participant's head and the dummy head. The blending of the past and live is important as it allows participants to interact with the sensations they are feeling through chatting and they would get live responses based on their statements, which leads to the perception that everything presented to them are happening right "here" and "now", including the past events.

USER STUDY

We conducted user studies to validate our design and implementation of our system. Our main goal is to study 1) does blending live and past make participants to perceive the past reality to be live more easily, and 2) how beneficial is it to provide haptic feedbacks in the recorded alternate realities. The hypothesis is that if we transition between live and past seamlessly, and augment the past with haptic feedbacks, the participants are more easily immersed in the

Figure 6. User study.

past realities. We observed how the participants reacted to live and past events.

Participants

We recruited 20 participants; 10 were male and 10 were female. They are aged between 20 to 35 years old (average: 26.6, SD: 3.53). All participants had no previous knowledge of our system. The 20 participants were divided into 2 equal groups. Each group was tested in two experiments but the two groups were tested in different conditions.

Environmental Setup

The experiments were conducted in a small meeting room as to provide a closed, quiet environment. The participants, blindfolded, were seated across a table from the experimenter and put their hands on the table (Figure 6). The table has a tactile sound transducer fixed to it. A dummy head is also placed in close distance from the participant's head. Each experiment was video-recorded.

Experimental Design

We designed two distinctive experiments to validate the two different element of our system. The first experiment is focused on the effectiveness of blending live and past realities. The second experiment is designed to test the haptic component in alternate realities. In both experiments, the participants are instructed to not react to anything if they do not believe the sensations they feel are actually happening in the live reality. We measure if they react to any past reality events.

Blending live and past

The goal of this user study is to examine the whole concept of whether having a sensation of live feedback and live interaction can make the participants believe that the past reality is actually happening before them and how our system performs in providing such kind of a experience that immerses the participants in a environment that is both now and the past. Ten participants saw the experimenter beforehand personally and were led into the room by the experimenter, and they experienced our system with live feedbacks from the live reality. The other ten participants were presented only with the past and received no live feedbacks from the experimenter, and they could not confirm that the experimenter is actually in the room because a different person led them into the room while they were blindfolded. The key point is to compare whether having a transition from live to past and live feedbacks, such as the constant touch from the experimenter, can create the illusion in the participant's head that everything is happening in live, even including the past reality.

The scenario used in this test focuses on the participants' reactions to four different scenes that were recorded beforehand.

- The experimenter asks the participant about the audio level of the headphone.
- The experimenter asks to take a picture of the participant.
- The experimenter's colleague joins, and the experimenter asks them to greet each other.
- The experimenter gets a phone call and leaves the room, then comes back and ends the experiment.

The four recorded-scenes were all presented to the 20 participants. The difference is that in the situation for the batch of participants where they experienced the blending of the live and the past, the experimenter encouraged the participants to chat and constantly touched the participants before playing the recorded-scenes, whereas for the other batch, the experimenter refrained from interacting with the participants as much as possible.

Haptic in alternate realities

As mentioned earlier, haptic feedbacks can greatly increase the feeling of immersion in VR. We designed this user study to examine if haptic feedbacks from the past reality can indeed help the participants to believe in the past reality more easily. Ten participants were tested with haptic feedbacks, whereas the other ten were tested without.

The idea is to present recorded past scenes to the participants that would normally result in haptic sensations had them happened in live situations. The four recorded past scenes presented to the participants are the following.

- The experimenter taps the table while making a conversation.
- The experimenter taps the table to instruct the participants to move their hands
- The experimenter places a book on the table and slides it to the participant.
- The experimenter stands up but trips over towards the participant across the table.

For the ten participants that were tested with haptic feedbacks, they would feel vibrations in the table with their hands although the scenes were not really occurring. The

other ten participants were not presented with any haptic feedbacks.

RESULTS

Blending Live and Past

We compared the results and reactions of the participants in the two different test situations. The first situation is that the participants knew beforehand that the experimenter is actually in the room and interacted with the experimenter; we consider this situation to be "with blending." The second situation is that the participants have no prior confirmation that the experimenter actually exists in the room, and received as little interaction as possible; we consider this situation to be "without blending."

