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# On the role of interaction mode and story structure in virtual reality serious games

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ABSTRACT

Educational Environmental Narrative (EEN) games in Virtual Reality (VR) provide rich, high-fidelity environments that provide a fully immersive and interactive storytelling experience for use in teaching. Yet, it is not fully known how learning experience is affected by freely exploring the environment (interaction mode) and having an explicit story structure. A randomized controlled 2 × 2 study with 42 adolescents was performed to correct this omission and find the effect that these two factors have on recalling important information and on how a player feels when playing a game. They explored an EEN VR game with different interaction modes (active vs passive) and story structures (explicit vs implicit) and then completed a knowledge test and standardized questionnaires, regarding their sense of presence, cognitive interest and engagement during the game. Results show that allowing players to navigate freely through the game has positive effects on cognitive interest and a feeling of presence. An implicitly structured game leads to increased recall of spatial information. However, for optimal learning of factual knowledge, guidance is beneficial.

## 1. Introduction

In the early 21st century, the use of Virtual Reality (VR) and games in general as teaching tools has become widespread, particularly with simulation games. This genre denotes games in which a complex process or mechanism is modelled and via interaction the player learns about it. One of the most well-known, off-the-shelf simulation games, is Sim City (Maxis, 1989). This was adapted to be used in education by Tanes and Cemalcilar (2010). They found that players changed their expectations of an ideal city to match the game as well as their expectations of, and appreciation towards city officials. Similarly, Woessner (2015) successfully created guidelines that enabled the simulation game to be used to illustrate important American government concepts in a classroom environment.

Outside of well-known, off-the shelf games, the growth of simulation games, and VR in particular, on the domain of training in the healthcare industry was noted by Wang, DeMaria, Goldberg, and Katz (2016). They found an increase in games developed, from two games with two genres to 42 games and eight genres from 2007 to 2014. Indeed, more and more surgeons use virtual reality training systems that have been proven to enhance performance in the operating room (Thomsen et al., 2017). Also, in the domain of the military, the use of video games has significantly progressed, from the US Marines using a modified copy of the video game Doom (id Software, 1993) to tailored and sophisticated simulations for drills and training (Curry, Price, & Sabin, 2015). One of the latest VR battlefield simulators Virtual Battlespace 3 (Bohemia Interactive Simulations, 2014), is used by multiple countries' armed forces and enables users to interact with the game and each other from different locations. Finally, on the domain of emergency training, Feng,

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González, Amor, Lovreglio, and Cabrera-Guerrero (2018) showed a transition from traditional training approaches for evacuation training or hazard awareness to VR serious games due to these being highly engaging and promoting greater knowledge transfer. The growth of these games in multiple different domains and industries are testament to the success of this technology for information acquisition and skill improvement.

With the growth of VR and the popularity of games as a means for storytelling, another type of simulation game is growing: 'Walking Simulators', a "genre of video games which lacks many of the traditional aspects of a game (such as a goal, win/loss conditions, any kind of game system to interact with) despite taking the form of a video game" (Prata, Oliveira, & Melo, 2018, p. 202). In Walking Simulator games players move through the game environment, often without a clear goal, explore the world offered by the game and while doing so learn gradually more and more about it. A genre called Environmental Narrative (EN) games would also fit into this category with the most well-known of these games is "Dear Esther" (The Chinese Room, 2012) being released to critical acclaim and leading to similar games being developed for VR platforms, such as the highly-rated "The Price of Freedom" (Construct Studio, 2016). EN games are characterized by rich, high-fidelity environments which are often unpopulated, but scattered with evidence of human activity which relates to the overarching narrative. The narrative is typically communicated through voice-overs or written artefacts which reveal the story in an intriguing, non-linear fashion (Habgood, Moore, Alapont, Ferguson, & Van Oostendorp, 2018). Revealing the story in this way promotes 'cognitive curiosity' (Malone & Lepper, 1987). This requires players to build and rebuild their own meaning through their active and free navigation in a constructivist-like process of assimilation and accommodation (Piaget, 1950) though some form of guidance (Vygotsky, 1978) remains important. As such, this genre naturally lends itself to experiential, discovery-based learning approaches (Harrington, 2012). It is this idea, which leads to the genre of Educational Environmental Narrative (EEN) games, which aim to use this technology for education and learning.

