Virtual Reality and Effects on Learning Retention

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1 INTRODUCTION

Since the advent of VR technology, society has seen great potential in immersing people in virtual environments and has recognized that it can be used for more than just a gaming platform. Adapting and utilizing this new technology has immense potential to enhance education and further develop critical thinking skills, according to [2, 6, 10, 17], immersive virtual reality can be a useful tool for learning problem-solving skills. Whether it is training neurosurgeons, mechanics, architects, or engineers, VR has been seen as a way to do just that, enhance training. [1, 4] But with such a rush towards this medium of learning, leads to the question of whether individuals who undergo VR training are able to comprehend the degree to which spatial information can be acquired and retained through VR, as opposed to real-world training. This is important because VR might actually negatively affect a person's ability to learn and retain spatial information.

2 RELATED WORKS

Spatial understanding and learning retention in virtual reality are newer concepts that have gained a lot of interest in recent years. Research interests in these fields range from academia to medicine to specialized training. Research in these fields has a variety of desired outcomes, but all of them explore whether virtual reality can be utilized to benefit learning processes. For example, VR is involved in the medical field. Medical Students are tested to see if teaching methods with VR in surgical training and neuroanatomy help learning retention. In the case of neuroanatomy, students were introduced to 3-D virtual reality with the goal of examining "the impact of immersive virtual-reality neuroanatomy and comparing it to traditional paper-based methods" [18]. Similarly to surgical training, the use of virtual reality ("VR") "...is of real interest to medical education because it blends digital elements with the physical learning environment"[8]. The application of training medical students' abilities to understand complex tasks is a main focus of our research

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with virtual reality. These complex tasks can be expensive and resource-intensive. Costs for virtual reality training simulations can be reduced if they are created effectively and efficiently [3, 5]. Our research aims to help find how people effectively use virtual reality in a training environment to improve learning retention. Another focus of virtual reality in learning retention is education. The majority of these studies compare virtual reality teaching methods to traditional education [11, 13, 15, 16, 20] . One research paper that addressed VR education in a broad sense was Sandra Helsel's Virtual Reality and Education. The research talks about how public perception of VR integration differs from what constitutes effective VR integration in practice. Helsel reasons virtual reality "holds a promise for education," as long as the staff and educators "become involved now to plan for VR's future development" for effective integration [9]. Crosier's research, which investigated "the potential of Virtual Reality for teaching secondary school science"[12], is another good example of virtual reality in education. The study focused on individual differences and how they affected the outcomes of new learning methods. The study found that "high ability students reported higher attitude scores, both overall and for the VR class"[12]. This study encountered a bias in the sample population, with higher-achieving or smarter students performing better on both platforms. We anticipate similar setbacks with our sample population within the sample used for this research. With educational virtual reality training and retention, environments are also an important factor. Essoe's research explored "an approach to leverage context dependence to optimize learning challenging, interference-prone material" [7]. This study was carried out by teaching participants 80 foreign words in different virtual reality environments. As shown in other research, virtual reality can assist the user's retention of a physical space by giving them alternative ways to view a reality[14, 19]. Our research is going to utilize different learning environments by comparing test subject's spatial retention in virtual reality to real life.

3 METHODOLOGY

This experiment is looking at how VR can impact the retention of spatial information with the implementation of a virtual reality environment and a traditional non-VR figurine. We devised an experiment to compare how well two groups retain spatial information from a spatial puzzle [Fig-1] for the first group and the same puzzle in a VR environment.[Fig-3]

3.1 Participants

Participants for this study were selected through a random sampling method to increase the heterogeneity of the sample population. The study population was comprised of individuals from the participants' social networks, such as friends, family, and classmates, who expressed their willingness to participate in the experiment. Following participant recruitment, we used random assignment techniques to assign individuals to either virtual reality (VR) or wooden puzzle training groups using simple random sampling.

