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Interactive storytelling in a mixed reality environment: The effects of interactivity on user experiences

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ABSTRACT

Interactive storytelling in a mixed reality environment merges digital and physical information and features. It usually uses an augmentation of the real-world and physically-based interaction to create an immersive experience that corresponds to the dramatic storyline of the interactive narrative influenced by the actions of the user. Immersiveness is a crucial aspect of such an installation, and can be influenced by multiple factors such as video, sounds, interaction and, finally, the density of all combined stimuli. We used one of the stages from our interactive ALICE installation to investigate immersiveness and its contributing factors in a between-group design with a special focus on the effects of interactivity, and the feedback and feedforward stimuli of the environment on the users' experiences. The study was carried out with 41 participants and the results showed that immersiveness not necessarily depends on the modality of stimuli, but instead on their time-density.

1. Introduction

Interactive storytelling in a mixed reality environment merges digital and physical information and features. It usually uses an augmentation of the real-world and physically-based interaction. The dramatic storyline of the interactive narrative is influenced by the actions of the user. 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.

Dow [15] addresses three experiential pleasures of immersive and interactive stories: presence, agency, and dramatic involvement. The features of the medium that can be manipulated by the design are: perceptually immersive interfaces, interactivity, and narrative structures. The terms immersion and presence often are used synonymously, addressing a set of physical properties of the media technology that may give rise to presence or immersion [33]. Presence in a physical, virtual, or mixed reality storytelling environment is defined as the feeling of *being* in a story world, while dramatic involvement is the feeling of being caught up in the plot and with the characters of a story [15].

Interactivity refers to the degree to which users of a medium can influence the form or content of the mediated environment, whereas agency refers to the empowerment of the user to take meaningful actions in the world, which yield effects that relate to her intention [36]. The user's agency in interactive storytelling environments is divided between the own sense of control and the empowerment of the story characters and events. The motivation for a user to act in an interactive narrative may be very different from common interaction with a product: in interactive storytelling, the source for agency may be the ability to navigate and to influence the environment, to interact with characters, or to have an effect on the course of events and the eventual outcome of the narrative.

To establish meaningful interaction in interactive storytelling, the user's actions and the events of the narrative are coupled to generate guiding information. This calls for the design of a set of affordances, in which interactive and behavioral aspects of the interactive (narrative) environment influence the user and evoke certain expected behavior. Feedback and feedforward are one of the most common used design principles in interaction design. Through feedback the user receives information about the effectiveness of her action, whereas feedforward communicates what kind of action is possible and how it can be carried out.

To explore the challenges in designing an interactive narrative in a mixed reality environment, we use the third stage "*Eat me, drink me*" from the ALICE project [6]. 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 [10]. The user takes the role of the character Alice and

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experiences the sequence of emotional and behavioral states as Alice did in the narrative. In this paper we focus on the technical and storytelling mechanisms and we study the effects of interactivity on the user experience: a between subjects experiment was conducted to explore potential differences in sense of presence, agency and satisfaction with different levels of interactivity. The independent variable was the interaction environment, with three levels: (a) Interactive responsive environment, (b) Non-interactive pre-programmed environment and (c) Non-interactive pre-programmed environment with minimum stimuli. The hypothesis was that a more interactive setting should lead to overall higher levels of presence, agency and satisfaction.

The remainder of the paper is structured as follows: after reviewing relevant research, we present the experimental setup and results regarding the relation between these variables of interactivity, presence and agency, resulting in several conclusions in the last paragraph.

2. Related work

There is a broad range of ongoing research projects on interactive storytelling that aim towards creating highly interactive stories. Interactive drama has been discussed for a number of years as an artificial intelligence based interactive experience [7,25]. Strategies like branching narrative [18,17], creation of autonomous virtual agents [3,35] and storyworld simulations are applied in interactive storytelling. There is a progress in building believable agents [7,8,19] and interactive plot [37]. Examples of such systems are: the interactive drama Faca¸de [28], the emergent narrative FearNot! [4], the multi-user tabletop system The Interactive Storyteller [2]. However, most of these prototypes use virtual reality as a medium, and the interaction mechanisms usually are mouse and keyboard.