In this study, we examine what the effective components of EEN games are. For this, we will investigate possible effects of both active navigation (freedom of choice) and an explicit story structure on the acquisition of knowledge. These were chosen as these types of games encourage exploration by promoting curiosity and come with strong narratives. In addition to knowledge retention, we will assess players' feelings, while playing an EEN game. The idea is that manipulating these two variables will enable us to examine what variables are important for learning and player experience.

### 1.1. *The role of interaction mode*

Within education, it is debated whether or not learning improves when students are allowed to explore the educational content and given choices on what to learn freely or if students must be strictly guided in the topics to be learned. On the one hand, in classroom environments, teachers present students choices because they believe it increases effort and learning (Flowerday & Schraw, 2000) and educational literature even indicates that choice leads to increased cognitive engagement, positive affect, creativity, and achievement (Kohn, 1993). On the other hand, Flowerday and Schraw (2000) also found that choice has a negative effect on cognitive task performance but a positive effect on attitude. Also Flowerday, Schraw, and Stevens (2004) report that effects of choice on learning are small, with choice having more effect on personal engagement and attitude. Moreover, it has also been found that controlling environments reduce autonomy, decrease motivation, and result in lower attitudes and performance in the classroom (Flink, Boggiano, & Barrett, 1990; Grolnick & Ryan, 1987; Miserandino, 1996). This could imply that giving students a choice could lead to a better interest in the subject matter and higher levels of engagement, at the risk of hindering learning performance.

The choice between freedom of choice and strict guidance can be traced back to the Zone of Proximal Development (ZPD): "the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem-solving under adult guidance or in collaboration with more capable peers" (Vygotsky, 1978, p. 86). This suggests that students can carry out easier tasks independently but require guidance to reach the next level and complete more difficult tasks. ZPD is usually combined with the concept of flow: "… the holistic sensation present when we act with total involvement." (Csikszentmihalyi, 2014, p. 136). In fact, Basawapatna, Repenning, Koh, and Nickerson (2013) presented a novel framework combining both theories and found that it was able to keep classrooms engaged and enable students to advance to more complex topics. In spite of this, it must be noted that focusing on full guidance could lead to players being assisted in tasks that they could already accomplish without assistance. This could account for the more positive attitude found in players that have freedom of choice.

When investigating video games in particular, this freedom of choice versus guided learning approach can also be applied in the context of the interaction mode that is present in a game: active navigation, where the player chooses which path to take, or passive navigation, where players are put on a set path similar to a guided tour in a museum. In this regard, research into games backs up the results found in classroom research. For instance, Conniff, Craig, Laing, and Galán-Díaz (2010) found that players were more motivated and attentive and felt more present in an active navigation condition, supporting further arguments that greater involvement and immersion occur as a result of increased interaction with an environment (Ysselsteijn, Freeman, & De Ridder, 2001; Witmer & Singer, 1998). On the other hand, Topu and Goktas (2019) instead found that there were higher levels of cognitive engagement as well as achievement when users were given guidance through a virtual environment.

The effect of these contrary interaction modes has also been investigated concerning spatial memory. It was found that memory for spatial layout was better with active navigation compared to passive (Brooks, 1999; Christou & Bülthoff, 1999) and that passive navigation was not sufficient for creating a sense of place (Conniff et al., 2010). However, it must be noted that Gaunet, Vidal, Kemeny, and Berthoz (2001) found no difference.

Based on this brief review, it would be expected that the attitude of players, namely engagement, presence and cognitive interest, in a virtual environment would be better in active interaction and also lead to better spatial knowledge retention. However, the literature on the retention of factual knowledge is sparse and inconsistent, so it remains to be seen which type of navigation is beneficial for this. The literature points towards the fact that players will recall more factual knowledge due to being guided through the environment and being less overwhelmed but, conversely, it could be that the lack of choice affecting their attitude may result in lower recall.