3.2 Apparatus

To design and construct our VR environment, we used Unreal Engine 5. This engine provided us with a wide range of options when constructing our environment.[Fig-5] For the hardware, we used two Meta Quest 2 headsets provided to us through the university. For the real-world training and testing, we purchased a wooden puzzle from Amazon. The VR puzzle was designed and based on this puzzle

3.3 Procedure

To conduct this experiment we followed the following procedure:

First, we had users sign a consent form. Second, we gathered our participants and had them fill out a survey that included relevant data that would aid in the statistical analysis of the experiment. This survey includes general demographics, VR experience, and confidence in the ability to solve puzzles. After the survey, participants were randomly split into two groups unrelated to the data recorded from the surveys.

Each participant in the first group was seated in a sterile room and given a picture of the solved puzzle and the wooden puzzle itself with all the pieces laid out in front of them.[Figs-1,2] They were instructed to assemble the puzzle 5 times. All 5 trials were timed to observe learning and to set a base time to compare how well they retained the information. After they concluded their 5 trials, they were dismissed.

Each participant in the second group was also seated in a sterile room and given a VR headset. Participants were instructed to adjust the tightness of the headset to give the most comfortable experience. The participants were placed in the scenario puzzle room. [Fig-3] This room contains the puzzle and a picture of the completed puzzle.[Fig-4] They were instructed to assemble the puzzle 5 times. All 5 trials were timed to observe learning and to set a base time to compare how well they retained the information. After they concluded their 5 trials, they were dismissed.

After one day, we invited the participants back to observe how well they had retained the information. This was done by having each group solve the wooden puzzle once without instruction.[Fig-1] This 6th trial was timed to compare to the 5th trial of the day prior. This comparison would give us insight into how well they retained the spatial information.

3.4 Design

This experiment was a 2x2 between-subject design. Our independent variables were the method of learning the puzzle, while our dependent variable was the time to construct the puzzle after a 24-hour retention period. We used an unpaired T-Test to calculate to observe the difference in time between the two independent variables.

4 RESULTS & DISCUSSION

4.1 Short Comings

Before the results are presented, a quick note on the possible shortcomings in the experiment.

While each group was only trained on the puzzle five times, there is a significant difference in the amount of time each group spent with the puzzle while training. This is due to the limitations of tactile ability and movement in VR. These limitations forced the VR group to spend more time on average with the puzzle.

Another point of concern would be the VR experience within the VR group. This group did all of their training in VR. While conducting the experiment, some participants were observed struggling with the controls and understanding how the VR world worked. This could have impacted how they interacted with the puzzle, and in turn, could impact how well they were able to learn the puzzle.

Lastly is how the different groups interacted with their medium of training. Some participants in the wooden puzzle group seemed to find the task trivial. While the Wooden training was somewhat trivial, it might have impacted how they interacted with the puzzle. Some participants were observed just "going through the motions" on the last few tests. This could have led to the Wooden puzzle group not learning the puzzle as well. On the same note, many of the VR participants were excited to be immersed in the VR world. The same participants seemed to be more engaged with the training task than their wooden participant counterparts. While this is understandable, the difference in engagement level could drastically affect our results.

4.2 Results

After the trials had concluded and all the data was collected, a statistical unpaired T-Test analysis was conducted to observe how the times between the two groups differed. The VR group had an average time of 115.1 seconds while the Wooden Puzzle group had an average of 74.98 seconds. The standard deviation for the Vr group was 96.73, and 58.71 for the Wooden group.[Fig-7] The result of this test was a p-value of 0.2322. This value was higher than our chosen significance level of 0.05.

4.3 Discussion

Our results did not show a statistically significant difference between the performance of the two groups after 24 hours. While the wooden puzzle group had a better average performance (74.98 seconds) compared to the VR group (115.1 seconds)[Fig-7], we are unable to draw a statistical conclusion between the two learning methods

There are several possible explanations for the difference in times. One factor could be the tactile feedback provided by handling the physical puzzle pieces, which may have facilitated the learning process and strengthened memory retention. Additionally, the real-world interaction with the wooden puzzle could have provided participants with a more intuitive understanding of the task compared to the VR environment.