With blending

10 participants experienced this situation. We observed if they reacted to recorded past scenes. Except for the case of 1 participant, all 9 participants reacted to at least one scene. Among them, 4 participants reacted to all 4 scenes. It was observed that the typical reaction include raising hand to signal the audio level is perfect, sitting straight for the picture, and turning and greeting the recorded colleague walking in. The most interesting reaction is during the last scenario where the recorded experimenter comes back into the room and walks to the front of the participant to end the experiment. Meanwhile, the live experimenter sneaks behind the participant's back. As a result, when the participants took off their blindfold, they were trying to search for the experimenter, who were nowhere in their field of sight. 5 participants were surprised when they were pat on the back by the experimenter. During the interview after the experiment, we learned that most participants reacted because they heard the live experimenter talking back to them so they felt everything has got to be real. For the one participant who did not react to any scenes, it was noted that there was a small difference in sound quality between live and past, and it did not escape the participant's ears, who was a musician in spare time.

Without blending

The other 10 participants experienced this situation. It was observed that half of the participants still reacted to the question about audio level because they thought it was a formal procedure to begin the experiment. Most participants did not react to any of the scenes because they felt no real interaction between the record experimenter's voice and them. 3 people also noted that they felt the experimenter was not actually in the room because they did not see and touch the experimenter beforehand.

Haptic in Alternate Realities

The participants were again divided into two groups. We observed how they reacted to the recorded events that would normally generate haptic feedback in the table had them happened in live reality. One group experienced with computer-generated haptic, and the other had no haptic feedback.

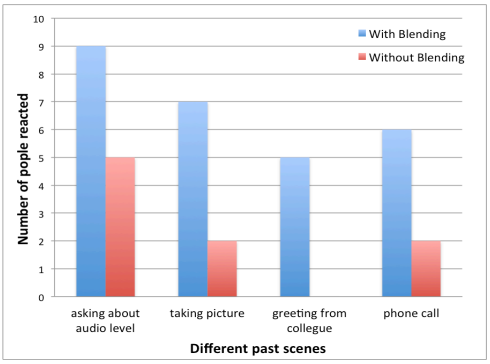

Figure 7. Comparison of the number of people who reacted to the past in the experiment "blending live and past."

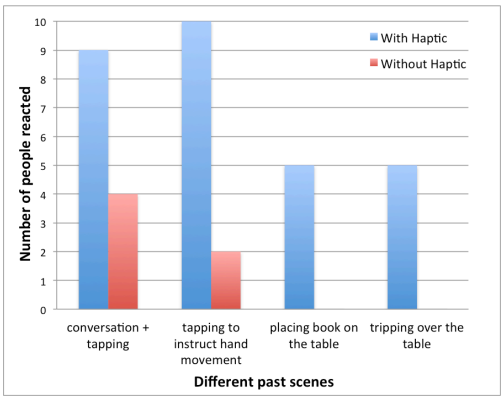

Figure 8. Comparison of the number of people who reacted to the past in the experiment "haptic in alternate realities."

With haptic

It was observed that more than half of the participants reacted to each scenes except the last two scenarios. The reason is that they felt the vibration in the table seemed too weak to be real had the scenes really happened. An interesting phenomenon is that during the recorded scene where the experimenter taps the table to instruct the participants to move their hands to the left, although the vibration should have came from one single point that is between the participants' two hands, all participants claimed that they felt the vibration came from the left because they also heard tapping sound from the left. This confirms our original design in that when audio and haptic feedback is in cross-modal effect, it creates more realistic illusion.

Without haptic

The result of this experiment is close to our hypothesis. The participants could easily tell that the scenes were recorded. They told us when they felt no vibration in the table when they heard the book being dropped and experimenter tripping over, they instantly knew the scenes were not real. When asked why some reacted to the first two scenarios, they said because although they heard tapping sound on the table, they were unsure that the gentle tapping would have actually caused haptic feedback in real life.

PUBLIC DEMONSTRATION

We had the chance to do a public demo of Reality Jockey at a Japan domestic conference. During a total time span of 6 hours in 2 days, a total of 42 participants experienced our system. For our demonstration, to better visualize the whole system and situation to the audiences observing the participant experiencing the system, we designed scenarios that involve the experimenter walking around the participant and asking the participant to point in the direction of the experimenter. This way, the audiences could get a rough idea of Reality Jockey even though they are not experiencing the blending of realties themselves because they could see, for example, the participant pointing at the recorded experimenter's voice on the right while in reality, the experimenter is actually on the left. The switch from generating haptic from the table to generating from the floor was easy. All we needed to do was to construct a wooden plank floor and record footstep conduction sound on it. During the demonstration, the participants place their feet on the plank; the tactile transducer is fixed beneath the plank.