2.1. Mixed reality environments

Nowadays, mixed reality is a form of interactive technology that offers new opportunities for building highly immersive storyworlds. In mixed reality environments, digital technology is used in conjunction with physical props and settings to create a variety of experiences in the 'virtuality continuum" [29]. The immersive technologies presented in the virtuality continuum offer many creative opportunities, as the created story elements and the participants are within the same space and may interact with each other. Stapleton et al. [34] refer to the traditional media: a novel occupies the imagination of the readers; traditional theme parks use the physical reality; whereas storytelling in mixed reality aims to occupy the imagination of the user and, at the same time, aims to create sensorial stimuli with physical elements in mixed reality to create a compelling immersive experience.

There are many attempts to develop mixed reality environments that will convey engaging and compelling user experience. By using the existing technologies various places may be transformed into platforms and playgrounds that aim to entertain, motivate and inspire. Mixed reality environments cover a variety of areas from media art and cultural computing [23,24,31] to games. Games are usually goal-directed, structured play experiences [9] which use a physical, real world environment and the physical context of the user influences the game play. Such projects are using the physical and social aspects of a game play. "Touch-Space" [12] provides a full spectrum of tangible game interaction experience ranging from the real physical environment. Jones et al. [22] present a proof-of-concept prototype, RoomAlive, which enables new interactive projection mapping experiences that transform any room into an immersive, augmented entertainment experience, where users can touch, shoot, stomp, dodge and steer projected content that seamlessly co-exists within their existing physical environment. Projection-based augmented reality in Disney parks is presented in [30], in the interactive applications such as the "The Storytellers Sandbox" and "Goofy's Paint 'n' Play House" attractions. Installations may also utilize the structure of the physical environment to create interfaces for interaction. Fischer et al. [16] created a façade mapping event in which the user interface was taken as an architectural piece instead of technical prop, and the interactive part was integrated into the overall narrative, providing a larger interaction space for multiple groups. While projection mapping is widely used in augmenting the physical space especially in the context of interactive theatre, Honauer et al. [20] tried to bring interactive costumes onto the stage in theatre, where the costumes became active as well.

The Media Convergence Lab at University of Florida researches the development and applications of mixed reality environments. Hughes et al. [21] present the museum Sea Creatures experience, which vividly alters a physical setup with an augmented scenery from an underwater world. The Mixed Reality for Military Operations in the Urban Terrain (MR/MOUT) project, uses an extreme and complex layered representation of combat reality, using all the simulation domains such as live, virtual, and constructive by applying advanced video see-through mixed reality technologies. Hughes et al. [21] note that to transform technical capabilities of emerging mixed reality technology into the mainstream involves the integration and evolution of unproven systems, which involves content, production, technical and business issues. They discuss the production and delivery tools, also claim that the success of mixed reality "will come about not only by advancing technological capabilities, but also by exploiting creative possibilities".

2.2. Interactive storytelling in mixed reality

In difference to the above-mentioned projects, interactive storytelling aims to put the story in the middle of the context development. One such example of an augmented reality interactive drama is AR Façade [14], based on the desktop-based interactive drama Façde [27]. The participants are engaged in interaction with virtual characters while they move inside a physical apartment. The AR Façade project initiates questions about the challenges of building the environment, designing a mixed physical and virtual interaction and how all of this influences the behavior of the participants and their experience.

The MIT Media lab presents several projects in physically interactive story environments: KidsRoom, It/I, Personal Aerobics Trainer, and Swamped! [32]. The environments are based on complex sensory mechanisms designed to make the interaction as natural as possible; the interaction is not based on explicit mechanisms but with implementation of responsive characters and environments. Pinhanez et al. [32] conclude that using unencumbering, rich sensor technology can facilitate user immersion in the experience as the story progresses and compelling interactive narrative story systems can be perceived as highly responsive, engaging, and interactive even when the overall story has a single-path structure.