The variability in the VR group's performance was higher than in the wooden puzzle group, as indicated by the larger standard deviation. This increased variability could be attributed to differences in participants' familiarity and comfort with the VR technology or individual differences in adapting to the VR learning environment.

It is essential to consider the limitations of this study, including the relatively small sample size of 12 participants per group. This is the reason for not being able to draw a statistical conclusion. Future research should involve larger sample sizes to increase the generalizability of the findings. Additionally, exploring the impact of different types of VR environments, puzzle complexity, and the length of the retention period could provide further insights into the effectiveness of VR as a learning tool for spatial tasks.

5 CONCLUSION

In conclusion, our study aimed to compare the effectiveness of learning and retaining spatial information using a wooden puzzle and a virtual reality (VR) environment. Although the wooden puzzle group performed better on average compared to the VR group, we were unable to establish a statistically significant difference between the two learning methods.

The difference in performance and the higher variability in the VR group's results may be attributed to factors such as tactile feedback, real-world interaction, and participants' familiarity with VR technology. However, these factors could not be confirmed as the cause of the observed differences within the scope of this study.

The limitations of our study, including the small sample size and the simplicity of the puzzle task, should be addressed in future research. Larger sample sizes and a more diverse range of puzzles and VR environments could provide more insights into the role of VR as a learning tool for spatial tasks. Additionally, investigating different retention periods might help determine the long-term effectiveness of VR in teaching and retaining spatial information.

Overall, our study suggests that there is potential for VR as a learning tool for spatial tasks, but more research is needed to fully understand its effectiveness and best applications in comparison to traditional methods.

6 FIGURES

Fig. 1. Wooden puzzle as part of the spatial retention experiment.

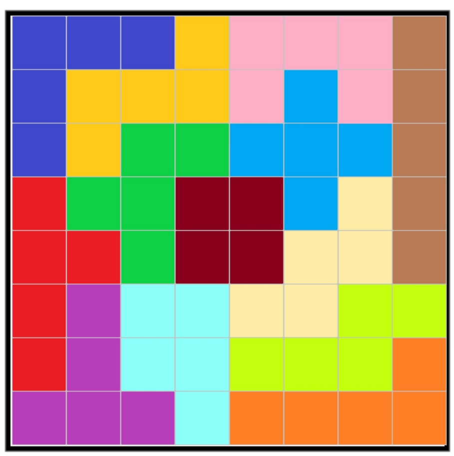

Fig. 2. To aid in distinguishing between pieces, each puzzle element is color-coded for easy identification by the user.

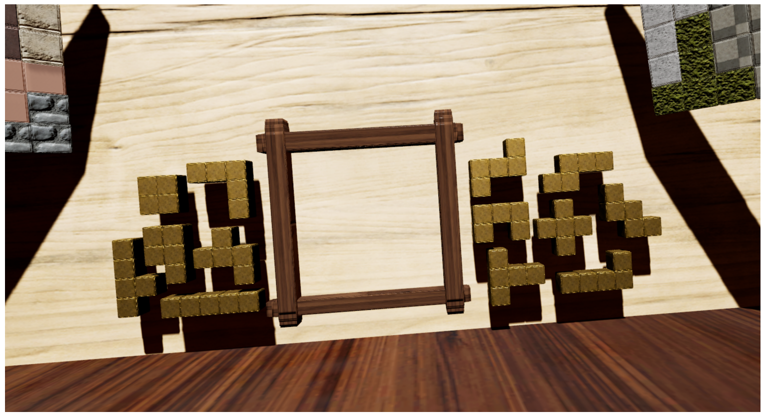

Fig. 3. The initial view of the immersive VR environment upon user entry.

Fig. 4. Instructions for completing the puzzle displayed, with each piece differentiated by unique color and pattern.

