Comparing Student-Based Context Priming in Immersive and Desktop Virtual Reality Environments to Increase Academic Performance

Dan Hawes
School of Information Technology
Carleton University
Ottawa, Canada
DHawes@Toonrush.com

Ali Arya
School of Information Technology
Carleton University
Ottawa, Canada
Ali.Arya@Carleton.ca

***Abstract*—Research suggests that 3D virtual environments can be designed to prime engagement, creativity, and improve performance on many cognitive tasks. In this paper, we report on a study that compares the efficacy of context (environmental setting) on the priming of these desired effects within Desktop Virtual Reality (DVR) environments compared to Immersive VR (IVR), viewed from within a VR Head Mounted Device (HMD). We presented a 27-minute seminar "The Creative Process of Making an Animated Movie" to 68 participants within 4 different learning spaces: two with IVR (Prime and No Prime) and two with DVR (Prime and No Prime). The priming scenarios for both IVR and DVR environments included subject matter and popular culture visual artifacts related to animated movies and characters placed within a theatre classroom. This was intended to create a situated learning effect. The No Prime condition was presented in a standard classroom theatre without visual artifacts or any subject matter augmentation. A 20-question multiple-choice content test and UX survey were administered following the seminar while an affective questionnaire measuring anxiety and positive affect were provided before and after the seminar. Increased academic performance was observed with a significant difference in both DVR and IVR priming scenarios compared to the no priming conditions.**

***Index Terms*—Context, priming, situated learning, immersive, DVR, artifacts, experiential, ELT, applied computing, education, computer-assisted instruction, human-centered computing, human computer interaction, interaction paradigms, virtual reality**

I. Introduction

Research suggests that the context of virtual learning environments can affect performance. In fact, 3D virtual environments can be specifically designed to prime engagement, creativity, and improve performance on many cognitive tasks [2]. While similarly designed environments in real-world space would also likely improve performance, the costs would be considerable and difficult to achieve ubiquity. Virtual Reality (VR), a 3D technology that provides the tools to visually simulate real-world environments, allows us to improve context by creating custom learning spaces intended to prime (act as stimuli that improves subsequent cognition) engagement and academic performance [20], [21], [2].

An important aspect of understanding the contextual effect of custom virtual environments is the level of immersion the user is experiencing. While there is little research on the comparable effect of VR immersion on user perception of context, the degree of immersion may well have an impact. This study expands on the notion of context from "what virtual environment the user sees" to "what physical context the user has". In this paper, we seek to understand whether varying levels of immersion changes the effectiveness of context priming interventions to improve academic performance within virtual environments. As such, we compare the priming effects of Immersive VR (IVR) environments to Desktop VR (DVR) environments. IVR is experienced from within a VR Head Mounted Device (HMD) while DVR is typically experienced on a desktop, laptop, or tablet-based computer.

Prime conditions were designed to induce a positive situated learning effect [3][14] intended to improve academic performance. While our main goal is to investigate the effect on academic performance, we also measure for affective elements (anxiety and positive affect) and additional affective filter elements (motivation and self-confidence) [11][12] that may be relevant to the VR experience and/or academic performance.

After reviewing related IVR, DVR, priming, and experiential learning we follow with study description, hypotheses, results, and user feedback that will inform the design of future IVR/DVR experiences. We conclude with discussion, limitations and propose further study of varying subject matter within IVR and DVR environments.

II. Related Work

A. IVR and DVR Research

VR technology has been evolving and becoming increasingly sophisticated over the past 57 years since Ivan Sutherland introduced the concept of the ultimate display to academia in 1965 [25]. While the technology has achieved recognition in popular culture, the evolving technology has been mostly relegated to academic research. Only recently with the release of low-cost sophisticated HMDs like the Oculus Quest has VR become an accessible mainstream product/service gaining popularity and growing in many fields:

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entertainment, education, learning, travel/tourism experiences, and myriad others. While IVR offers a fully immersive experience and an enhanced feeling of presence [20], [21], DVR environments have been shown to similarly create positive learning effects [2].

