The Relation between Virtual Presence and Learning Outcomes in Serious Games – The Mediating Effect of Motivation.

Claudia Schrader

Institute of Psychology and Education, University of Ulm, 89081 Ulm, Germany
Claudia.Schrader@Uni-Ulm.de

Abstract. Does the immersive design of a serious game affect learners' virtual presence? Does virtual presence improve learning? By identifying virtual presence as a variable that may determine learning outcomes, it is argued that computer gaming environments present a new challenge for researchers to investigate. Particularly, the effect of games on virtual presence might help designers to predict which instructional configurations will maximize learning performance. Results indicate that the serious game used as an example in this study leads to a strong form of virtual presence. Virtual presence enhanced retention and comprehension but not transfer. It also significantly increased learners' motivation. Mediation analyses report that the positive relation between virtual presence, retention and comprehension is mediated through increased motivation. These findings suggest that the relation between all variables should be considered an important factor in the design of virtual worlds for learning.

Keywords: Serious Games, Motivation, Virtual Presence

1 Introduction

Since the use of serious games, i.e. games that are designed for training or to promote learning, the question of designing gaming worlds to foster learners' virtual presence has been of interest in the fields of sociology [1] [2], computer science [3] [4] [5] and psychology [6] [7]. Learners' experience of virtual presence is seen as an affective-like state of fully immersing into an activity in response to and interacting with a virtual world. Research findings on games suggest that the design of games generally includes the antecedents of virtual presence by providing three-dimensionality [8], spatialised sound, music [9], the stimulation of tactile sense through physically touching virtual objects, experimenting and testing [10], and the possibility of autonomous interacting and receiving immediate feedback [11] [12].

However, even if the game design supports learners' virtual presence, the use of such virtual worlds for learning is not always seen as effective [13] [14]. This assumption is mainly explained by assuming an overload of working memory while learning in gaming environments. The generally used design features to impact a high degree of virtual presence might also impose processing demands on learners' working memory capacity through including interesting, but for learning unimportant (visual), information, or technical requirements [15] [16]. Learners have to split their attention between storyline and learning information. Also, at the same time, learners have to pay close attention to navigate through the gaming environment, control characters and objects via mouse or joystick movement. This will compete with or interrupt the attention to and processing of relevant learning information and therefore result in decreased learning outcomes.

Schrader & Bastiaens [7] confirm this assumption in their study, testing a game example. It was demonstrated that a learning adventure game supports learners' virtual presence compared to a hypertext-animated learning environment. But, at the same time, it poses high demands on learners' working memory due to operating in the gaming environment and therefore decreases learning. However, the experimental study also has yielded some intriguing correlation and regression evidence that is suggestive of a positive relationship between virtual presence and learning outcomes. As virtual presence increased, the retention and comprehension as learning outcomes increased as well.

In conclusion in line with game design, learning occurs when learners feel virtually present [6] [7], even if additional design elements to foster presence may add processing demands. It is not likely the virtual presence itself, but learners' motivation, that accompanies virtual presence in serious games that might best explain any significant relation between virtual presence and learning outcomes. Feeling virtually present in the gaming environment entails greater levels of identification with the content and sorting out the presented problems as personally relevant [17].

This might result in both intrinsic (engaged in enjoyable, self-determined behaviour) and extrinsic motivation (driven by the goal of obtaining rewards or outcomes such as achievement and winning the game) [18]. From the motivational perspective on learning information processing [19] [20], this motivation should predict learning performance and outcomes by driving purposeful behaviour [21], directing attention toward learning goal-relevant information and away from goal-irrelevant information [22] and keeping the learner focused on the task [23].

Whereas studies on learning with serious games give evidence of the impact of actual motivation on learning outcomes [24] [13] [25] [26] with regard to the motivational touch of the game design [27] [28] [29] [27], the role of motivation as a mediating variable has not been causally linked to the relation of virtual presence and learning outcomes.

Thus, the aim of this study is not only a repetition of previous work on how the sense of virtual presence directly affects learning outcomes. The question that arises is if virtual presence might be related to important predictors of learning during learning processes, such as motivation that might positively mediate the relation between virtual presence and learning results.

2 Method

2.1 Participants

Forty-two pupils (20 boys and 22 girls) from two different year eight classes at a preparatory high school in Hagen, Germany, participated in the study. Their mean age was 13.5 years (SD = .52).

