Awe Yields Learning: A Virtual Reality Study

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Abstract

There is a considerable amount of literature on the role of immersion and presence in virtual reality learning environments. Far less is known about the interaction of immersion and presence with the important individual characteristics that influence learning behavior, particularly, dispositional awe. Dispositional awe is manifested by an emotional response to information that defies existing mental schemas in a given domain and by a need to accommodate this experience. In a virtual reality study with eight elementary school classes, we investigated the interaction of immersive tendencies with dispositional awe and compassion on learning gains in the domain of nature conservation. We tested this interaction using a novel virtual reality concept in which children are sent to virtually simulated space to experience the overview effect, a cognitive shift in awareness reported by astronauts. The findings of the study showed that participants experienced strong feelings of awe and scored highly on overview effect constructs. Importantly, their learning gains were influenced by the overview effect which was, in turn, supported by presence, dispositional awe, and compassion. This study shows the potential of using immersive virtual reality experiences in educational programs, combining wonder and learning.

Keywords: learning; virtual reality; awe; structural equation modeling; ecological validity

Introduction

Virtual environments are considered to be highly immersive and to elicit a feeling of presence, thereby leading to an improved learning performance in some domains. For example, Alhalabi (2016) investigated performance using three different virtual reality (VR) systems with engineering students and reported significant improvements compared to non-VR engineering education. Similarly, Dede, Salzman, and Loftin (1996) showed that VR can aid in the learning of complex scientific systems. Roussou and Slater (2017) demonstrated that virtual environments can also benefit learning in children. Albeit not all learning in VR is effective, it is often found more engaging and motivating than other types of learning (Parong & Mayer, 2018). For example, de Back, van Hoef, Tinga, and Louwerse (2018) who compared performance in high- and low-immersive conditions on a spatial location task, did not find an effect on performance but reported a difference when considering measures of presence.

Presumably, the positive impact of virtual learning environments could be further amplified by engaging learners' emotions. The most relevant emotion experienced by learners appears to be awe, an emotion known to promote inquiry. An awe eliciting experience is triggered by encountering a person or an event that is perceived as much bigger, more complex or more important than the self (Keltner & Haidt, 2003). A typical example involves the experience of vastness, i.e., of open, rugged scenes, or an extreme level of perceived depth (Klatzky, Thompson, Stefanucci, Gill, & McGee, 2017). In addition to scenes, a famous or selfless person can be perceived as awe-inspiring as well (Graziosi & Yaden, 2019). Awe-inspiring events or scenes violate learner's current mental model about the world, and cause feelings of uncertainty that, in turn, cause a need for accommodation. The gap between current knowledge, and knowledge needed to accommodate that unexpected event, motivate learning (Valdesolo, Shtulman, & Baron, 2017). People who score highly on dispositional awe are more comfortable with altering their mental schemas (Shiota, Keltner, & Steiner, 2007), and are thus more open to learning from these experiences (Gottlieb, Keltner, & Lombrozo, 2018).

Inducing awe with the help of immersive VR has been shown to be successful in past studies (Chirico et al., 2017; McPhetres, 2019; Stepanova, Quesnel, & Riecke, 2019a). For example, Chirico, Ferrise, Cordella, and Gaggioli (2018) showed that virtual environments that were specifically designed to produce feelings of awe achieved this goal. The authors related the success of VR to participants having a high feeling of presence in the environment (Schubert, Friedmann, & Regenbrecht, 2001). Both Stepanova, Quesnel, and Riecke (2019b), and Quesnel and Riecke (2018) induced strong feelings of awe through VR by having participants view the Earth from space. This feeling of awe is linked to what has been called the overview effect (Yaden et al., 2016). The effect has been frequently reported by astronauts who experience a cognitive shift in awareness when viewing planet Earth from space (White, 2014), and when reflecting on this experience (Nezami, 2017).

In the current study, we investigate the link between an awe-inspiring VR inducing the overview effect and learning in an ecologically valid setting. The learning program taught in several primary schools in the Netherlands, could be considered a bridging program (Moher, Johnson, Ohlsson, & Gillingham, 1999). Below, we first give an overview of the theoretical framework on which our study was based, using a

structural equation modeling approach. Subsequently, we describe the methods of the study and its outcomes.

Theoretical Framework

We followed Makransky and Petersen (2019) and used a structural equation modelling (SEM) approach to model how the concepts of awe, the overview effect, and learning are related when experiencing VR. The hypothesized model (Figure 1) consists of presence, dispositional awe, dispositional compassion, gender and age, as well as the overview effect and learning gains. These factors are discussed in further detail below.