A 2020 study comparing a DVR field trip, IVR field trip, and an actual geoscience field trip observed that both DVR and IVR participants preferred the VR field trips to the actual field trip experience [33]. Further, both IVR and DVR yielded higher learning outcomes than the actual field trip experience. While participants expressed higher motivation and feelings of presence in IVR compared to the DVR, there was no learning performance difference between the IVR and DVR conditions [33]. Researchers have acknowledged that other visual simulation applications may have benefitted more from the IVR (e.g., procedural memorization and data visualization) [13], [18], [19], [23]. In line with this insight, a 2020 study focused on optimizing the use of VR for pedagogical value, discovered that both methods have merit and while many students are comfortable and more familiar with DVR, there may be cases where a first-person perspective could better serve the learning situation [15].

B. Priming and VR

Priming occurs when a stimulus (the prime) makes the content and subsequent cognitive processes more accessible [8]. Most often, priming stimuli are supraliminal (observable but not obvious) where changing the context of an environment can create effects with little or no perceptual awareness. A picture can create bias and affect how a person thinks [7] or placing codes (A vs. F) on pre-test forms can affect academic performance [4].

Central to the concept of VR is the quantifiable concept of immersion and the more subjective idea of "presence" or the feeling of being there. Based on these immersive possibilities and the ability to create a sense of presence, VR is an ideal environment to create scenarios to evoke different forms of conscious awareness [20]. For designers, VR offers the possibility to create learning spaces that are more conducive to learning while “designing out” potential anxiety-inducing barriers. In a 2013 study, 3D virtual environments were used to test the effects of priming on creativity. The results showed that when teams created ideas in the primed virtual environments, they created more ideas and of higher quality than the control groups [2]. While these early priming studies are promising, much research is required to determine how the feelings of presence in VR trigger emotions and engagement leading towards better cognitive outcomes [28], and how to design VR experiences for maximal priming and cognitive effects within learning environments [5].

C. Learning Theories

Priming efficacy directly benefits from repetition [32] and authentic experiences [1] where priming effects can be woven subtly into the environmental context. As such, of particular interest for our research was Kolb’s Experiential Learning Theory (ELT) [10]. With ELT, learning begins with having a concrete experience, followed by a reflection of that experience, the conceptualization of abstract concepts that incorporates the new insights from the experience, and finally active experimentation of the lessons learned. The cycle continues to repeat as the learner’s conceptual worldview is repeatedly refined. Learning is achieved as a process: a continuing reconstruction of experience.

The ELT cycle can provide iterative experiences and timed trigger points where various priming interventions may be activated. Trigger points may occur before, after, or during the experience. Such guided priming can lead to increased motivation, better situational context, and ultimately better learning outcomes [5]. Stephen Krashen’s Affective Filter (AFH) hypothesis with second language learning advocates for creating experiences that reduce anxiety, while increasing motivation and self-confidence [11][12]. The ELT cycle offers a fertile substrate where priming interventions to reduce these affective filters could improve academic performance.

Situated Learning Theory (SLT) [3], [14] recognizes the value of social and contextual experiences within a community of practice. Within a specific situation learners can see, hear, do, and feel the experience resulting in higher retention and improved performance. Based on SLT, technology solutions that offer improved situational contexts should induce confidence through better understanding, increase motivation to try something new and ultimately improve academic performance. For example, placing a student within an animation studio could amplify the understanding of an animation-related idea or concept [6] [3][14] and given this improved understanding, perhaps increase their willingness to participate in the process.

Hence, by combining insights on priming, experiential/situated learning, and VR, we intend to better understand the comparable effectiveness of IVR and DVR in primed environments to improve academic performance and related affective elements.