2.3. Interactivity and experience

Dow et al., present results of a qualitative, empirical study exploring the impact of immersive technologies on presence and engagement, which shows that "immersive AR can create an increased sense of presence", and "increased presence does not necessarily lead to more engagement" [13]. Another interactive storytelling game [11], engages the users in a physical deck while playing the part of James Bond and uses gesture recognition and spoken utterances to converse with the virtual actors. The multimodal mixed reality installation Synthetic Oracle is used for an empirical study investigating the importance of the choice of interaction mode, and the study showed that "the activity level and behavior of users modulates their experience, and that, in turn, the interaction mode modulates their behavior" [5].

In this article, we focus on how interactivity in a mixed reality environment influences the visitor's experience. Empirical research [13,5,1] suggests that interactivity and interaction type can have an impact on the behavior and the user's personal experience. It is important to further evaluate the experiences from an empirical perspective given more complex environments and experiences. In our experiment, we aim at investigating the effects of interactivity with different stimuli and environmental responsiveness on the personal experience. The experiment uses a one of the six stages of the entire ALICE installation. In this installation, each stage addresses different emotions and experiences as a visitor transitions from stage to stage, guided by the narrative "Alice's Adventures in Wonderland". For instance, the first stage from the ALICE installation, "*In the park*", addresses boredom and curiosity as drivers of the user behavior. Aart et. al. [1] conducted an empirical study on the users' behavior in this stage and demonstrated that "particular sequence of events has a significant positive influence on the arousal of curiosity and on triggering and guiding intended user behavior". In the next section we describe the setup of the "*Eat me, drink me*" stage and the results from the experiment that involved 41 participants.

3. Experiment

The experiment is part of larger research project, and the concrete context of the study is one of several stages of the ALICE installation: "*Eat me, drink me*". The visitors of this installation go through two other stages before entering the actual experiment setting, thus preparing and priming them for the experience and narrative episode they encounter in the third stage of the ALICE installation. When entering the "*Eat me, drink me*" stage, visitors have experienced the first stage, "*In the park*", which let's them shift from an open park-like setting towards the second stage, "*Down the rabbit hole*", which consequently is a dark vertical space that the participants experience through a short ride downwards. They will follow a tunnel walking towards the third stage, which is set in a room that conforms to the narrative and from which the visitors exit after certain interactions (see below). The original ALICE installation continues after this third stage for three more stages that deal with different experiences relating to different parts of the narrative [6].

3.1. Experiment setting

The "*Eat me, drink me*" stage is designed to induce a similar experience to the one described in the original narrative [10], in summary: *Alice enters a room with doors all around that differ in size. She finds a key that unlocks one small door, but she is too big to fit through it. After she drinks and eats, she undergoes several changes, she grows and shrinks. Eventually she has the right size and the key from the small door.*

After entering the third stage of the ALICE installation, the participant finds herself trapped in a cubical room and to continue in the installation (and narrative), the user needs to find the right relation between her size and the room, and needs to acquire the key to "open" the exit door. The ALICE installation has six stages in total, through which the participants has to pass in a limited amount of time. We designed the interaction within this stage to support each participant to move on to next stage in three to five minutes.

Spatial design. Fig. 1 depicts the different components of the physical setup of the "*Eat me, drink me*" stage. The five-sided Cave Automatic Virtual Environment (CAVE) is $3 \times 3 \times 3$ meter cube made of white semi-translucent canvas. We use back-projection, from five projectors positioned outside the CAVE, to project a seamless virtual environment onto the walls and ceiling of the CAVE. The floor has no projection; instead it has pressure sensors to measure the position of the participant in the room. The CAVE is equipped with a five-side full projection which is enabled when the participant is located in the CAVE. On each wall of the room, virtual (VR) doors (Fig. 3a) is projected. On the exit side of the cube a white VR door smaller than the others is projected, which features a doorknob (Fig. 3b) as a character from the story. The CAVE is equipped with a sliding door that spans an entire side of the CAVE (see Fig. 1a, top side); the door can be moved to open the entrance, close doors or open the exit as shown in Fig. 1b top to bottom respectively. Furthermore, an multi-channel audio system is installed underneath and around the CAVE that is used for ambient sounds, sound effects and auditory feedback. Fig. 1a shows the locations of the speakers.