Immersive Tendencies and Presence

Immersive tendencies are personal characteristics which describe the degree to which a participant feels immersed in fictional situations. For example, Ling, Nefs, Brinkman, Qu, and Heynderickx (2013) found that immersive tendencies were significantly correlated with felt presence in a study where participants used VR for public speaking. Presence measures represent the degree of felt realism, and of "being there" (Witmer & Singer, 1998). Presence has been observed for adults and children alike: Mikropoulos and Strouboulis (2004), and others, reported a sense of presence with 12-year olds in an educational VR having a positive effect on engagement and motivation. However, there is no direct evidence that presence has a positive effect on learning (Buttussi & Chittaro, 2018; Makransky, Terkildsen, & Mayer, 2019). Since presence increases the feeling of actually being in a situation, in our VR simulation viewing planet Earth from space, we would expect presence to influence the overview effect (Stepanova et al., 2019a).

Dispositional Awe and Compassion

Awe is a feeling of being overwhelmed and impressed by a great or vast experience (Klatzky et al., 2017). It has been reported to lead to a "need to accommodate" (Shiota, Keltner, & Steiner, 2007). Awe can result in a feeling of self-transcendence and transformation, as well as spirituality (Chirico & Yaden, 2018; Van Cappellen & Saroglou, 2012), and is in that sense related to the overview effect. Awe can cause the observer to feel small, increase pro-social behavior, and support integration into social groups (Bai et al., 2017; Piff, Dietze, Feinberg, Stancato, & Keltner, 2015). This suggests that it is related to compassion, which is an attitude of concern, care, support and help towards humanity. Both are correlated items on the Dispositional Positive Emotions Scale (DPES) by Shiota, Keltner, and John (2007), which measures, among others, awe and compassion in a subjective way. Dispositional awe and compassion are personal traits and thus can be used as predictors.

Following Gottlieb et al. (2018) and Valdesolo et al. (2017) and given that awe results in a need for accommodation to new mental schemas, we expect dispositional awe to promote learning.

Gender and Age

In the review by Mikropoulos and Natsis (2011), gender could have an effect on performance in VR scenarios. Learning gains in VR experiments for girls and boys have been reported to differ using VR (Mackinnon, Bacon, & Osunde, 2018). Age has been added because older children might have more prior knowledge on the subject than younger children (Borgers, de leeuw, & Hox, 2000), and prior knowledge influences the effectiveness of a learning environment (Otero, 2001).

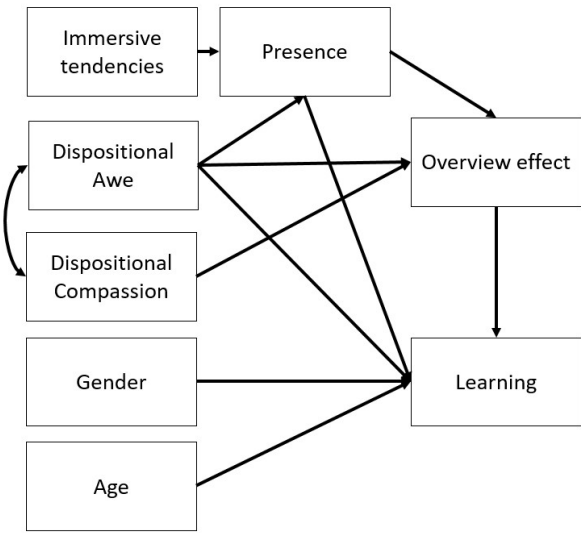

Figure 1: The hypothesized model.

Figure 2: VR hardware

Study

A mobile VR experience was created by the non-profit organization SpaceBuzz . It resembles a rocket ship that is 13 feet high, 8 feet wide and 50 feet long. It has a futuristic interior, and contains nine moving chairs that can rotate and tilt. Eight HTC Vive Pro headsets (Resolution: 1440 x 1600 pixels per eye, 615 PPI, 3D Spatial Audio, refresh rate of 90Hz) present a VR simulation, created in Unity, to emulate a 15-minute journey to space. In the VR journey an embodied avatar of European Space Agency (ESA) astronaut André Kuipers is visible and narrates the journey, virtually present as the rocket ship's captain. The rocket ship virtually flies in orbit around the Earth, explaining the world's wonders, and its journey through space finally returns back to Earth (Figure 2). As of yet children cannot interact with the VR world.

Methods

Participants

In total, 233 children from eight classes in six schools participated in the study, of which 193 questionnaires were returned. A total of 183 usable data cases were analyzed, after removal of five extreme outliers (over three SDs away from the mean) on proportional learning gains (2.6% of the total) and five experimenter errors (age M = 10.67, SD = .70; 87 boys, 89 girls, 6 unknown).

Parents gave prior consent for children to participate in the study. Children who were given consent to participate, but were worried about being dizzy or nauseous, experienced VR under direct supervision of their teacher. The study was approved by the Ethical Review Board of Tilburg University (REDC # 2019/04a).

Procedure

Prior to the VR simulation, participants received a pre-test questionnaire. All children received identical questionnaires on paper and filled them out individually.