### 1.2. The role of story structure

Story structure is often cited as important in the context of education, particularly when it comes to retention and recall. This is of high importance as this is how assessments take place in the form of examinations. There is a wide array of consistent research into the positive effect of a strong story structure on learning. People use a story schema as a means for understanding as well as use it as a set of retrieval cues (Bartlett, 1932) and texts with a clear structure help in understanding and retention (Lorch, Lorch, & Inman, 1993; Rouet, 2006). Story-based texts are better comprehended than texts without storylines. They are read faster and better recalled (Graesser, Hauft-Smith, Cohen, & Pyles, 1980; Norris, Guilbert, Smith, Hakimelahi, & Phillips, 2005; Thorndyke, 1977; Zabrucky & Moore, 1999).

When investigating the effect of story structure in games, in particular, strong explicit story structures in educational games were found to have a positive effect on declarative knowledge acquisition (Gustafsson, Katzeff, & Bang, 2010; Smith & Baker, 2011), performance (Kelleher, Pausch, Pausch, & Kiesler, 2007) and particularly a positive effect on procedural knowledge or skill acquisition (Serrano & Anderson, 2004). Research also found a positive effect on learning, (programming) skills and engagement (Dickey, 2006; Dickey, 2011; Jemmali, Bunian, Mambretti, & El-Nasr, 2018; McQuiggan, Rowe, Lee, & Lester, 2008; Rowe, Shores, Mott, & Lester, 2011). Moreover, in their recent quantitative meta-review, Wouters and van Oostendorp (2017) report a positive effect of narrative elements in games, especially on motivation. This indicates that a strong story structure is necessary for optimal learning as well as keeping the player engaged and motivated, which are important indicators of learning. On the other hand, Adams, Mayer, MacNamara, Koenig, and Wainess (2012) found no positive effect on declarative knowledge and Garneli, Giannakos, and Chorianopoulos (2017) found no performance effect at all. Moreover, some research was only able to find an effect on motivation and enjoyment (Armstrong & Landers, 2017; Bopp, 2016; Cordova & Lepper, 1996; Hsu & Wang, 2010; Kopfman, Smith, Ah Yun, & Hodges, 1998).

All in all, multiple claims have been made about the importance of structuring educational content, particularly when recalling stories (Mandler & Johnson, 1977); but, this has not (yet) been applied to EEN VR games. This study will inform on whether an explicit structure is important for recalling information learned in these types of games as well as the effect this has on how a user feels whilst playing the game. In addition to this, because of the planned implementation of the implicit storyline condition (see methods section), it is expected that this condition may also have a positive effect on the recall of spatial information. Rather than players having to follow the explicit story structure to continue to different parts of the game, they will be able to explore the whole environment from the beginning and, thus, be able to build up a detailed spatial mental representation.

We assume that story structure and the specific interaction mode are important features of EEN VR games. We want to know empirically the importance of each, and also of their eventual interaction effect on learning and feeling (presence, engagement, and cognitive interest) of participants. Therefore, the current paper explores the effect of both interaction mode and story structure via a randomized controlled trial (RCT). This involves playing a narrative serious game in a VR environment, identifying if an explicit story structure and interaction, in the form of freedom of choice, is necessary for retention and positive experience.

## 2. Research questions

In a randomized controlled study with a 2 × 2 factorial design, we will examine the underlying factors (interaction mode and story structure) determining the effects of EEN VR games on learning and player experience. The following research questions will be studied by examining two variables that together, might be involved:

a. What is the role of typical VR interaction and interactive navigation compared to merely a passive simulation, i.e. navigating through a virtual environment without interactive opportunities, such as a guided tour?
b. What is the role of structuring educational content through an explicit story structure compared to an implicit story structure, i.e. a virtual environment where the in-game story is completely unstructured and the story structure implicit?

Both of these variables (interaction mode - passive *vs* active - and story structure – implicit *vs* explicit) will be simultaneously examined in a 2 × 2 factorial design enabling to also investigate their interaction. For example, we might find that retention is better in the active interaction mode than in the passive interaction mode (guided tour) when the structure is explicit, and no difference when the structure is implicit.