Physical props. On one side of the room on a table, the participant finds a cookie box labelled "Eat Me" and a bottle labelled "Drink Me" (Fig. 2). These objects contain sensors to register interaction: the box is equipped with an IR sensor that detects movement when the participant takes a cookie, and the bottle contains a wireless connected tilt sensor, which detects if the participant is drinking from the bottle. Behind the table, a physical key with the label "Take me" is hidden.

Interaction design. The interaction design can be divided into a part that involves the spatial design and the mechanics of the sliding door, and a part that uses projection and animation when the participant reside inside the CAVE. Before a participant enters the CAVE, the sliding door (cf. Fig. 1a, top side) is in a position to admit the participant through the right side entrance into the CAVE. This setting of the sliding door is shown in Fig. 1b(1). By using the floor sensors, the presence of a participant can be detected and the sliding entrance door closes behind the participant as shown in Fig. 1b (2). When it is time to leave the CAVE (as determined by the narrative), the sliding door moves to the third position (cf. Fig. 1b (3)), which opens an exit door toward the next stage of the overall installation. Again, the floor sensors can detect when the participant has left the stage and the sliding door moves to its original position as shown in Fig. 1b(1).

The interaction design inside the CAVE uses back-projection on the walls and the ceiling as means to create a strong experience of being inside a room and then using this to simulate a participant's growing or shrinking relative to the virtual room as determined by the narrative: When the participant performs an action (eats or drinks) the projected room becomes smaller in a particular animation that gives the participant the impression that she is growing. When she performs a second action (eats or drinks) the room becomes bigger, giving the participant the impression that she is shrinking. Both actions feature specifically designed sound effects (custom developed echo and reverb effects on the ambient sounds), which emphasize the impression that the participant herself is getting smaller or bigger. During the experiment we observe if the participant takes the physical key. The action of taking the key is coupled with a virtual key that appears in front of the virtual door featuring VR sparkles and a piano "fantasy" sound.

Each step on a pressure sensor results in a cracking sound played on loudspeakers. 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, the cracking sounds are shorter and lighter. An additional ambient sound is

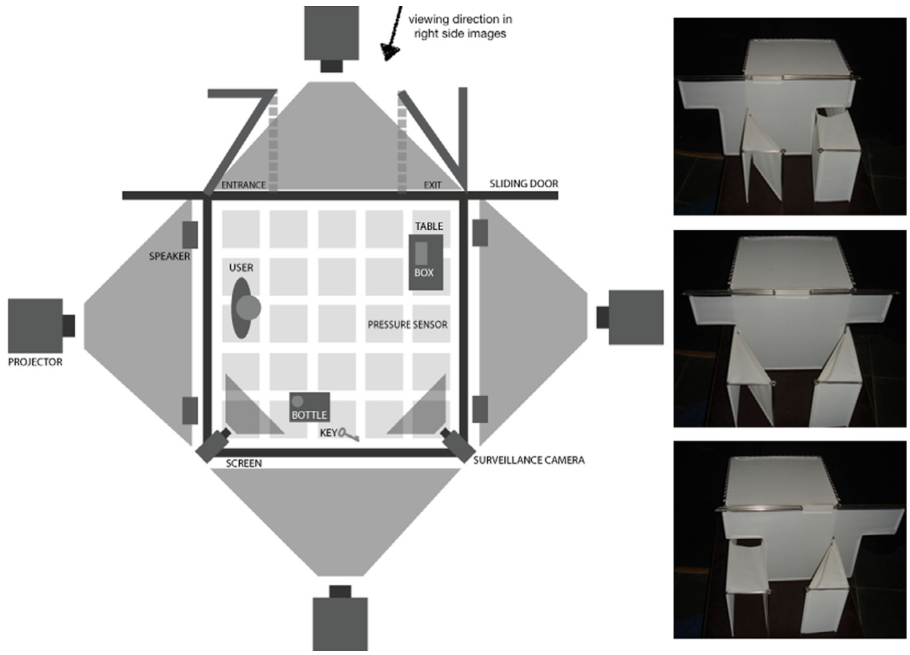

Fig. 1. Overview of "*Eat me, drink me*" stage. (a) left, the schematic overview of the physical setting as a floor plan, a view from the top of the installation; (b) right, the scale model of the CAVE in a perspective view (direction indicated in left side figure), from top to bottom: (1) the entrance is opened, (2) the entrance and exit are closed, (3) the exit is opened.