III. Methodology

We conducted a user study to perform an evaluation of context priming efficacy to impact academic performance in IVR and DVR environments by comparing data from a previous IVR study [6]. This study will deploy a remote research process where a DVR web link is accessed by each participant in their own home. Our study was approved by the University’s Research Ethics Board and followed all the guidelines, including those for safe experimentation during the COVID-19 pandemic.

A. Study Overview

The study, a 2x2 between-subjects test with two independent variables (Prime condition, immersive context), compared the effectiveness of VR-based priming in IVR and DVR environments. A 27-minute seminar “The Creative Process of Making an Animated Movie” was presented to 34 participants and compared with 34 participants from a previous study [6] to create four unique conditions, 2 Prime and 2 No Prime.

1) IVR with Prime environment (17)
2) IVR with No Prime environment (17)
3) DVR with Prime environment (17)
4) DVR with No Prime environment (17)

The Prime conditions included a situated learning environment: a theatre with animation artifacts vs. the No Prime: theatre without animation artifacts. The priming conditions were selected based on SLT [3][14] that emphasized the role of authentic and realistic environments in learning. The immersive context was either IVR or DVR. The IVR study participants observed the same classrooms and priming conditions as DVR participants but from within an Oculus Quest VR Head Mounted Device (HMD) [6]. The study used three dependent variables (academic score, user experience, and affective improvement).

Academic score is our main subject and represents the learning effect of the context. It was measured with a 20-question multiple choice test completed immediately after the seminar. Affective factors: anxiety and positive affect, were measured using a pre and post course short-form State Trait Anxiety Inventory (STAI) [16] and Positive Negative Affect Schedule (PANAS) [29] surveys respectively. The STAI measured changes in self-reported anxiety levels while the PANAS measured changes in both positive and negative affect. Other affective elements (motivation and self-confidence) were queried in the UX survey with two 5-point Likert scale questions. The questions were 1) How motivated do you feel to participate in the creation or production of an animated movie? and 2) How confident do you feel in your ability to create your own animated story?

Hypotheses

H1: The Prime conditions will improve academic performance compared with the No Prime condition in **H1: a)** IVR and **H1: b)** DVR environments, supporting the notion that environment context priming maintains efficacy between varying levels of immersion.

H2: There will be no improvement in academic performance observed due to immersion in both Prime conditions: **H2: a)** (Prime IVR vs. Prime DVR) and **H2: b)** (No Prime IVR vs. No Prime DVR).

H3: Key affective filter elements [11] will be reduced because of the ELT/SLT learning process including **H3: a)** Anxiety **H3: b)** Motivation and **H3: c)** Self-confidence.

B. Participants

The user study was performed with 34 DVR participants compared with 34 IVR participants from a previous study [6l. Participants were from a varying programs within a university student audience, 18+, and ongoing adult education students with an interest in exploring VR educational technology. Participants were paid $20 CDN (via e-transfer) upon completion of the course and the post seminar questionnaires.

C. Apparatus

Participants were provided with a Desktop VR link from Youtube VR36*0* to be viewed on a desktop PC, laptop, or computer tablet. The IVR participants in the previous study [6] observed the same VR environments but from within an Oculus Quest HMD. Similarly, testing and questionnaires were completed on desktop PC or mobile tablets within a standard browser for both IVR and DVR participants. A link to the Prime and No Prime DVR conditions are provided below.

No Prime Classroom

https://www.youtube.com/watch?v=68e_XW1nQYY&t=1162s

Prime Classroom (with Artifacts)

https://www.youtube.com/watch?v=VkayjGBUVaQ&t =13s

The 27-minute seminar, "The Creative Process of Making an Animated Movie" was presented in an audio-visual format on a large screen with the professor, an experienced animation producer (embodied within a human-like avatar), located behind the podium (see Figure 1A and 1B). The content consisted of charts and videos that described the creative process including sections related to the idea, story structure, characters, aesthetics, prototyping, and key creative roles. Popular movie examples were first analysed (The Lion King, Monsters Inc), then as an example, a new movie idea was presented and walked through each stage of the process to demonstrate how to approach the problem from scratch. While the audio and visual course content was identical (rendered from the same source files), the Prime environments presented popular culture animation icons and artifacts that iterated every 2-3 minutes above the main content screen. The artifacts/posters at the sides of the classroom did not change in order not to create visual distractions away from the front of the classroom. The multiple-choice questions (20) related directly to the content presented in the seminar. Certain questions (15) required the student to apply what they had learned from the theory while others (5) challenged the student to choose solutions that applied what they had learned from the new movie idea presented.