For the VR program, classes traveled to an external location. Nine participants at a time could experience the simulation together, while others were playing a collaborative game in a separate room. After completing the VR experience, children filled out questionnaires at a separate table under supervision of research assistants.

Materials

Pre-test The pre-VR program included several questionnaires in between learning activities (about astronauts, the solar system, rockets, and satellites): a personality questionnaire, a demographics questionnaire, an immersive tendencies questionnaire, a compassion and awe questionnaire, and a knowledge test. The immersive tendencies questionnaire was an adaptation of the questionnaire by Schubert et al. (2001). The 'compassion and awe' questionnaire was an adaptation of the DPES compassion and awe items (Shiota, Keltner, & John, 2007), reduced to around six items per questionnaire, and simplified for better comprehension by children (van Kesteren, Bekker, Vermeeren, & Lloyd, 2003). They were validated using an online questionnaire taken by 43 native Dutch speakers (age: M = 32.4, SD = 14.79) who answered both the original and the new questions after an immersive experience, in random order. The new Immersive Tendencies questionnaire had a reliability score of Cronbach's α = .70. The original questionnaire and children's questionnaire correlated strongly (r = .73, p < .001), using Pearson correlations. The original compassion and awe questionnaire and children's questionnaire correlated strongly as well (r = .783, p < .001), as did the subscales of the questionnaire, compassion (r = .694, p < .001), and awe (r = .640, p < .001). We can therefore conclude that the newly adopted questionnaire measured the same constructs as the original. The knowledge test was written by the developers of the educational program to check for knowledge acquired in the lessons and consisted of 15 multiple-choice questions. From these 15 questions, eight matched the post-test in content. These were used for analysis of learning gains.

Post-test Immediately after experiencing the VR, another set of questionnaires was administered: a presence questionnaire, an emotions questionnaire, an awe and compassion questionnaire, an overview effect questionnaire, a personality questionnaire, and a knowledge test. The presence questionnaire was an adaptation of Witmer, and Singer (1998). The questionnaire was simplified, shortened,

Table 1: Correlations of all items in the hypothesized SEM

Observed variable	1	2	3	4	5	6	7	8
Immersive tendencies (1)	1							
Presence (2)	0.10	1						
Dispositional Awe (3)	0.21**	0.18*	1					
Disp. Compassion (4)	0.03	0.15*	0.37**	1				
Overview Effect (5)	0.11	0.27**	0.58**	0.39**	1			
Gender (6)	-0.02	0.11	0.15	0.15	0.19*	1		
Age (7)	-0.01	-0.05	-0.8	-.24**	-0.24**	-0.11	1	
Learning Gains (8)	-0.24**	0.02	0.11	0.16	0.16	-0.09	0.10	1

Note: ** indicates significant correlation at the 0.01 level (2-tailed), and * indicates significant correlation at the 0.05 level (2-tailed).

and evaluated. The new presence questionnaire had a reliability score of α = .80. The original questionnaire and new questionnaire correlated strongly (r = .89, p < .001).

The emotions questionnaires rated feelings of awe, happiness, boredom, excitement, fear, and nausea on a 5-point scale, similarly to Piff, et al. (2015) and Rudd, Vohs, and Aaker (2012). The awe and compassion, and the personality questionnaire were the same as the ones used in the pre-test. The overview effect questionnaire contained nine questions that addressed a learner's attitude towards the planet and prosocial behaviour.

The knowledge test consisted of ten multiple choice questions, where eight questions matched the questions from the pre-test in content and were thus comparable. The questions were reviewed by the developer of the first questionnaire for a good match.

After the virtual reality experience, schools covered the last six lessons back in their own classroom within the week following their VR experience. These covered a world without borders, what aspects of life that are important right now, and what people in the future can use, and research based on satellite images. The lessons also included the final post-test questionnaires: awe and compassion, the overview effect and personality (evaluation letter for astronauts). The findings from these classroom sessions are not the focus of the current study and are therefore not further discussed here.

Statistical analyses The SEM, using unstandardized residuals (β), was calculated with the IBM SPSS Amos 24.0 statistical package. Questionnaires corresponding to the theorized model were used. To account for prior knowledge, we computed proportional learning gains (Craig, Graesser, Sullins, & Gholson, 2004) for the eight matched questions in Pre- and Post-VR. Gender was also included in the SEM. For correlations, means and standard deviations see Table 1. Maximum likelihood was used in the SEM, and missing values were handled using means and intercepts estimates.

Results and Discussion

The reliability of the questionnaires was assessed by computing Cronbach's Alpha for interrater reliability. All scores were at an acceptable level with Cronbach's Alpha of around .6 or higher, with the exception of immersive tendencies and presence that had a lower reliability score.

Table 2: Final model estimates.