2.2 Materials

For learning in a gaming environment, the adventure game Elektra [30] for year eight pupils was chosen and modified. The game is a coloured, three-dimensional single-user adventure including spatialised sound. The game facilitates virtual presence with an effect size of $\eta 2$ = .16 compared to working in a simple animated hypertext-learning environment [7]. In an interactive way, learners can learn about the topics of light refraction, magnetism and air resistance. For example, one experimental task is learning that light consists of rays and how this can be focused. The learner has to send a strong beam of light through the keyhole of a strange door in order to open it. Behind the door, the beam has to fall on a specific light cell, but not on anything next to this cell. The learner is invited to examine a lab table with a little flashlight and learns how to blind this to create a narrow beam of light and transfer it to open the door.

2.3 Measures

In order to take into account the learners' subjective experience of virtual presence, Witmer and Singers' [31] Presence Questionnaire (PQ) was used. It consists of 10 items to be answered on a 5-point Likert scale ranging from 1 (totally disagree) to 5 (totally agree), addressing the feeling of being involved so deeply that learners could fade out external distractions that interfered with performance, having control and feeling the interactions and movements as natural. The total score for each learner was obtained by adding the 10 responses. The reliability of the virtual presence questionnaire was .76 (Cronbach's alpha).

Learners' current motivation while learning with the game was measured using the short three-item self-reporting instrument developed by Vollmeyer and Rheinberg [32]. Participants were asked to rate their confidence of success, behaviour-oriented motivation and how enjoyable they found the experience (Cronbach's α = .68).

To access the learning outcomes of the physics content, trivial learning outcome (retention), and non-trivial learning outcome (comprehension and transfer) were measured. For measuring the retention of facts and concepts, five multiple-choice questions were graded (e.g. for a task concerning magnetism: "Which objects are attracted by magnets? Please choose the objects!"). Due to a low item-scale test correlation (rit = .20) and high index of complexity (p = .82), one question was not included in the analysis. Each question was scored according to whether it was answered correctly or wrongly, ranging from one to zero points. Therefore the maximum test score was four points. The reliability of retention test was .62 (Cronbach's alpha). Comprehension was measured on four open-ended questions in which the learners had to demonstrate the comprehension of the acquired knowledge in their own words (e.g. "Why do you think that the objects are attracted by magnets? Please give reasons for your choice!"). Due to a low item-scale test correlation, one question was not included in the analysis (rit = .22). The reliability of comprehension test was .60 (Cronbach's alpha). The maximum test score was four points. The transfer tasks were structured in six near transfer tasks (Cronbach's α = .85) and four far transfer tasks (Cronbach's α = .74) to consider the quality of the transfer of the acquired knowledge in new situations (for an example, see a discussion on differentiating transfer [33]). The near transfer tasks were analogous to the used learning objects in both virtual environments, but contained different objects than those presented in the environment, e.g. a match instead of a wooden ball. The far transfer tasks were different in structural features and were meant to determine whether learners were able to apply the acquired knowledge to unknown and more complex situations. For example, a task for magnetism in which the learners had to explain why one couldn't use knobs the size of a coin instead of real coins to pay for the parking charge of a car. The maximum test score here was ten points. Two tasks (1 near and one far transfer task), however, were not included in the analyses due to a low index of complexity (r< .20).

2.4 Procedure

The study was conducted in the computer labs of the FernUniversität in Hagen. In the beginning, demographical data from the participants was collected. Filling out the tests took about 5 min. Afterwards, learners started to work within the gaming environment individually. The learners worked until they had completed all tasks embedded in the game. Depending on the pace of the individual learners, it took them between 40 and 50 minutes. While learning in the gaming environment, learners filled out the virtual presence and motivation questionnaires (5 min). These questionnaires were followed by the learning tests (20 min) directly after the exploration

3 Results

To answer whether virtual presence might foster learning and whether virtual presence supports learners' motivation while learning with the serious game, first initial preliminary analyses (i.e., descriptive statistics; one-sample t-tests, bivariate correlation analyses) were conducted. To test the assumed direction of prediction between all these variables, regression analyses were then used. Last, whether motivation might mediate the relationship between virtual presence and learning outcome was tested using the mediation procedure proposed by Baron and Kenny [34]. Due to the homogeneity of variance and normal distribution, correlation and regression analyses were justifiable. A significance level of .05 was also maintained for all analyses.