Based on the above-mentioned related studies, we formulate the following hypotheses:

Compared to a passive simulation (guided tour), active interaction leads to:

a) Participant's improved understanding;
b) Lower retention of the materials after some delay;
c) Higher cognitive interest for the subject matter
d) More engagement and (sense) of presence; and

e) A mental representation that is more detailed and includes more accurate spatial information.

Compared to implicitly structured games, explicitly structured games lead to:

a) Participant's improved understanding;
b) Higher retention of the materials after some delay;
c) Higher cognitive interest for the subject matter; but
d) Less engagement and (sense) of presence; and
e) A mental representation that is less detailed and includes less accurate spatial information.

Regarding the interaction effects of structure with interaction mode, it is predicted that structure will have no significant effect within the guided tour conditions compared to the conditions featuring active interaction. This is because the guided tour provides the structure that is missing in the implicit-structured condition.

## 3. Method

### 3.1. Participants

A total of 42 adolescents, 38 males and 4 females, aged 13–17 (mean: 15.12, SD: 1.17), were recruited from a University Technical College. They had differing levels of VR experience and indicated this experience on a post-experiment questionnaire on a 5-point Likert scale (from 1 = "Used very little" to 5 = "Used all the time"; mean: 2.57, SD: 1.31). Informed consent, both individual and parental, was obtained before the experiment along with information that would disqualify a participant from taking part, such as being susceptible to migraines. The participants were randomly assigned to the four conditions, making groups of 12 (2 female), 10, 10 (2 female), and 10 participants.

### 3.2. Materials: game, measurements, and apparatus

*Game:* "The Chantry", an EEN game for the PlayStation VR platform, is used in this study. This tells the story of Dr. Edward Jenner and his invention of vaccination against the smallpox virus (https://jennermuseum.com/). The game describes the background of Dr. Jenner, where and when he lived and what events he experienced and how he came to the end of his life. To progress through the game, the player needs to explore the house of Jenner, finding out information in different rooms about a different story topics before moving on and navigating through the game. See Fig. 1 for some screenshots of the game.

In the original game, to progress, players interact with closed doors and even window shutters. Upon trying to open these, the player is presented with a list of objectives (see Fig. 2): items that contain story information, in the form of an audio narrative, which must be found and interacted with to continue through the game and access further parts. In the *explicit* story structure condition, these tasks will remain whereas, in the *implicit* structured version, these doors and shutters will be open from the start. Items can still be interacted with to access the game narrative but not interacting with these items will not hinder access to different parts of the game as what happens in the original version of the game.

For the *active* interaction condition, this will be the same as the original game, where the player can choose where to go, in which order to pick items up and how long to stay in one place listening to the game narrative. On the other hand, those in the *passive* interaction condition (guided tour) will be forced to take the most optimal path through the game, picking up items in the most appropriate order and being forced to listen to the complete audio narrative before moving on (see Fig. 3). Apart from the differences in structure and interaction, all of the participants played the same game with the same educational content.

*Measurements:* To evaluate learning in the game, participants were provided with a short knowledge test, consisting of 24 true/false statements about the in-game story to gauge how well this was remembered. 16 of these questions concerned facts, relating to the story, and 8 involved spatial aspects, relating to the location of items/rooms in the game. Standardized questionnaires consisting of 5-point Likert scales were used to measure engagement (Brockmyer et al., 2009), presence (Igroup, 1999) and cognitive interest (Schraw, Bruning, & Svoboda, 1995).

*Apparatus:* Each participant wore a Sony PlayStation VR headset (model: CUH-ZVR1) to play the game on a Base PlayStation 4 Development Kit. They controlled the game using a standard PlayStation DualShock 4 controller (model: CUH-ZCT1). To realize maximum comfort, all groups wore their own over-ear headphones for audio. To control the game, participants used their head movements to look at a node and used a single button press on the controller to move to that node or pick up an item. In the active interaction condition, an item is moved and rotated by doing the same action holding on the controller, this is done automatically in the passive interaction condition.