Fig. 2. Physical objects in the immersive environment.

played in the background that consists of fantasy music and water drops. This was implemented to give a better impression of the spatial properties of the stage; the water drop sound features a different echo depending of the relative size of the VR room.

Feedback and feedforward. The position of the participant in the room is used as input for the interaction. The interactive doorknob gives hints for possible participant actions. When the participant approaches the VR door (Fig. 3b), but is still too big to fit through, the doorknob says: *"Sorry! You're way too big."* When the participant approaches the door and has no key with her, the doorknob says: *"No use. Haha! I forgot to tell you. I'm locked."* And if the participant approaches the door with the key in her hand, the virtual door will open and reveal the exit. If the VR door opens the participant sees the White Rabbit in a beautiful garden waving and saying: *"Oh, dear! Oh, dear! You will be late"*(Fig. 3c).

A narrator voice gives guidance based on the participant's behavior. As the participant moves around in the environment, the number of triggered pressure sensors is counted. When the number of steps passes eight the narrator voice says: *"Are you just moving around in here, will you ever find the way out?"*. If standing on the same position is detected the narrator voice says; *"Oh dear! You are just standing here!"*.

To facilitate the progress through the story, we introduced explicit feed-forward hints from the interactive doorknob, like *"Alright, try the bottle"*, *"Now try the box on the table"*. After three minutes, the doorknob gives the appropriate guidance, depending on the last taken action from the participant and waits for the participant to finish it.

System structure. The 3D model projected on the CAVE is designed and animated in 3DS MAX and imported into the game engine Unity. We used Blender to design, rig and animate the virtual 3D characters and we imported them into Unity. To control the environment we have a setup of five computers, one server and four clients. Each computer is connected to a projector that projects one part of the five-sided virtual room.

A schematic overview of the used software is depicted in Fig. 4. We used Processing to control the sliding door and play the ambient sounds in the environment. In Processing we receive the input from the pressure sensors and calculate the number of triggered sensors. The performed actions of the participant (eating/drinking/taking the key) are received in Unity, where we control the animations and the featured sounds. We used the Open Sound Control protocol to transfer data between Processing and Unity.

3.2. Procedure and participants

The participants were invited to take part of the "Alice's Adventures in Wonderland" and they were led into the room with the instruction to "have fun". It was not mentioned to the participants that it is interactive environment, or how and when they should find the way out from the VR room. They experienced one of the following interaction modes:

– Interactive environment (IE): The environment used all the available interaction features of the "Eat me, drink me" stage as explained above. The interactive setting was designed to give

Fig. 3. The virtual room and characters. (a) User inside the CAVE (b) VR door with interactive doorknob (c) White Rabbit in the Garden.

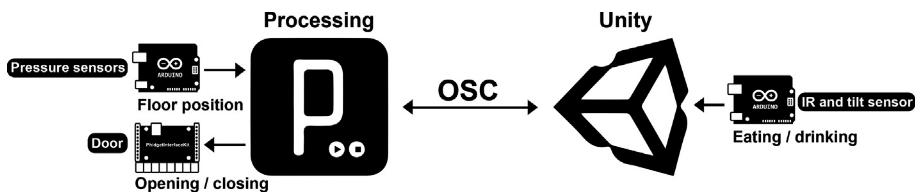

Fig. 4. Schematic overview of the software.

a range of feedback and feedforward messages from the story characters. The feedback is implicit and depends on the actions of the user in the physical environment (walking, standing, drinking, taking cookie). For example, the steps of the participants are coupled with sound design simulating a wooden floor; a narrator voice gives feedback on the behavior of the participant over longer time (by observing if she walks or stands in the environment). Explicit feedback is given by a doorknob: if the participant does not find the exit, after ten minutes, the doorknob points out which actions can be taken in order to finish the intended story plot.

– Non-interactive environment (NIE): A pre-programmed scenario of the story plot is played without taking in consideration the behavior of the user. This scenario uses ten features of the IE scenario.
– Non-interactive with minimum stimuli (NIMS): A pre-programmed scenario of the narrative that involves minimum stimuli is played. This scenario uses only four features of the IE scenario.