3.1 Preliminary Analyses

In Table 1, means and standard deviations of scores for virtual presence, motivation and mental effort are reported. One-sample t-tests were conducted to investigate the impact that the used game has on virtual presence and motivation, i.e. whether the mean of virtual presence and motivation is significantly greater than 3. The one-sample t-test revealed a statistical difference between the mean value and virtual presence ($t(42) = 2.28$, $p = .02$) and the mean value and motivation ($t(42) = 3.34$, $p = .002$).
Bivariate correlation analyses (see also Table 1) between the scores of dependent and independent variables were conducted to access the need for regression and within mediation analyses. Correlation analyses revealed a moderate association between virtual presence and learning outcomes in terms of retention and comprehension. Also, there was a high relation between virtual presence and motivation. Also of interest was an existent relation of motivation on learning outcomes. All associations between variables (specifically between virtual presence and motivation) indicate a need for mediation when investigating the effect of virtual presence on learning.

Table 1. Mean Scores, Standard Deviations, and Bivariate Correlations between Measured Variables.

Variables	Mean (*SD*)	1	2	3	4	5
1.Virtual Presence	3.23 (*.66*)					
2. Motivation	2.76 (*.74*)	.60**				
3. Retention	65 (*.41*)	.48**	.36*			
4. Comprehension	.67 (*.34*)	.33*	.52**	.18		
5. Near Transfer	.51 (*.34*)	.20	.02	.28	.15	
6. Far Transfer	.50 (*.38*)	.04	.05	.49*	.39*	.45*

* $p < .05$, two-tailed; ** $p < .01$, two-tailed

3.2 Effect of Virtual Presence on Learning Outcomes as Mediated by Motivation

Retention. First, a series of regression analyses was run to explore the impact of virtual presence on retention and the role of motivation in mediating this relationship. In line with the correlation analysis, the regression analyses show that the feeling of virtual presence is related to retention ($\beta = 0.46$, $p < .001$).

Next, the role of motivation was explored in mediating the effect of virtual presence on retention. As previously established, virtual presence had an effect on retention. Also, there was an effect of virtual presence on motivation ($\beta = 0.57$, $p < .001$), and there was a direct effect of motivation on retention ($\beta = 0.44$, $p < .01$). Finally, the analysis shows that the effect of virtual presence on comprehension is mediated by motivation: Including motivation in the linear model of regression, the direct effect of virtual presence on retention was significantly reduced ($\beta = 0.35$, $p = .04$), suggesting mediation as defined by Baron and Kenney [34]. Also, the result from the Sobel test [35], which was employed to directly assess the mediation, suggested mediation ($z = 3.27$, $p < .001$). Results imply that the addition of motivation significantly mediates the direct effect of virtual presence on retention.

Comprehension. Next, a series of regression analyses was realized to explore the role of motivation in mediating the relation between virtual presence and comprehension outcomes. Virtual presence had a direct effect on comprehension ($\beta = 0.37$, $p = .05$) and a direct effect on motivation ($\beta = 0.57$, $p < .001$) as already reported above.

Motivation had a direct effect on comprehension ($\beta = 0.42$, $p = .006$). Based on the result from regression analyses ($\beta = 0.13$, $p = .49$) and the Sobel test ($z = 2.61$, $p = .008$), motivation was found to mediate the effect of virtual presence on comprehension outcomes.

Near and Far Transfer. Results of regression analyses to explore the role of motivation in mediating transfer outcome imply that whereas virtual presence as an emotional-like variable is adequate for more trivial learning outcome in terms of retention and comprehension, it does not seem to be sufficient for more complex transfer outcomes. Virtual presence failed to have a direct effect on near transfer ($\beta = 0.03$, $p = .78$) and far transfer ($\beta = 0.22$, $p = .06$), suggesting that there was not a unique effect of virtual presence to be mediated by motivation..

3.3 Discussion and Conclusion

For instructional designers, results should shed light on the need for optimising instructional design of serious games supporting learners' sense of virtual presence. The objective of the current study was to examine the relation between virtual presence and learning outcomes for learning with serious games. The regression analyses show that virtual presence increases motivation and enhances the learning outcomes as retention and comprehension. Therefore, it is at least partly inconsistent with the argument of overloading working memory capacity that results in lower learning outcomes through the introduction of design elements aimed at inducing virtual presence. The results are consistent with Park, Moreno, Seufert, and Brünken's [36] finding that seductive details can improve learning performance in a multimedia narrative.

The current findings also lend insight into the processes by which virtual presence impacts more indirect learning. Results from mediation analyses indicate that virtual presence induced by game design has an impact on learning in terms of retention and comprehension at least in part via motivation.