### 3.3. Procedure

Upon being seated, participants were given instructions in both oral and written form. This involved safety information, such as not to try and physically grab anything and what to do in the event of motion sickness. This was followed by instructions on what to do in the game and how to use the controls. After all of the participants were satisfied with the instructions, they were given 30 min to play through the game, including a simple controls tutorial and learning about the story.

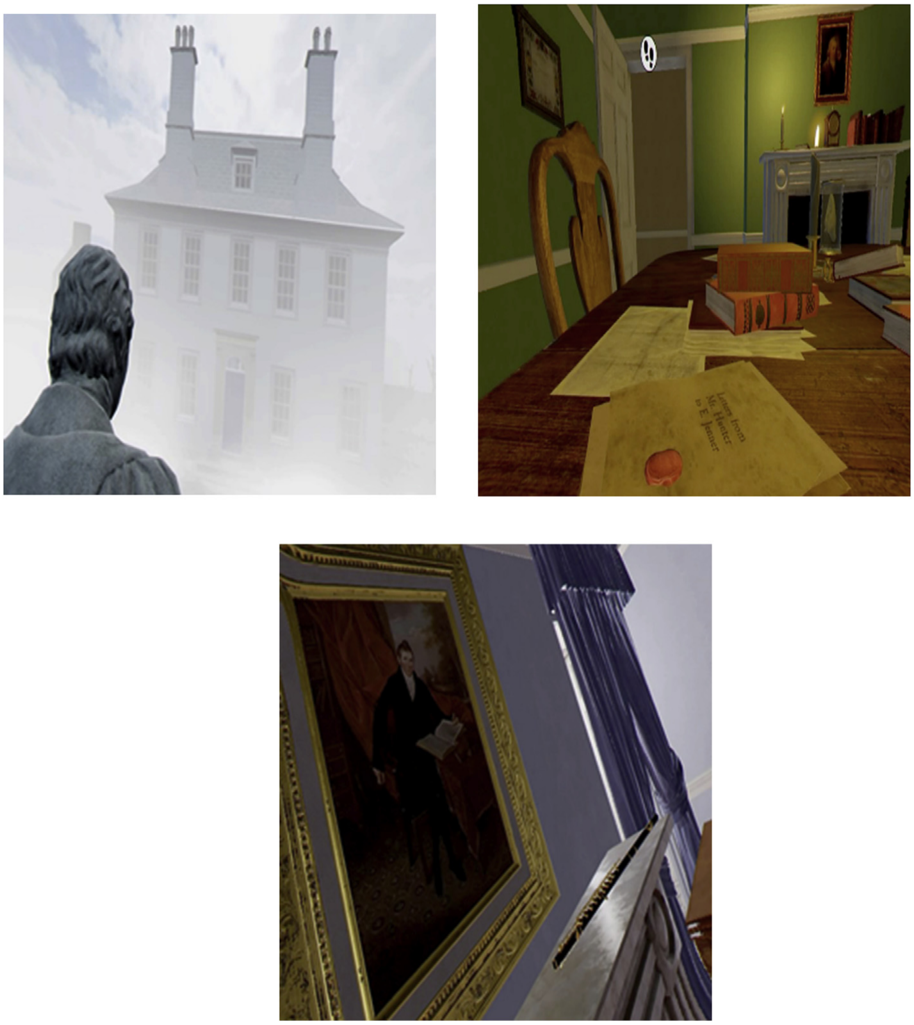

**Fig. 1.** Screenshots of the game.


**Fig. 2.** The objective lists that provide the explicit story structure in the game. These are removed in the implicitly structured version.

Afterward, the participants were invited to complete the knowledge test and the three questionnaires (see Subsection Materials: Game, Measurements and, Apparatus). Once these were completed, all of the participants were debriefed and informed about the nature of the study, including how their condition differed from the full game, and the future plans for the game.

After the experiment, the average scores on the engagement, presence, and cognitive interest questionnaires, and the percentage of correct answers on both the factual and spatial questions of the knowledge test were collected and analyzed.