The participants were not told the exact details of the demonstration before experiencing the system besides knowing that we are mixing realities through audio and haptic feedback. The participants were asked to either wear a blindfold or close their eyes. During the demonstration, we interacted with the participants through chatting, asking them to raise their hands or point, and lightly touching on the arms. Example scenes of blending of the realities include 1) the live experimenter stays stationary, but the participant hears and feels the past experimenter walking around and talking, 2) the participant hears a recorded scene of the experimenter getting a phone call during their conversation, and 3) the past experimenter talks before the participant while the live experimenter sneaks behind the participant to give the element of surprise through a light pat on the back.

Since the goal was to demonstrate our system, the participants were told the truth after every time they responded to an event that happened in the past reality. Still, during each demonstration that consisted of several instances of blending, even though the participants had their guard up after the first instance, they were still generally tricked in the instances that followed. For example, participants pointed or faced in the direction of an empty space while talking, or trying to search for their cellphones when they heard the ring, just like what people usually do when they hear a cellphone ring in a public place, and many participants tried to search the place of the experimenter before them after they took of their blindfold because the demonstration ended with the recorded experimenter standing right before them, only to be surprised by the gentle pat on the back by the live experimenter who sneaked behind them. Through this demonstration, we observed priceless expressions on the participants' faces (Figure 9). These expressions come from the realization of having just been tricked. It also confirmed that Reality Jockey could be used and appreciated by the public as a mean of experiencing past realities.

Figure 9. Participants enjoying Reality Jockey.

DISCUSSION

Seamless Transition

A problem of experiencing current virtual reality systems is that there has always been a barrier between the real reality and the virtual (alternate) realities. The alternate realities may have truly realistic sensation feedbacks that provide immersive feeling, but without a seamless transition between the realities, the participants would know that although what they are feeling is so realistic, it is not really happening and is computer-generated.

In Reality Jockey, the whole experience first starts with live. Then gradually the past (alternate) reality blends in, and because the participant can still interact with people in the live reality, the participant feels that everything should still be happening in live. Finally, the portion of the past reality increases and the live reality decreases and the seamless transition is complete. The effect of seamless transition is confirmed in the user study that experimented on the blending of live and past. In the last part of the experiment, we played only recorded past of the experimenter asking for permission to answer a phone, walks out of the room, then coming back to end the experiment. During that whole time, the portion of live sensation is already less than the past sensation, and yet half of the participants still reacted to the past reality as though everything is live.

Live and Past Modality

For the transition between live reality and past reality to seem seamless, the live and past modalities in the sensation of audio and touch should feel closely the same. For example, if the audio level and tone of the live experimenter and the recorded experimenter is too different, the participants could instantly detect a transition between live and past. This happened in one of the case of the participants. That participant has a particular precise sense in hearing and could differentiate a single flick in the audio quality when recorded audio is played. To solve this, during the recording of past audios, we should conduct in a space that is absolute quiet. Then in the live experience, playing a

small background static white noise may also help. For the haptic sensation, we could achieve close to reality sensations for small vibrations by frequency filtering and amplifying. However, the sensation of weight could not be simply generated from the tactile sound transducer so some of the participants detected that the book on the table and the experimenter tripping over is indeed not in the reality.

Effect of Audio and Haptic Cross-Modality

Our system excludes the visual sensation and focuses on the cross-modal effect of audio and touch sensation. The idea is that excluding the visual sensation is the easiest and most intuitive way of decreasing the presence of the live reality and increasing the presence of the alternate realities through imagination and stimuli in other sensations.

The effectiveness of the cross-modality is proved in the user study and the public demo. Although the haptic sensation comes from one single point in our system because we only implemented one tactile sound transducer, the participants claimed that they felt the origin of the vibration moving such as when the recorded experimenter taps the desk in different locations in the user study, or when the recorded experimenter walks around during the public demo. The reason is that the spatial moving sound gave them the illusion that the vibration source was also moving.

