Interactive Storytelling in a Mixed Reality Environment: How Does Sound Design and Users' Preknowledge of the Background Story Influence the User Experience?

Marija Nakevska, Mathias Funk, Jun Hu, Berry Eggen, and Matthias Rauterberg

Department of Industrial Design, Eindhoven University of Technology, P.O. Box 513, 5600 MB Eindhoven, The Netherlands
{m.nakevska,m.funk,j.hu,j.h.eggen,g.w.m.rauterberg}@tue.nl

Abstract. Interactive storytelling in a mixed reality environment merges real and virtual worlds, and physically immerses the participant in a narrative. The participant is engaged to participate in an exploratory experience, which is influenced by personal and situational factors. We used three stages from the ALICE installation to investigate the effects of sound design and participants' preknowledge of the background story. The study was carried out with 60 participants and the results show that immersiveness (presence) is influenced by both factors. Furthermore we discuss the user experience through observations and information gathered in interview sessions.

Keywords: interactive storytelling, user experience, mixed reality.

1 Introduction

Interactive storytelling in a mixed reality environment merges digital and physical information and features. The participants are engaged in an interaction taking place in a real physical environment that does not involve direct use of a computer and interaction devices. We use the first three stages from the ALICE installation [1], to explore the challenges in designing an interactive narrative in mixed reality. The ALICE installation consists of six consecutive stages, creating an experience based on selected parts from the novel "Alice's Adventures in Wonderland" by L. Carroll [3]. In this paper we present the technical and storytelling mechanisms in the ALICE project, and the implemented sound design. Dow [5] refers to embodied narrative engagement as a combination of: the feeling of being in a story world (presence), the feeling of empowerment over unfolding events (agency), and the feeling of being caught up in the plot and characters of a story (dramatic involvement). We study the effects of sound design and participant's preknowledge of the narrative on the feelings of presence.

Sound Design. The film industry has recognized the importance of sound and has developed techniques for producing sound that allows the audience to

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feel immersed. There are several types of sound used in the entertainment industry: speech, sound effects and music [8]. Speech and dialog convey clear messages, usually from characters or an off-screen narrator. Sound effects are the sounds that result of events in the physical world. Ambient sound creates a sense of physical presence that can set the basic mood, and can communicate emotions and tension. Music can be used to set the basic mood, to induce feelings, or to encourage activity; it can create tension, expectation, and suspension. Music and sound effects can convey semantics in a very universal way as the participants often can immediately relate to familiar music, which greatly enhances the experience and creates a sense of recognition and presence. We investigate how an elaborate sound design with music and ambient sound (effects) can affect the user experience in a mixed-reality environment like the ALICE installation.

Preknowledge of the Background Story. The participant should be intrinsically motivated to keep participating in the exploratory experience in the ALICE installation. The background story increases the participants' familiarity with the characters, context, and environment, and ultimately helps them quickly understand the designed story. Each participant has different preknowledge of the background story as they might have seen movies, played games, or visited attractions that are inspired by the narrative "Alice‘s adventures in Wonderland" [3]. We investigate the practical implications that are coming from different preknowledge of the background story and to which extent different preknowledge will affect the participants' experience.

Related Work. The importance of sound in media like film, theater and video games is well recognized. Many projects show that sound based games give more freedom in movement and the users have rich and immersive experiences [6,9]. The interactive storytelling community also recognizes the importance of sound design to enrich the interactive narrative experience [7,2]. A number of research projects report on sound and audio's ability to create rich, strong and immersive experiences in mixed and virtual reality [9,11]; also that music is able to increase or decrease immersion depending on the choice of music and suggests that music could be an important factor in the perception of time whilst playing video games. The effects of pre-game stories on the feeling of presence and evaluation of computer games is empirically demonstrated [10,12]. However, there is a lack of empirical research that will explain the user experience in an interactive storytelling in mixed reality environment.

Overview and Hypothesis. A between-groups, two-by-two factor design was employed with the two factors being the *sound design* and the participants' *preknowledge* of the narrative. We expect that the enhanced sound design and richer preknowledge of the narrative both to increase the feelings of spatial presence and the experience to be evaluated more positively. In the remainder of the paper, we present the experimental setup with the statistical results, interviewing data and discussion, resulting in several conclusions summarized in the last section.

2 Experiment

2.1 The ALICE Project and Installation

In this experiment, we focus on the first three stages of the ALICE installation. We designed two different sound conditions: (1) AMSS–a sound scape that consists of ambient sound effects, music, and speech (for all three stages); (2) SS–a sound scape without ambient sound effects and music, but with speech (only in the first stage). In the following, we describe the design of each stage with the implemented sound scape.