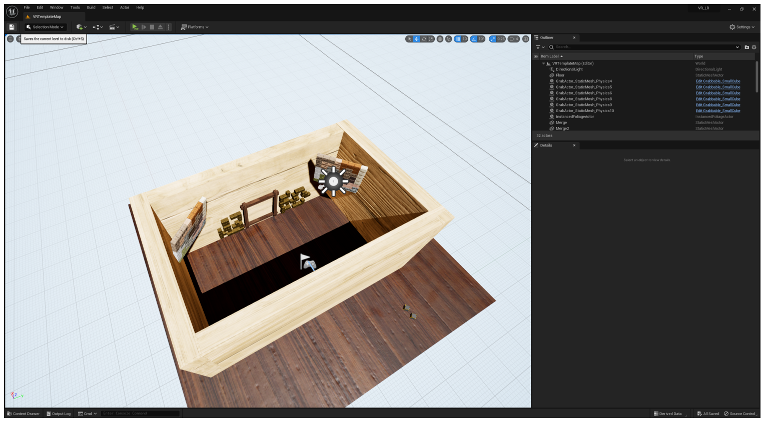

Fig. 5. Top-down perspective of the VR environment providing a bird's-eye view.

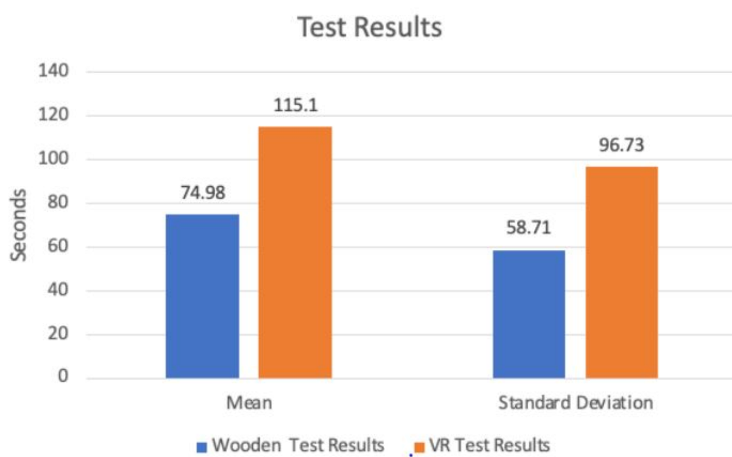

Fig. 6. Comparison of Means and Standard Deviation

REFERENCES

[1] Ali Alaraj, MichaelG Lemole, JoshuaH Finkle, Rachel Yudkowsky, Adam Wallace, Cristian Luciano, PPat Banerjee, SilvioH Rizzi, and FadyT Charbel. 2011. Virtual reality training in neurosurgery: Review of current status and future applications. *Surgical Neurology International* 2, 1 (2011), 52. https://doi.org/10.4103/2152-7806.80117

[2] Paola Araiza-Alba, Therese Keane, Won Sun Chen, and Jordy Kaufman. 2021. Immersive virtual reality as a tool to learn problem-solving skills. *Computers Education* 164 (2021), 104121. https://doi.org/10.1016/j.compedu.2020.104121

[3] E. Z. Barsom, M. Graafland, and M. P. Schijven. 2016. Systematic review on the effectiveness of augmented reality applications in medical training. *Surgical Endoscopy* 30, 10 (2016), 4174–4183. https://doi.org/10.1007/s00464-016-4800-6

[4] Juan Manuel Davila Delgado, Lukumon Oyedele, Peter Demian, and Thomas Beach. 2020. A research agenda for augmented and virtual reality in architecture, engineering and construction. *Advanced Engineering Informatics* 45 (2020), 101122. https://doi.org/10.1016/j.aei.2020.101122

[5] Chelsea Ekstrand, Ali Jamal, Ron Nguyen, Annalise Kudryk, Jennifer Mann, and Ivar Mendez. 2018. Immersive and interactive virtual reality to improve learning and retention of neuroanatomy in medical students: A randomized controlled study. *CMAJ Open* 6, 1 (2018). https://doi.org/10.9778/cmajo.20170110

[6] Ramy Elmoazen, Mohammed Saqr, Mohammad Khalil, and Barbara Wasson. 2023. Learning analytics in virtual laboratories: A systematic literature review of empirical research. *Smart Learning Environments* 10, 1 (2023). https://doi.org/10.1186/s40561-023-00244-y