D. Procedure

Given the limitations caused by COVID-19, we designed a study that could be performed independently by participants at their homes. Each participant received a unique participant code which was used to link the pre and post seminar questionnaires and results. Participants were provided with a Youtube 360VR link for the main seminar content and a link to a website that provided the following information:

- Short Video Guide
- Consent Form
- Pre-Post Test Surveys (STAI and PANAS)
- Post Seminar VR User Experience Survey
- Post VR Seminar Content Test

Upon completion of the short video guide, (a 2-minute explanation of the process and surveys/tests that we expected the participants to complete), participants were asked to complete a consent form, STAI and PANAS surveys and then proceed to the Youtube 360VR link. Upon completion of the seminar, participants returned to the website to complete the post seminar STAI and PANAS surveys, multiple choice test and UX Questionnaire.

Fig. 1A. The No Prime environment (classroom theatre).

Fig. 1B. The Prime (classroom theatre with artifacts).

IV. Results

We had a 2x2 experiment design with two independent variables (Prime condition, immersion) and three dependent variables (academic performance, UX satisfaction, and affect). While this test only sampled two conditions, we also wanted to test the results against results in Study 2a with the comparable immersive environments. After reviewing the outlier data, we opted to eliminate the highest value from all four conditions (two immersive and two desktop) to avoid skewing results based on potentially contaminated data. These high values occurred for academic score and were more than twice the average. They came from participants who were very familiar with the subject matter. Hence our sample size was reduced to 16 participant inputs per condition, 64 in total. The independent test scores for all four condition groups are presented in Table 1 below.

With an equal number of participants (16) we conducted a two factor ANOVA with independent samples to test for differences in academic score (Table 2). After confirming a significant difference in means between columns (Prime vs. No Prime) (p=.0002), we used a Tukey HSD post-hoc test at (.05) to determine significance for the various combinations. For Tukey test results, see Table 3 below. Both IVR and DVR Prime conditions compared to their No Prime conditions were significant whereas Prime IVR compared to Prime DVR and No Prime IVR compared to No Prime DVR were nonsignificant.

TABLE I. Test Results for Academic Score

Data for 2x2 Anova (Prime Condition, Immersion)			
IVR Prime	IVR No Prime	DVR Prime	DVR No Prime
10	10	11	9
12	8	12	8
12	12	7	11
13	10	10	12
16	10	14	9
13	7	11	9
10	11	9	12
11	10	12	8
13	11	14	9
11	9	10	8
8	10	11	7
16	8	13	11
13	7	15	11
11	7	13	11
13	11	11	6
9	14	11	14

TABLE II. 2F Anova (Prime/No Prime, IVR/DVR)

Anova: Two-Factor for Independent Samples						
SUMMARY	Prime	No Prime	Total			
IVR						
Count	16	16	32			
Sum	191	155	346			
Average	11.938	9.688	10.813			
Variance	4.863	3.829	5.512			
DVR						
Count	16	16	32			
Sum	184	155	339			
Average	11.5	9.6875	10.59			
Variance	4.133	4.496	5.023			
Total						
Count	32	32				
Sum	375	310				
Average	11.719	9.688				
Variance	4.402	4.028				
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Sample	0.7656	1	0.7656	0.1768	0.6756	4.0012
Columns	66.0156	1	66.0156	15.2454	0.0002	4.0012
Interaction	0.7656	1	0.7656	0.1768	0.6756	4.0012
Within	259.8125	60	4.3302			
Total	327.3594	63				