	β	S.E.	p
Awe → Presence	.108	.045	.017
Presence → Overview	.179	.070	.010
Awe → Overview	.339	.046	< .001
Compassion → Overview	.194	.066	.003
Overview → Learning	.215	.101	.031
Gender → Learning	-.156	.108	.151
Compassion ←→ Awe	.149	.033	< .001

The awe score (M = 4.49, SD = .72) showed that children felt awed by the VR, with t (177) = 27.48, p < 0.001, compared to neutral (3 on a 5-point scale).

The hypothesized model did not have an acceptable fit (CFI = 0.799, TLI = 0.597, RMSEA = 0.091). We therefore iteratively removed the non-significant paths, based on the greatest misfit, until a proper model fit was reached. The final simplified model in Figure 3 reached an acceptable fit (CFI = .956, TLI = .885, RMSEA = .059). For model estimates, see Table 2.

Immersive Tendencies and Presence Immersive tendencies did not have a significant effect on presence in this study, and were removed from the model. Presence did not have an effect on learning either, and this link was also removed. Presence did, however, have an effect on the overview effect questionnaire score (β = 0.179, p = .010), in line with our expectations. This means that the degree of felt realism influenced the strength of the felt overview effect, albeit the case that these results have to be taken with caution because of the low reliability scores that the questionnaires had in this study.

Dispositional Awe and Compassion Dispositional awe and compassion were correlated, as expected (β = 0.149, p < .001). Dispositional awe influenced how present someone felt (β = 0.108, p = .017) and it was a strong predictor of the overview effect (β = 0.339, p < .001); it did not directly influence learning. Dispositional compassion was another predictor of the overview effect (β = 0.194, p = .003).

Gender and Age Age did not have an effect on learning and was removed from the model. Gender remained in the model, despite not having a significant effect because an acceptable model fit was reached. Unknown gender was coded as 0, boys were coded as 1 and girls as 2. The effect of gender on learning was negative, meaning that it was stronger for boys (β = -0.156, p = .151).

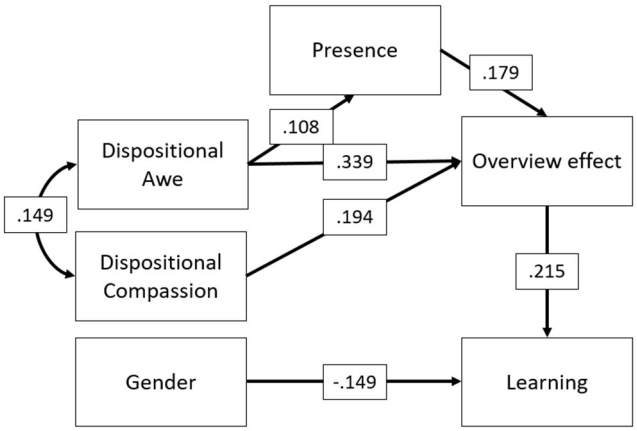

Figure 3: The final model.

Overview Effect and Learning The overview effect had a significant effect on learning ($\beta = 0.215$, $p = .031$). This shows that the overview effect, which is strongly correlated with awe, yields learning.

General Discussion

The current study demonstrated the learning benefits of awe-inspiring immersive VR for primary school children. We reported a link between dispositional awe of young learners and their experience of the overview effect, which had a positive impact on learning, especially for children with lower prior knowledge of the learning domain.

When comparing our hypothesized SEM model and the final SEM model, there are some differences. A previously reported claim about a strong relation between immersive tendencies and presence was not confirmed by our data. The cause of this difference could be the low reliability scores in the questionnaires. Not surprisingly, there is a trade-off between reliability and amount of questions that can be used for research with children, which could be the cause of that.

Presence did not have a direct link to learning but did have an indirect effect on learning through the overview effect. For future research, the link between awe, the overview effect, presence, and learning needs to be investigated. Dispositional awe and compassion did not have a direct link to learning either, although feeling awed in 'this moment', such as in the overview effect, did have an effect.

The most important finding concerns the overview effect has an effect on learning. This has not been reported in literature before. With awe and the overview effect being strongly related, the finding is in line with previous studies on awe. The results thus support the potential use of awe-inspiring experience in education for a younger generation.

The current study did not investigate two important avenues: 1) What is the effect in terms of learning gains of the educational program without the VR simulation, and 2) what is the effect of the VR simulation without the educational program. By comparing these three different scenarios, the effect of awe, virtual reality and learning can be better mapped out. Practically, however, such studies are difficult to conduct, for instance because in one condition children will be deprived of the VR experience. Nevertheless, such studies are planned to be conducted in the near future.

The findings of the current study open the door for future research on the combination of immersive virtual reality, learning, awe, and the overview effect. Moreover, they demonstrate the potential of using immersive virtual reality experiences in educational programs, combining wonder and learning.

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