[7] Joey Ka-Yee Essoe, Nicco Reggente, Ai Aileen Ohno, Younji Hera Baek, John Dell'Italia, and Jesse Rissman. 2022. Enhancing learning and retention with distinctive virtual reality environments and mental context reinstatement. *npj Science of Learning* 7, 1 (2022). https://doi.org/10.1038/s41539-022-00147-6

[8] Sharon Farra, Elaine Miller, Nathan Timm, and John Schafer. 2013. Improved training for disasters using 3-D virtual reality simulation. *Western Journal of Nursing Research* 35, 5 (2013), 655–671. https://doi.org/10.1177/0193945912471735

[9] Sandra Helsel. 1992. Virtual reality and education - JSTOR. https://www.jstor.org/stable/44425644

[10] Elliot Hu Au and Joey J. Lee. 2017. Virtual reality in education: A tool for learning in the experience age. *International Journal of Innovation in Education* 4, 4 (2017), 215. https://doi.org/10.1504/ijiie.2017.10012691

[11] Lasse Jensen and Flemming Konradsen. 2017. A review of the use of virtual reality head-mounted displays in education and training. *Education and Information Technologies* 23, 4 (2017), 1515–1529. https://doi.org/10.1007/s10639-017-9676-0

[12] Joanna K. Crosier, Sue V. G. Cobb, and John R. Wilson. 2000. Experimental Comparison of Virtual Reality with Traditional Teaching Methods for Teaching Radioactivity. *Education and Information Technologies* 5, 4 (2000), 329–343. https://doi.org/10.1023/a:1012009725532

[13] Sam Kavanagh, Andrew Luxton-Reilly, Burkhard Wuensche, and Beryl Plimmer. 2016. A systematic review of virtual reality in education. https://eric.ed.gov/?id=EJ1165633

[14] Michael S Miller, Deborah M Clawson, and Marc M Sebrechts. 1999. Long-term retention of spatial knowledge acquired in virtual reality. In *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, Vol. 43. SAGE Publications Sage CA: Los Angeles, CA, 1243–1246.

[15] Kimberley Osberg. [n. d.]. http://www.hitl.washington.edu/projects/education/puzzle/spatial-cognition.html

[16] Jaziar Radianti, Tim A. Majchrzak, Jennifer Fromm, and Isabell Wohlgenannt. 2020. A systematic review of immersive virtual reality applications for higher education: Design Elements, lessons learned, and research agenda. *Computers amp; Education* 147 (2020), 103778. https://doi.org/10.1016/j.compedu.2019.103778

[17] Ya-Ming Shiue, Yu-Chiung Hsu, Meng-Huei Sheng, and Cheng-Hsuan Lan. 2019. Impact of an augmented reality system on students' learning performance for a health education course. *International Journal of Management, Economics and Social Sciences* 8, 3 (2019). https://doi.org/10.32327/ijmess/8.3.2019.12

[18] Sherrill J. Smith, Sharon Farra, Deborah L. Ulrich, Eric Hodgson, Stephanie Nicely, and William Matcham. 2016. Learning and retention using virtual reality in a decontamination simulation. *Nursing Education Perspectives* 37, 4 (2016), 210–214. https://doi.org/10.1097/01.nep.0000000000000035

[19] Brian N. Verdine, Roberta M. Golinkoff, Kathryn Hirsh-Pasek, Nora S. Newcombe, Andrew T. Filipowicz, and Alicia Chang. 2013. Deconstructing building blocks: Preschoolers' spatial assembly performance relates to early mathematical skills. *Child Development* 85, 3 (2013), 1062–1076. https://doi.org/10.1111/cdev.12165

[20] Peng Wang, Peng Wu, Jun Wang, Hung-Lin Chi, and Xiangyu Wang. 2018. A critical review of the use of virtual reality in Construction Engineering Education and training. *International Journal of Environmental Research and Public Health* 15, 6 (2018), 1204. https://doi.org/10.3390/ijerph15061204