**Fig. 3.** The left picture shows the active interaction condition, where more than one option is available, and the right picture shows that the player is forced to choose the option on the right.

## 4. Results

A Multivariate analysis of variance (MANOVA) was performed to see if there was a significant difference between passive *vs* active interaction as well as between explicit *vs* implicit structure of the game. Presence, engagement, cognitive interest, and the results on the spatial and factual knowledge tests were examined as dependent variables. Interaction mode and Structure were independent between-subjects variables. Player age, gender, and VR experience served as covariates. Interaction mode was found to have in the MANOVA an overall significant effect in favor of the guided tour ($F(5, 31) = 4.006$, $p = 0.006$, $\eta_p^2 = 0.393$), whereas the variable structure showed neither a main effect nor was an interaction effect found. Means and standard deviations are shown in Table 1.

Next, we analyzed the univariate effects on the dependent variables. It was found that all but one of the dependent variables were affected by one or more of the conditions. The number of correct answers based on the story (factual knowledge) was significantly affected by interaction mode ($F(5, 31) = 7.203$, $p = 0.011$, $\eta_p^2 = 0.171$), in favor of the guided tour condition, with participants giving approximately 10% more correct factual answers (see Fig. 4). Although the interaction mode affected factual knowledge, this was *not* true for spatial knowledge. Moreover, when we investigate the effect of structure on spatial knowledge, we find an effect in favour of implicit structure ($F(3, 31) = 4.373$, $p = 0.044$, $\eta_p^2 = 0.111$), where approximately 7% more correct answers were given by participants (see Fig. 5). No significant interaction effects were found.

Interestingly, cognitive interest was significantly affected by the interaction mode ($F(5, 31) = 4.65$, $p = 0.038$, $\eta_p^2 = 0.117$), in favor of active interaction (see Fig. 6). There was also a significant difference in participants' experienced presence ($F(5, 31) = 4.163$, $p = 0.049$, $\eta_p^2 = 0.106$) in favor of active interaction (see Fig. 7). This shows that freedom of choice does lead to a better experience although no differences were unveiled on engagement across any of the conditions.

There was a significant overall effect of the covariate age ($F(5, 31) = 2.941$, $p = 0.028$, $\eta_p^2 = 0.322$). This can be contributed solely to spatial knowledge ($F(5, 31) = 8.136$, $p = 0.007$, $\eta_p^2 = 0.189$), which increased with participants' age. For neither participants' gender nor VR experience differences were found.

## 5. Discussion and conclusion

VR Educational Environmental Narrative (EEN) games are used for environmental storytelling. In this study, we focused on active interaction and an explicit storyline within EEN games. This allowed us to verify whether or not both characteristics are important when it comes to knowledge acquisition and a positive experience: the key goals of these types of games.

**Table 1**
Mean and standard deviation (SD) of all measures of each condition.

| | Passive Interaction (Guided Tour) | | Active Interaction | |
|---|---|---|---|---|
| | Explicit Structure | Implicit Structure | Explicit Structure | Implicit Structure |
| Factual Knowledge (0–1) | 0.71 (0.12) | 0.66 (0.15) | 0.61 (0.11) | 0.56 (0.16) |
| Spatial Knowledge (0–1) | 0.45 (0.20) | 0.54 (0.17) | 0.50 (0.13) | 0.56 (0.12) |
| Presence (1–5) | 2.87 (0.37) | 3.06 (0.36) | 3.36 (0.47) | 3.18 (0.53) |
| Cognitive Interest (1–5) | 3.02 (0.82) | 2.8 (0.77) | 3.66 (0.85) | 3.39 (0.63) |
| Engagement (1–5) | 2.77 (0.72) | 2.98 (0.59) | 3.07 (0.61) | 3.07 (0.46) |