Thus, on the theoretical and practical side, it was demonstrated that virtual presence should be incorporated in instructional design especially for immersive media, i.e. media that are "(...) capable of delivering an inclusive, extensive surrounding and vivid illusion of reality to the sense of a human participant" [16, p. 601]. It was reported that virtual presence not only affects motivation and cognition. It also has a partial effect on learning outcomes being mediated through motivation. These results are consistent with current assumptions in literature [6] [37]. However, as already mentioned, results reported a positive relation between virtual presence and learning outcomes in terms of retention and comprehension, but not for transfer. This finding supports the idea that virtual presence might compensate for the added processing demands adequate for more trivial learning outcome but insufficient for deeper learning in terms of transfer. Based on complexity, transfer tasks demands cognitive processes more than retention or comprehension [38] and might be taken up through environmental design, and complexity of task. This result is in line with previous work from Schrader and Bastiaens [7], indicating that the effect of virtual presence on learning is, in part, negatively influenced through overloading cognitive processes through game design. However, one limitation of the study is the missing measurement of the load increase on working memory capacity. Thus, it is not possible to make claims; this will be the subject of future studies. Identifying design strategies that reduce the cognitive load based on the design, but without reducing virtual presence, seems to be issues of practical concern to game designers.

References

1. Short, J., Williams, E., & Christie, B. (1976). The social psychology of telecommunications.
2. Rice, R. E. (1992). Task analyzability, use of new medium and effectiveness: A multi-site exploration of media richness. Organization Science, 3(4), 475-500.
3. Hatata, T., Sakata,H., & Kusaka, H. (1980). Psychophysical analysis of the ‚sensation of reality' induced by a visual wide-field display. SMPTE Journal, 89, 560-569.
4. Heeter, C. (1995). Communication research on consumer VR. In F. Biocca & M. R. Levy (Eds.), Communication in the age of virtual reality (pp. 191-218). Hillsdale, NJ: Lawrence Erlbaum Associates.
5. Neumann, W. R. (1990). Beyond HDTV: Exploring Subjective Responses to Very High Definition Television. MIT Media Laboratory, Television of Tomorrow Research Consortium.
6. Heers, R. (2005). Being There. Untersuchungen zum Wissenserwerb in virtuellen Umgebungen. Dissertation. Eberhard-Karls-Universität Tübingen, Tübingen.
7. Schrader, C., & Bastiaens, T. (2012). The Influence of Virtual Presence: Effects on Experienced Cognitive Load and Learning Outcomes in Educational Computer Games. Computers in Human Behavior, 2, 648-665.
8. Muhlbach, L., Bocker, M., & Prussog, A. (1995). Telepresence in Videocommunications: A Study on Stereoscopy and Individual Eye Contact. Human Factors: The Journal of the Human Factors and Ergonomics Society, 37(2), 291-305.
9. Wenzel, E. M. (1992). Localization in virtual acoustic displays. Presence: Teleoper. Virtual Environ., 1(1), 80-107.
10. Held, R. M., & Durlach, N. I. (1992). Telepresence. Presence: Teleoperators and Virtual Environments, I(1), 109-112.
11. Sheridan, T. B. (1992). Musings on telepresence and virtual presence. Presence:

Teleoperators and Virtual Environments, 1(1), 120-126.
12. Steuer, J. (1992). Defining Virtual Reality: Dimensions Determining Telepresence. Journal of Communication, 42(4), 73-93.
13. Parchman, S. W., Ellis, J. A., Christinaz, D., & Vogel, M. (2000). An evaluation of three computer-based instructional strategies in basic electricity and electronics training. Military Psychology, 12(1), 73-87.
14. Rieber, L. P., & Noah, D. (1997). Effect of gaming and graphical metaphors on reflective cognition within computer-based simulations. Paper presented at the Annual meeting of the American Educational Research Association, Chicago.
15. Kalyuga, S., & Plass, J. (2009). Evaluating and Managing Cognitive Load in Games. In R.E. Ferdig (Ed.), Handbook of Research on Effective Electronic Gaming in Education (pp. 719-737). Hershey, PA: Information Science Reference.
16. Moreno, R., & Mayer, R. E. (2002). Learning Science in Virtual Reality Multimedia Environments: Role of Methods and Media. Journal of Educational Psychology, 94(3), 598-610.
17. Wild, C. T., Kuiken, D., & Schupflocher, D. (1995). The Role of Absorption in Experiential Involvement. Journal of Personality and Social Psychology, 69(3), 569-579.
18. Barfield, W., & Weghorst, S. (1993). The sense of presence within virtual environments: A conceptual framework. In G. Salvendy & M. Smith (Eds.), Human-Computer Interaction: Software and Hardware Interfaces (pp. 699-704). Amsterdam: Elsevier Publisher.
19. Humphreys, M.S. & Revelle, W. (1984). Personality, motivation and performance. A theory of the relationship between individual differences and information processing. Psychological Review, 91(2), 153-184.
20. Kahneman, D. (1977). Attention and effort. Englewood Cliffs: Prentice-Hall.
21. Lawler, E. J. (2001). An affect theory of social Exchange1. American Journal of Sociology, 107(2), 321-352.
22. Dweck, C.S., Mangels, J., & Good, C. (2004). Motivational effects on attention, cognition, and performance. In D.Y. Dai & R.J. Sternberg (Eds.), Motivation, emotion, and cognition: Integrated perspectives on intellectual functioning. Mahwah, NJ: Erlbaum.
23. Heinrich R. Molenda M. Russel J. B. & Smalide (2002). Instructional media and Technologies for learning (7th ed). New Jersey: Pearson Education, Upper Saddle. River.Held, R. M., & Durlach, N. I. (1992). Telepresence. Presence: Teleoperators and Virtual Environments, I(1), 109 - 112.
24. Cheng, C. H. & Su, C. H. (2012). A Game-based learning system for improving student's learning effectiveness in system analysis course. Social and Behavioral Sciences, 31, 669-675.
25. Tüzün, H., Yılmaz-Soylu, M., Karakuş, T., İnal, Y., & Kızılkaya, G. (2008). The effects of computer games on primary school students' achievement and motivation in geography learning. Computers & Education, 52(1), 68-77.
26. Virvou, M., Katsionis, G., & Manos, K. (2005). Combining software games with education: Evaluation of its educational effectiveness. Educational Technology & Society, 8(2), 54-65.
27. Malone, T. W. (1981). What makes computer games fun? Byte, 6(12), 258-277.
28. Malone, T. W., & Lepper, M. R. (1987). Making learning fun: A taxonomy of intrinsic motivations for learning. In R. E. Snow & M. J. Farr (Eds.), Aptitude, Learning and Instruction, Volume 3: Conative find Affective Process Analyses (pp. 223-253). Hillsdale, NJ: Erlbaum.
29. Garris, R., Ahlers, R., & Driskell, J. E. (2002). Games, Motivation, and Learning: A Research and Practice Model. Simulation Gaming, 33(4), 441-467.
30. European Commission’s IST−Programme (2009). ELEKTRA [Computer Game]. Retrieved 09.11.2011, from http://www.elektra−project.org/
31. Witmer, B. G., & Singer, M. J. (1998). Measuring Presence in Virtual Environments: A Presence Questionnaire. Presence: Teleoper. Virtual Environ., 7(3), 225-240.

32. Vollmeyer, R. & Rheinberg, F (2003). Aktuelle Motivation im Lernverlauf. In J. Stiensmeyer-Pelster & F. Rheinberg (Eds.), Diagnostik von Motivation und Selbstkonzept (p. 281-295). Göttingen: Hogrefe.
33. Hasselhorn, M., & Mähler, C. (2000). Transfer: Theorien, Technologien und empirische Erfassung. In W. Hager, J.-L. Patry & H. Brezing (Eds.), Evaluation psychologischer Interventionsmaßnahmen. Standards und Kriterien: Ein Handbuch (pp. 86 - 101). Bern, Göttingen, Toronto, Seattle: Hans Huber.
34. Baron, R. M., & Kenny, D. A. (1986). The Moderator-Mediator Variable Distinction in Social Psychological Research: Conceptual, Strategic, and Statistical Considerations. Journal of Personality and Social Psychology, 51(6), 1173-1182.
35. Sobel, M. E. (1982). Asymptotic confidence intervals for indirect effects in structural equation models. Sociological Methodology, 13(1982), 290-312.
36. Park, B., Moreno, R., Seufert, T., & Brünken, R. (2011). Does cognitive load moderate the seductive details effect? A multimedia study. Computers in Human Behavior, 27(1).
37. Schrader, C. (2012). Educational Computer Games and Learning: Three Empirical Studies of Games' Impact on Virtual Presence, Cognitive Load and Learning Outcomes: Südwestdeutscher Verlag für Hochschulschriften.
38. Vrugt, A., & Oort, F. J. (2008). Metacognition, achievement goals, study strategies and academic achievement: pathways to achievement. Metacognition and Learning, 3(2), 123-146.