TABLE III. Tukey HSD Test Results

Tukey HSD Test [.05]		Rows	HSD(.05) = 1.04	
		Columns	HSD(.05) = 1.04	
Results Table Comparison		Delta Means	Tukey	Result
IVR Prime vs No Prime		2.28	1.04	significant
DVR Prime vs No Prime		1.8	1.04	significant
Prime IVR vs Prime DVR		0.438	1.04	nonsignificant
No Prime IVR vs No Prime DVR		0	1.04	nonsignificant

No affective changes were observed in anxiety reduction (STAI) for DVR (p=.423) or IVR (p=.3876) or positive affect (PANAS) for DVR (p=.4188) or IVR (p=.1937). We did however observe a significant positive impact on both motivation and self-confidence through the UX feedback comparing Prime to No Prime conditions. The post-test UX question assessing the priming effect of motivation to participate in creating an animated movie observed significance, in both IVR (p=.0285) and DVR (p=.0242) scenarios compared to the control conditions. See Figure 4. Similarly, the post-test UX question assessing self-confidence in their ability to create an animated movie observed a significant difference comparing Prime to No Prime conditions in both IVR (p=.0067) and DVR (.0282) scenarios. See Figure 5.

1) UX Commentary Feedback

The UX commentary provided relevant feedback related to the design of the VR experiences. As the comparable priming conditions were not shared with the participants, most feedback was related to the general design of the UX experience in either IVR or DVR contexts. In general, the immersive conditions from the comparable study [6] seemed to generate slightly more favourable commentary as was shown in previous studies comparing IVR and DVR. A few examples of the more salient comments in each condition are presented below.

2) Example IVR Comments

- When in VR classroom, you feel totally immersed
- It reminds me of the university setting but with the elimination of the anxiety.

3) Example DVR Comments

- It feels like you are in attendance
- It was clear that I was not actually in the environment, but it did still feel like I could interact with and explore the environment.

Motivation to participate in creating an animated movie				
t-Test: Two-Sample Assuming Equal Variances	IVR Prime	IVR No Prime	DVR Prime	DVR No Prime
Mean	4	3.1875	3.56	2.6875
Variance	0.93	1.7625	1.46	1.4292
Observations	16	16	16	16
Pooled Variance	1.35		1.45	
Hypothesized Mean Difference	0		0	
df	30		30	
t Stat	1.98		2.06	
P(T<=t) one-tail	0.0285		0.0242	
t Critical one-tail	1.7973		1.6973	
P(T<=t) two-tail	0.057		0.048	
t Critical two-tail	2.0422		2.0422	

Fig. 4. UX feedback on motivation (Likert Scale 1-5).

Self Confidence in your ability to create an animated movie				
t-Test: Two-Sample Assuming Equal Variances	IVR Prime	IVR No Prime	DVR Prime	DVR No Prime
Mean	3.6875	2.625	2.8125	2.0625
Variance	0.7625	1.85	0.9625	0.729167
Observations	16	16	16	16
Pooled Variance	1.30625		0.845833	
Hypothesized Mean Difference	0		0	
df	30		30	
t Stat	2.629		2.3066	
P(T<=t) one-tail	0.0067		0.014	
t Critical one-tail	1.6973		1.6972	
P(T<=t) two-tail	0.013		0.0282	
t Critical two-tail	2.0422		2.0422	

Fig. 5. UX feedback on self-confidence (Likert Scale 1-5).

V. Discussion and Limitations

In this study, we focused on extending our understanding of context priming to increase cognitive function and improve the user experience within desktop VR environments.

Our hypotheses were designed to test the priming effects of our Primed Desktop VR environment compared to our No Prime condition and to compare the relative effect of immersion. While IVR has the advantages of full immersion and novelty, DVR is more familiar and less complicated. Existing literature is not conclusive on the effect of immersion and superiority of IVR or DVR. So, our research adds to an increasing body of research on the subject.