Fig. 1. *Stage-1 "In the park"* and *Stage-2 "Down the rabbit hole"* (a) *Stage-1*, with the printed canvas and artificial arrangements and "rabbit hole" in the left back corner (b) "Moving grass" prototypes (c) the projected VR rabbit

Stage-1: "In the Park". The first scene of Carrolls original book is represented in stage 1: *Alice is bored [...] Her curiosity is triggered by white rabbit which runs, looking at its pocket watch and cries out "Oh dear! Oh Dear! I shall be late!".* The spatial setting represents a park environment, a picture from nature depicted on a printed canvas and artificial arrangements, see Fig. 1(a). In the left back corner is the "rabbit hole", the entrance of the rabbit hole is closed with a curtain, attached with electrical magnets. The white Rabbit "running" in the scene is simulated as movements in artificial grass (implementing using vibration motors) and virtual projections, see Fig. 1 (b) and (c). After the rabbit "runs" through the scene, the entrance of the "rabbit hole" is opened (by deactivating the magnets) and a light points to a seat that is mounted on a rail (Fig. 2 (c)). The sound scape was different for the two sound conditions: (1) Ambient sound and music (AMSS)–The ambient sound in *Stage-1* consists of nature ambiance and singing birds combined with pleasant piano music. Next to the "rabbit hole", a pressure sensor is positioned to detect if the participant walks too close by. If this happens before the rabbit is shown on the scene, the "grass module" that is close to the entrance is moved, ambient sound featuring crows and dramatic piano music. However, when the participant is expected to continue in the next stage, the ambient sound fades out from *Stage-1*, while a "wind" sound starts from *Stage-2*. If the participant does not enter the second stage within three minutes, an inviting "fantasy" piano sound is played from direction of *Stage-2*. (2) Speech (SS)–An ambient sound or music is not included. If the participant does not enter the "rabbit hole" after the rabbit runs in the scene she is invited with one of several pre-recorded samples, e.g., *"Come on, follow me!"* or *"In the left corner, follow me!"*, played randomly every 3 minutes until the participant decides to go further.

Fig. 2. *Stage-2 "Down the rabbit hole"* (a) *Stage -2*, the "rabbit hole" with bookshelves and lighting (b) The electronic seat and the security gate in the background

Stage-2: "Down the Rabbit Hole". The second stage is the point where "the journey begins", and return to the pleasant and safe "park" environment is blocked. When entering the "rabbit hole", the participant finds a seat that is mounted on a rail (Fig. 2 (b)), a security gate closes the physical entrance to keep the participant safe. When the participant is safely seated, the security gate opens and the seat starts moving downwards slowly. The "rabbit hole" is a vertical cylindrical room that is decorated with bookshelves, lamps, clocks and old-fashioned objects (Fig. 2 (a)). The lamps are gradually dimmed one by one, as the the participant passes them. At the bottom of the rabbit hole is a corridor that leads to the next stage.

In this second stage there is no sound for the SS condition, only for the AMSS condition: Music is composed for each part of this ride, directly matched to the participant's ride. The sound scape was designed as a mixture of fantasy and mysterious music, and incorporates sound effects from the physical objects, such as electricity from the lighting or ticking clocks.

Stage-3: "Shrinking and Growing". The third stage is associated with the perception of personal space and the changing thereof in relation to the environment. After the participant enters, a sliding door behind her closes and she is trapped. This stage is implemented as a CAVE [4] with five side projections. Each side of the CAVE shows one projected door (see Fig. 3 (c)), however, only one VR door is shinny white and smaller than the others, (Fig. 3(a) and (b)). On a table in the middle of the CAVE, a box is placed, which is labeled "eat me" and

Fig. 3. Stage-3 “Shrinking and growing”: (a) VR small white door, (b) opening of the door and view on the garden, (c) one of the VR doors projected on one of the other four sides, (d) bottle “Drink me”, cookie box “Eat me”

next to it a bottle labeled “drink me” (see Fig. 3(d)): the box detects with an IR sensor when the participant takes a cookie from the box, while the bottle detects with a tilt sensor when the participant drinks from the bottle (reacting on tilting angle). Eating or drinking triggers the projected room to become bigger, creating a feeling of getting smaller. A second action (eat or drink) afterwards lets the room become smaller. The floor of the CAVE is covered with pressure sensors. If the participant approaches the door where she should be able to exit the room, the virtual door will open and a beautiful garden will be shown, see Fig. 3 (b). If she goes away from there, the door will be closed, see Fig. 3 (a).

Similar to Stage 2, in the third stage there is no sound for the SS condition, only for the AMSS condition: Each activation of a pressure sensor on the CAVE floor is manifested as a cracking sound. The cracking sounds are different depending on the previously taken actions, if the participant is “big”, the cracking sound of the floor is heavier, and vise versa, if “small” the cracking sounds are more short and light.The ambient sound is composed by fantasy music and the sound of water drops. Also the “water drop” sound has different echo depending on the relative size of the room (and the participant).

2.2 Procedure and Participants

The experiment was advertised as “an experience in a designed environment”. Participants were introduced to *Stage 1* and instructed to “explore and have fun”. Information about the consecutive spaces was not given. Each of the participants experienced Stage 1, 2, and 3 with just one of the sound conditions (AMSS or SS). Immediately after the experience, the participants completed several questionnaires and were interviewed by the experimenter. The duration of each session was approximately 45-60 minutes, including briefing and instructions (5-7 min.), experience in the installation (15-30 min.), filling out the questionnaires (10-15 min.) and the closing interview (5-10 min.). Sixty participants joined the study, from 18 to 39 years old (26 male, 37 female, mean age 25, SD = 4), of which 29 were in the AMSS condition and 31 in the SS condition. All participants received an incentive of 10 euros for their participation.