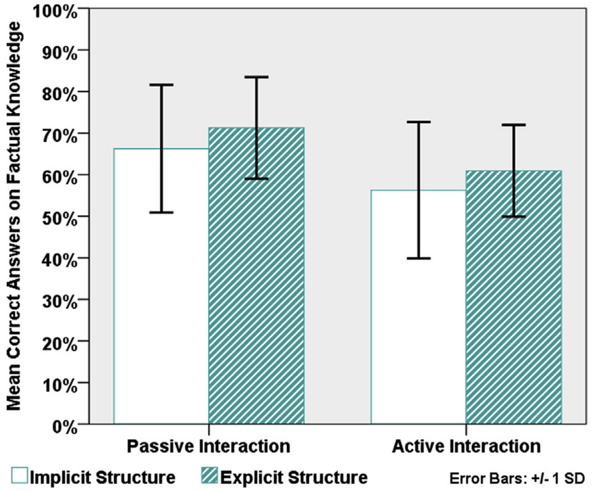


**Fig. 4.** Means of correct answers on factual knowledge questions in all conditions.

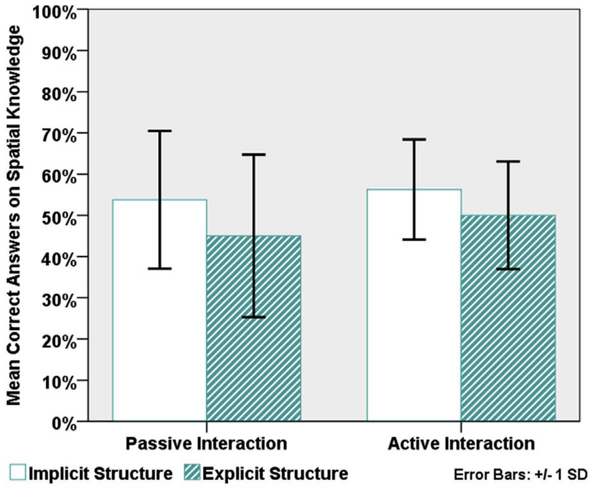


**Fig. 5.** Means of correct answers on spatial-based questions in all conditions.

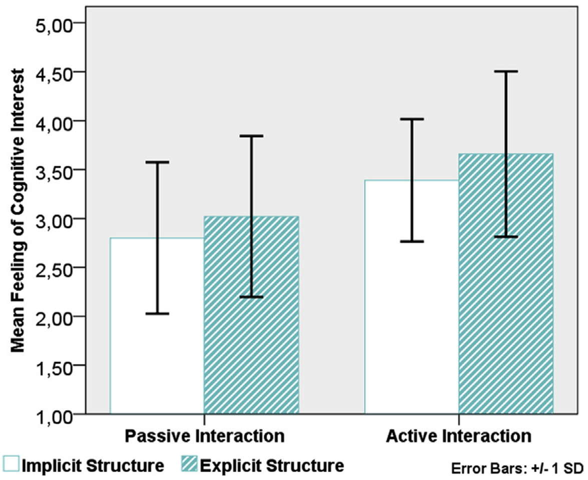


**Fig. 6.** Means of cognitive interest in all conditions.

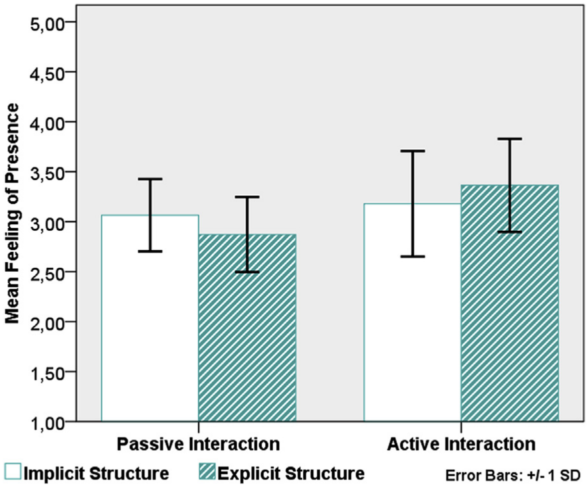


**Fig. 7.** Means of presence in all conditions.

Firstly, we examined the role of active interaction compared to a passive, guided tour. Some significant differences were found related to interactive mode. As predicted in the hypotheses, in the passive interaction (guided tour) condition, it was found that participants had higher percentage of correct answers on the test focusing on factual knowledge showing that participants were able to retain and recall knowledge better although, contrary to the hypothesis, there was no significant difference for spatial knowledge between conditions. This does, however, back up Vygotsky's (1978) theory of the Zone of Proximal Development as scaffolding through the guided tour (passive interaction condition) enabled participants to reach a higher level of learning. Nevertheless, it was shown that participants felt more present and showed more cognitive interest in the active interaction condition. This backs up the findings of Flowerday and Schraw (2000) who found that freedom of choice and interaction led to a negative effect on task performance (learning) but a positive effect on attitude. Unfortunately, one of these elements, less engagement, was unproven as no significant difference was found regarding engagement. On one hand, it is expected that cognitive interest would correlate positively with the higher retention of story-based knowledge measured in the guided tour condition but, on the other hand, this also fits with Flowerday and Schraw's (2000) research showing that people find a subject more interesting when given freedom of choice. This leads to an interesting dilemma where educators and developers of such games must choose between either a more positive learning experience for a player resulting from active interaction or better factual knowledge retention via a guided tour. Alternatively, as mentioned earlier, participants were fully guided in the passive interaction condition so they might have been assisted with tasks that they were already able to complete without assistance. This could account for the better learning but the lack of positive feeling. Therefore, if the game was able to detect and adapt when the player needs guidance, this could lead to optimal learning and a better positive feeling in the game. This could also get players into the aforementioned state of flow, implying full immersion whilst losing sense of physical space and time (Wegerif, 2013). This consideration points to a game environment in which adaptivity plays a role: only controlling and supporting a player when it is really necessary (Shute, Ke, & Wang, 2017).