Forty-one participants joined the study, all university students from 18 to 33 years old (13 female, 28 male, mean age 23 with a standard deviation of 3). None of the participants had previous experience with the ALICE installation. By random selection the participants experienced one of the three settings: 12 participants joined the IE setting, 16 joined the NIE and 13 the NIMS setting. Due to the random assignment of participants to the different treatments, only the NIE condition was gender-balanced. After the experience in the room, the visitors answered a questionnaire. All experimental sessions took less than 20 min: the experience itself took approx. 4 min and filling the final survey approx. 15 min. The participants were observed through several security cameras by an experimenter who, depending on the experimental condition, would interact with the participant, prompting actions or even giving them hints how to proceed through the narrative.

3.3. Measurements

The experiment with 41 participants measures participants' experiences through self-reports given in different questionnaires, and the participants' behavior through recording and observation.

Presence. Participants were administered with the ITC-Sense of Presence Inventory (ITC-SOPI) to evaluate their levels of physical presence [26]. The ITC-SOPI is a validated 44-item self-report questionnaire that was used in this study to measure how physically present and involved the users feel in the storytelling environment through four factors: spatial presence, engagement, ecological validity and negative effects.

Agency. We measured the subjectively perceived agency based on the perceived proficiency, the perceived responsiveness and technical aspects of the environment and how much the participants are aware of their influence on the events in the environment. The following items were created: *"I felt proficient in my actions with the environment during the experience"*, *"I was aware of my influence on control mechanisms in the environment"*, *"I felt that the environment was responsive to my behaviors"*. Since agency is perceived when the actions of the user are causing the intended effect on the mediated world, we added items to check if the user's intention and the hints from the environment match. *"I knew what actions I should take to do to go out"*, *"I knew what I should do because the environment gave me a hint"*, *"The physical objects were obvious hint for interaction"*. All items were rated on a 5-point Likert scale between *"Very dissatisfied"* – *"Very satisfied"*.

Satisfaction. We also measured how much the participants appreciated the experience. They were asked to rate the experience on several scales. First the general experience, *"The experience was:* ... on a 5-point Likert scale between *terrible, okay, good, great, best thing of entertainment experiences, best thing in my life"*, and second comparing to other mediated experiences *"This is one of the best mediated experiences I have ever had"*, and rating enjoyment *"I have really enjoyed myself during this experience"*, both on a 5-point Likert scale between *"Very dissatisfied"* – *"Very satisfied"*.

Behavioral measures. We observed the users' behavior via video records from the surveillance system. The actions of the users recognized by the sensing mechanisms (pressure sensors, IR and tilt sensors) were recorded in a text file. We noted the actions that participants performed: walks around, touches objects or walls, eats, drinks, takes the key; and the emotional reactions such as smiling, laughing and verbal communication. The distinction of more complex reactions like confusion, frustration, or satisfaction was based on the verbal reactions and body language.

4. Results

Distributions. The experiment results include questionnaire data submitted by all 41 participants and interactivity recorded from 28 participants. First we will look at the self-reported items which included factors generated by the ITC-SOPI questionnaire, the agency and satisfaction questionnaires. Fig. 5 illustrates the means of the factors, spatial presence, engagement, naturalness, negative effects, agency data, and satisfaction, for each condition: IE, NIE and NIMS. The figure plots the results as six differently color-coded box plots grouped by condition. Outliers for the different dimensions are present in the data and plotted accordingly. For the three conditions, five of the six dimensions show similar results: satisfaction, engagement and spatial presence are rated high with all medians and even 1st quartile ranked above 3. Naturalness is ranked between 2.5 and 3 for all conditions and the dimension Negative Effects is ranked below 2.5 for all conditions (both regarding the third quartile). The Agency data is generally ranked between 4 and 2, and this dimension shows larger differences in the different experimental conditions which are analyzed and described below.