2.3 Measurements

We used the MEC–Spatial Presence Questionnaire [13], which consists of several scales that measure different dimensions of spatial presence. This instrument assesses nine constructs associated with spatial presence, from which we included: attention allocation, self location, possible actions, higher cognitive involvement, and suspension of disbelief. The items were adapted to refer to *story* as a mediated environment instead of "environment of presentation" in the original questionnaire.

The participants were asked to rate their preknowledge of the background story: *How familiar they are with the story "Alice's Adventures in Wonderland"; the characters and events and the character of Alice.* Also, whether they *have watched any movies, played games or have other experience inspired or related to the story "Alice's Adventures in Wonderland".* After the survey, the participants were asked to share their experiences within the environment in a semi-structured interview, and to think about possible improvements.

3 Results

Six participants withdrew from the experiment, and five participants were excluded from the data analysis because there were technical problems during their experimental sessions. From the participants who withdrew, four were afraid to continue in *Stage 2* because it seemed too dark, and two failed to discover the rest of the story. In summary, we analyzed the data from 49 participants as shown in the following: Based on the data regarding the preknowledge of the background story we could divide the participants into two groups: (a) participants that have high preknowledge of the background story (HPKS) and (b) participants that have low preknowledge of the background story (LPKS). The number of participants per conditions are presented in Table 1.

A two-way ANOVA of sound design conditions (AMSS, SS) and preknowledge of the story (HPKS, LPKS) on presence and subjective rating of the experience was conducted.

Table 1. Number of participants per condition

Preknowledge	Sound	
of the narrative	AMSS	SS
High (HPKN)	14	12
Low (LPKN)	7	16
Interuptions	5	1
Technical problems	3	2

A significant main effect of the sound condition on *Self location* was found, $F(1, 45) = 4.59, p = 0.038$. *Self location* was rated higher for [Sound, AMSS]

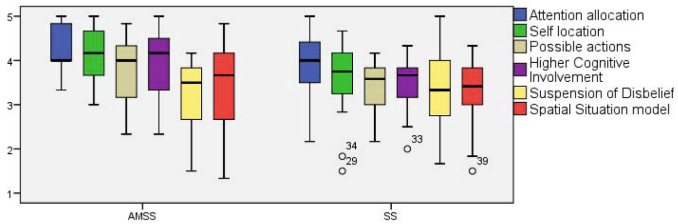

Fig. 4. Presence indicators in the AMSS and SS sound conditions

($M = 4,04$) than for [Sound, SS] ($M = 3,67$). The main effect of *Attention allocation*, *Possible Actions*, *Higher Cognitive Involvement*, *Suspension of disbelief* and *Spatial Situation Model* was not significant.

A significant main effect of the preknowledge of the narrative was found on *Attention Allocation* $F(1,45) = 10.98, p = 0.002$, on *Self location* $F(1,45) = 20.24, p < 0.001$, and *Higher Cognitive Involvement* $F(1,45) = 1.72, p = 0.001$. *Attention allocation* is higher for high ($M = 4.36$) than for low ($M = 3.78$) preknowledge of the story; *Self location* rated higher for high ($M = 4.25$) than for low ($M = 3.47$) preknowledge of the story; *Higher Cognitive Involvement* is higher for high ($M = 3.98$) than low ($M = 3.33$) preknowledge of the story. The Sound x Preknowledge of the story interaction was significant for *Higher Cognitive Involvement* factor, though it did not qualify the main effects, $F(1,45) = 4.55, p = 0.038$.

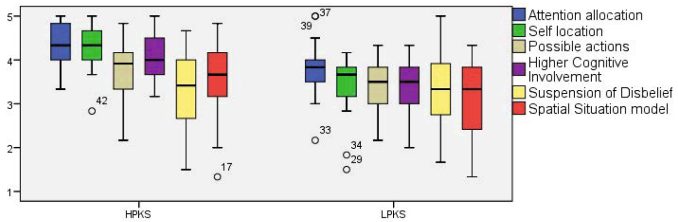

Fig. 5. Presence indicators in the HPKS and LPKS variables

4 Conclusion

We described a fully realized interactive story inspired by three chapters from the narrative "Alice's adventures in Wonderland", and present the interactive story with the design choices and designed sound scape. In this setting, we investigate the immersiveness and the overall user experience. The results show that the enriched sound design affects self location in the storytelling environment, while participants' preknowledge of the underlying story has significant effect on attention allocation, self location, and higher cognitive involvement presence indicators. One limitation of this study is the usage of subjective post-hoc measures of experience such as MEC, where presence is measured based on the overall perception of the immersive environment. As future steps we will research the effect of *separate* sound types, and how the *quality* of the sound design influences the experience in the installation. Further studies will explore the user experience in more detail, focusing on smaller parts of the overall experience.

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