Importance of Blending Live

As opposed to presenting everything that is recorded in an immersive experience, we take the approach of blending live sensations. This is important because just presenting the past reality cannot provide a fully interactive experience. The interactivity makes everything seem more real, even the past events. This was confirmed by the participants who experimented with the blending of live and past who told us although they kind of doubted some of the conversation was not real, but because the live experimenter responded to their statements during the conversations and also touched them, they believed everything really did happen before them.

Potential Applications

Since our system dwells around the concept of time, space, and reality, we have conceptualized several potential application areas that are best used by using our system.

Reliving memories

Our system creates the illusion that the past is happening right "here" and "now." Therefore, it is the perfect solution for using with keeping permanent records of the memories that one would like to keep. Then, one could always relive the experience as if went back in time, no matter how long it has passed. For example, parents could record the babies' first words, first steps, and experience them many years after. The difference between our system and the commercial recording techniques now is that we provide an immersive 3D spatial sound environment enhanced with haptic feedbacks.

Treating mental trauma

One suggested treatment to mental trauma patients is to have them experience the situation again and to have psychiatrists guide them during the re-experiencing. Our system can aid those situations, being able to focus on the patient's mental imagination ability and create an immersive experience of the past easily and safely.

Digital shrine

To talk with their passed-away loved ones have been one of people's most desired dream. Unlike the non-immersive and non-interactive way of simply listening to voice records, with Reality Jockey, if we have recordings of their voice conversations, we can create an experience that is immersive so one would feel like actually talking to the passed-ones again in real time because the alternate reality has blended into the live reality.

Immersive entertainment platform

Our system blends alternate realities through a realistic vibration environment that generates haptic feedbacks in sync with the 3D sounds that the participants hear. They would experience the seamless transition from reality to virtual reality, and before they know it, they could be experiencing everything from the virtual world and yet feel no barriers during the transition. Therefore, it can be used as an entertainment platform to bring the virtual worlds to the reality.

Limitations and Future Work

Our system's goal is to become the foundation of creating a illusion of the past so users can re-experience their memories. An illusion is fully immersive if we can provide all of human's five senses. As of now, we only have the hearing and touching sensation. We are looking to add in the other three sensations once we are certain in their cross-modal value with hearing and touching. The first sensation we are looking to add is visual because works like The Rubber Hand Illusion has already suggested the effectiveness of visual and touching cross-modality.

Another limitation is the lack of a more versatile haptic feedback. We have yet to implement other kinds of haptic sensation such as the explicit grabbing action from the participant. Adding them would allow more varied scenarios capable to be experienced with the system.

The capability of providing a communication experience makes our system interactive and immersive. However, this interactivity requires us to do versatile recordings beforehand, and yet there is the possibility of communication gap had the participant asks very specific questions while trying to interact with the past. Also, although our audio component is complete with head orientation tracking so the participants can move their heads around, we have yet to implement body tracking, a feature that can allow the participants to actually stand up and walk around.

One interesting idea that can be derived from our system is the usage in Out-of-Body Experience. Since our system can record the participant's actions, such as talking and knocking the table, and play it back to the participant to create such illusions. The illusion can be even more effective if we combine our system with means of affecting how the user moves such as the PossessedHand [20].

CONCLUSION

Reality Jockey is a system that aims to lift the barriers when one experiences alternate realities. To do that, the seamless transition from the real reality to the alternate realities is important. We therefore blend the sensation from live and from past that the participants would feel. Our goal is to create a system that can provide such an immersive feeling of the past events that the illusion of them happening again is achieved. As opposed to the conventional way of providing visual sensations in virtual reality systems, we exclude visual and implements audio and haptic feedback in cross-modality. The idea is that excluding visual is the intuitive way of decreasing the presence of the live reality and increasing the presence of the alternate realities.

The participants can feel live sensation and interaction from people in live time. while feeling blended-in recorded audio and haptic sensations from the past. The result is they are immersed in an environment that is both the present and the past. We conducted user studies to validate our concept on blending the live and past, and on providing audio and haptic feedback in cross-modality. The results showed that the participants felt more immersed and would react to the recorded events even though it was not actually happening in real-time if both the blending and the haptic sensation is present in the system. We demonstrated Reality Jockey at a Japan domestic conference and received valuable feedbacks. We also conceptualized potential applications of Reality Jockey.

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