Compared to the active interaction mode that allowed players to skip, the guided tour version of the game forced participants to listen to the full game narrative that contained the story information. Consequently, these participants were exposed to more of this content, which explains some of the increased factual knowledge retention. Because of this finding, before release, the game was modified to queue important narrative audio so that important information is still played even when the player moves on. It is also plausible to propose that these results could be interpreted as showing that EEN games influence learning better when a player is guided through the environment, perhaps by a schoolteacher. Future studies into the effect of an EEN game within a classroom environment would be beneficial for this area of research as it would show one of the possible applications of this kind of technology.

Secondly, we also examined the effect of maintaining an explicit story structure, where all story elements are explicitly structured in an effective order, compared to having an implicit structure. Only one significant difference, in favor of the implicitly structured version, was found. Participants scored higher on the spatial part of the knowledge test in the implicit version, showing that they were able to retain and recall this type of knowledge better when the game was not following an explicit structure. This can be explained by the fact that this condition effectively changed the game into an 'open-world' scenario, meaning that the entire game environment (and therefore a large amount of spatial information) was available to the participants immediately from the beginning of the game, rather than players having to follow the explicit structure to access areas of the game only available in later parts of the story. Moreover, this open-world design may have encouraged exploration around the environment and take in more spatial information, leading to this result. This, in turn, shows that a game with an implicit story structure (open-world) is best for spatial knowledge transfer without necessarily hindering factual knowledge acquisition.

Finally, there was an effect of the covariate age found, which was unexpected. However, this was only due to a highly significant relationship with spatial knowledge retention, which aligns with research from Gathercole, Ambridge, Wearing, and Pickering (2004) which found a linear increase in memory from age four through adolescence. As such, this study emphasizes the significant development of adolescent's cognitive skills and the importance of considering this when designing educational games, with and without VR.

Taken together, EEN VR games have the potential to provide a fully immersive and interactive storytelling experience for use in teaching. Yet, it is not fully known how learning experience is affected by freely exploring the environment and an explicit story structure, both characteristics which are assumed to be important for EEN VR games. This study showed that allowing players to navigate freely through the game has positive effects on presence and cognitive interest. Furthermore, an implicitly structured (open-world) game leads to increased recall of spatial information. However, for optimal learning of factual knowledge, guidance remains beneficial.

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