In reviewing the first hypothesis, the DVR Prime condition observed significant improvement over the No Prime condition. This is consistent with the previous IVR study. Hence, H1 a) and H1 b) are supported. Further, the DVR Prime condition did not observe a significant difference in academic performance compared to the IVR Prime condition, nor did the DVR No Prime condition observe a difference in academic performance relative to the IVR No Prime condition. As such, H2 a) and H2 b) are supported.

Our final hypothesis sought to determine if the affective filters (Anxiety, Motivation, and Self-Confidence) would be reduced because of the varying levels of immersion. As presented above, STAI results did not observe a significant reduction in anxiety. Hence H3 a) is not supported. A significant difference was observed in increased motivation (IVR (p=.0285) and DVR (p=.0242)) for DVR and increased self-confidence IVR ((p=.0067) and DVR (p=.0282)) for both IVR and DVR. Hence, H3 b) and H3 c) are supported (for DVR) and H3: c) is supported for both IVR and DVR. The priming effect of the virtual environments did not decrease anxiety but did increase motivation and self-confidence compared to the No Prime conditions for both IVR and DVR environments.

The UX and affective feedback did provide some relevant information for further reflection, however. There appeared to be a slightly different tone in the qualitative feedback even though we did not observe a significant difference in affect or subjective UX between Prime and No Prime conditions in either medium. The commentary for the IVR participants seemed to be slightly more positive when compared to the DVR conditions suggesting that the affective elements of learning between immersive and desktop conditions warrant further study. It's very possible that the immersive activity can serve as somewhat of an escape, allowing students to filter out distractions from their real-world environments including smartphone and personal interruptions. In desktop conditions, students remain subject to influences within their real-world environments, and as such may have experienced the learning session more like a typical computer application rather than a fully immersive learning experience.

There were limitations to be considered for future research. First, these studies were small numbers (16 per condition) and could benefit from a much larger study. Further, the affective surveys (anxiety and positive affect) were subjective user responses and could be more accurately ascertained using F-MRI and/or galvanic skin response technology. While most of the participants had little or no history with the subject matter of the course, it would have helped to include a pre-test measure to ensure that students were evenly distributed. This could have helped avoid the outlier effects. We were also concerned with the timing of the survey and the potential for COVID-19 situational effects. The study was performed in the summer and early fall of 2021, a time when most students were at home with no commuting requirements for work or school due to COVID-19. As such, we noticed that pre-test anxiety levels were on the low side while positive affect appeared high compared to previous studies which may have mitigated a priming effect for these affective elements.

Finally, while we achieved an academic performance improvement for both IVR and DVR contexts, effectiveness between IVR and DVR may differ depending on specific types of content within other learning domains. In this study, there was no requirement for 3D visualization but likely experiences with high 3D visual requirements would be served better in IVR. The seminar for this study was a creative process that was conducive to collaboration, community-based learning, and the ELT cycle. Similar testing should be performed on varying subject matters with different types of content experiences related to geography, history, mathematics, music, and other creative arts to determine the optimal immersive environments.

VI. Conclusion

Motivated by the results of context priming within IVR environments, we wanted to understand if we could apply these priming methods to DVR environments to achieve a similar effect.

In our study of 34 participants, combined with 34 participants from an earlier study [6] with two conditions (1 Prime, 1 No Prime) we observed a clear priming effect that we attribute to the subject matter artifacts and a potential situated learning effect, consistent with the IVR study. Also, consistent with established research on supraliminal priming, as deployed in previous studies, [5][6] the UX feedback, STAI, and PANAS did not observe a significant difference between Prime and No Prime conditions. We did note a general affective trend, where the immersive conditions elicited more positive commentary than the less immersive conditions. While anxiety and positive affect did not show improvements, motivation and self-confidence showed positive priming effects in both IVR and DVR compared to the No Prime conditions.

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