ANOVA. Differences between the means for the three conditions for presence, engagement, naturalness, negative effect and satisfaction were examined for significance using a one-way ANOVA for a between-group design. The results showed no significant differences between the three conditions for presence, engagement, naturalness, negative effect and satisfaction. Overall, it can be noted that measurements for the NIE and NIMS conditions resulted in more outliers and larger variance, which is also visible from Fig. 5. For the agency factor, however, different observations could be made: A one-way between subjects ANOVA was conducted to compare the effect on agency for IE, NIE and NIMS conditions. There was a significant effect on agency for the three conditions [$F(2, 38) = 8.209$, $p = 0.001$]. Post hoc comparisons using the Tukey HSD test indicated that the mean score for the IE condition ($M = 3.56$, SD = 0.54) was significantly different from the NIE condition ($M = 3.02$, SD = 0.54) and the NIMS condition ($M = 2.71$, SD = 0.49). The NIE condition did not significantly differ from NIMS condition.

Taking the data from the sensing mechanisms, we counted the number of actions that were triggered by the users (cf. Fig. 6a). These data were recorded for 28 participants, and we considered only actions that were relevant to the narrative: eating, drinking, and interactions with key and door of the CAVE. We compared the number of actions by the participants in each settings for the IE, NIE and NIMS conditions with one-way ANOVA. There was a significant difference for the three conditions [$F(2, 25) = 6.237$, $p = 0.006$]. Post hoc comparisons using the Tukey HSD test showed that the mean score for the IE condition ($M = 5.08$, SD = 2.46) was significantly different than the NIE condition ($M = 9.06$, SD = 4.14). The NIE condition is significantly different from the NIMS condition ($M = 4.66$, SD = 3.44). However, the number of actions from the participant in the IE condition does not differ significantly from the NIMS condition. The analysis of agency in the different treatments is again reproduced as Fig. 6b to allow for a comparison with interactivity.

5. Discussion

The results showed that the different treatments, i.e., interaction types, did not influence the feeling of presence and the satisfaction visitors gained from the experience. We originally expected that the presence factors of the interactive environment with several interactions that were integrated with the narrative would be significantly higher than those of the NIE and NIMS environments. We assume that the CAVE as a strongly immersive environment contributes for high ratings of presence even though the environment does not respond to the actions of the users.

Through observation of the actions of the users and by quantifying the number of actions we noticed clear differences in the users' behavior. The participants that were immersed in a not responsive environment (NIE) were more active and tried out more interaction possibilities (touch, walk, look around). The participants who experienced minimum stimuli in a non-interactive environment (NIMS) did not performed as many actions, instead they would rather stand and look around. The participants in the non-interactive environment (NIE) more often showed confusion and frustration, while the participants in the interactive environment (IE) seemed satisfied every time they discovered an interaction asset. The stimuli provided by the environment evoke different behaviors and with that also a different personal user experience.

In the interactive setting (IE) everyone had slightly different experience depending on the triggered stimuli and the actual context. Not everyone would reveal all of the events from the narrative, e.g. the virtual garden was visible only if the participant approached the small VR door and had the key. The order in which they would discover the events or the pace in which the story would be played differed for different participants. The events from

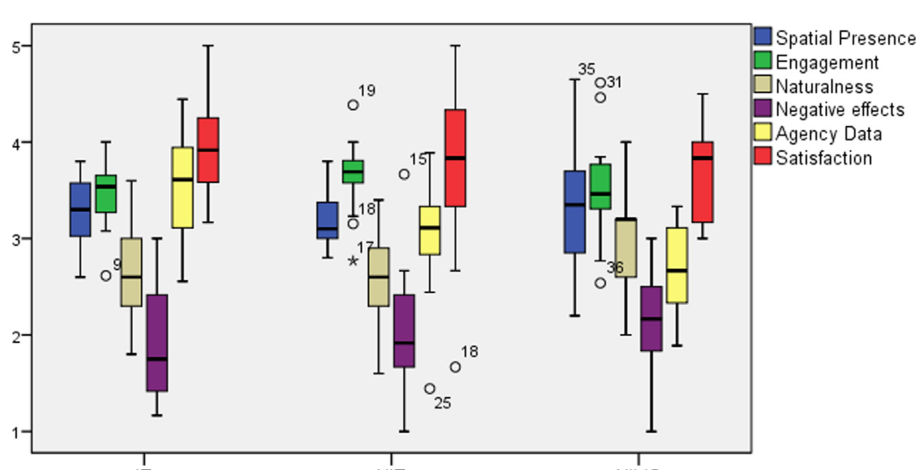

Fig. 5. Dimensions of the presence (spatial presence, engagement, naturalness, negative effects), agency and satisfaction by treatment conditions: IE, NIE and NIMS.

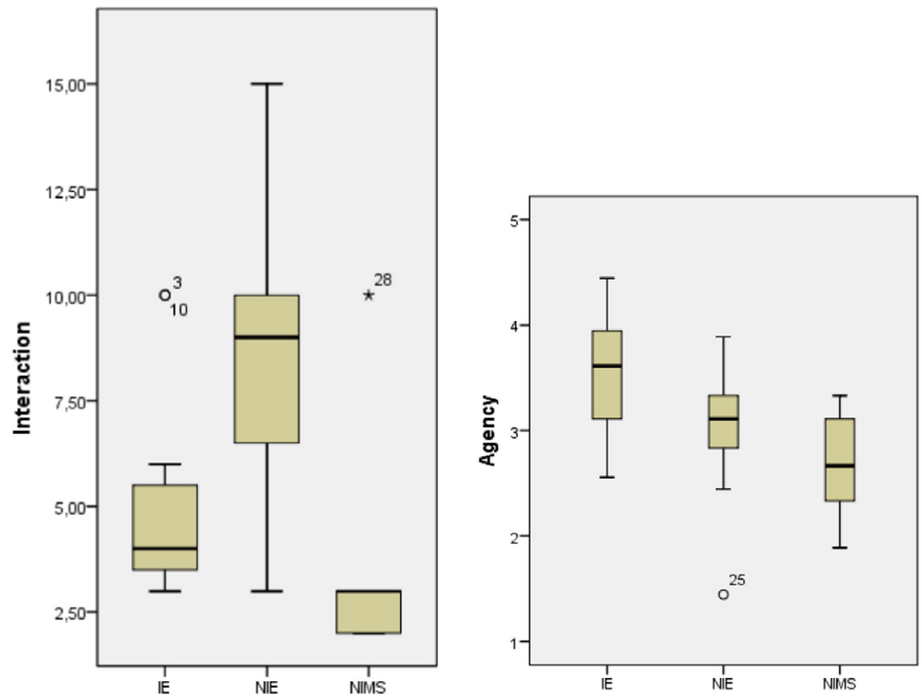

Fig. 6. Treatment comparison by (a) interactivity (mean of the number of participant actions as interactivity metric per participant by treatment conditions; actions relevant to the narrative such as eating, drinking, key and door interactions were considered) and (b) self-reported agency, for IE, NIE and NIMS conditions.

the story were context related and they would trigger only if the person was at the right place on a right time.

We have to point out that results obtained with the different settings over short durations of time have to be taken with precaution since its effects may vary over longer time periods. One limitation of this study is the usage of subjective post hoc measures of experience such as ITC-SOPI, where presence and engagement are measured based on the overall perception of the immersive environment.

6. Conclusion

This paper describes an experimental study that was performed in the fully realized interactive story *"Eat me, drink me"* which is inspired by one of the chapters from the narrative "Alice's adventures in Wonderland" [10] as part of the interactive mixed reality ALICE installation. We present the essential aspects of the narrative episode as an interactive story, the technology utilized to realize the experimental setup with the desired experience, and important design decisions that went into creating the system. We investigate the user interaction and measure the overall experience in three conditions: with a fully interactive environment (IE), in a non-interactive, but dynamic setting (NIE), and in a non-interactive setting with minimal stimuli. The findings of the between groups experiment with 41 participants show that immersiveness is not necessarily depending on the modality of the stimuli, but instead on their time density. The study thereby contributes to our knowledge about the design of interactive and mixed reality spaces, and how the responsiveness and the amount of stimuli induce or bias behavior and experiences. In future studies, this effect could be explored in more detail looking, e.g., at specific effects of different modalities or potential other contributing factors that influence the perception of immersiveness under time-density controlled stimuli. Further studies could also explore the user experience in an enriched interactive setting that implements more challenging scenario of the interactive narrative.

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