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6 authors, including:

Aliane Loureiro Krassmann
Instituto Federal de Educação, Ciência e Tecnologia Farroupilha

Miguel Melo
Institute for Systems and Computer Engineering, Technology and Science (INESC …

Bruno Peixoto
Universidade de Trás-os-Montes e Alto Douro

Rafael Darque Pinto

Learning in Virtual Reality: Investigating the Effects of Immersive Tendencies and Sense of Presence

Aliane Loureiro Krassmann[1](✉), Miguel Melo[2], Bruno Peixoto[3], Darque Pinto[3], Maximino Bessa[2,3], and Magda Bercht[1]

[1] Universidade Federal do Rio Grande do Sul, Porto Alegre, Brazil
alkrassmann@gmail.com
[2] INESC TEC, Porto, Portugal
[3] Universidade de Trás-os-Montes e Alto Douro, Vila Real, Portugal

Abstract. The goal of this study is to examine the effects of the sense of presence and immersive tendencies on learning outcomes while comparing different media formats (Interactive VR, Non-interactive VR and Video). An experiment was conducted with 36 students that watched a Biology lesson about the human cells. Contrary to expected, the results demonstrate that the Non-interactive VR was the most successful format. Sense of presence and immersive tendencies did not have an effect on learning gain, and the latter was not a critical factor to experience the sense of presence. The findings provide empirical evidence to help understand the influence of these variables on learning in VR.

Keywords: Virtual Reality · Video · Sense of presence · Immersive tendencies

1 Introduction

The technology of Virtual Reality (VR) allows the creation of vivid and highly realistic 3D Virtual Environments (VE). In this sense, it can be a useful tool for education, especially in disciplines where it is important to visualise learning materials (e.g. Chemistry and Biology) [1], allowing students to develop a better understanding of the relationship among components by engaging with information from multiple roles and perspectives. Students also have the opportunity to experience subject matter that would be difficult if not impossible with conventional methods, in a more stimulating and motivating setting, where learning can be both challenging and fun [2].

One of the keys aspects involved with the VR experience is the sense of presence. According to Heeter [3], "the sense of being there" is the best definition of presence in this context, where the users feel like they are part of that virtual world such as the real world. Consequently, it is the degree of how much the user feels present in that VE. Literature suggests that this is a crucial aspect for learning in VR, as it is connected to many constructs influencing its process, as attention and focus [4, 5]. Studies have already demonstrated a positive relationship between sense of presence and performance, as Schrader & Bastiaens [6] and Lee, Wong & Fung [7].

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Several physiological reasons collaborate to explain the association between sense of presence and learning. According to Riva, Waterworth & Murray [8, p. 10], "presence is a core neuropsychological phenomenon whose goal is to produce a sense of agency and control: I am present in real or virtual space if I manage to put my intentions into action". Tjon et al. [9], discovered that the feeling of presence during a VR experience was associated with a decrease in electroencephalography (EEG) frontal alpha power, which in Neuroscience indicates a stronger engagement.

Another important factor of a VR experience is the immersion, which differs from the sense of presence as it refers to an objective description of the used technology, including the stimulus-driven variables vividness and interactivity [10]. For example, the use of Head-Mounted Displays (HMD) allows more immersion than just use a screen (desktop-based VR). Immersion is considered one of the main factors influencing the sense of presence, in that a higher level of immersion can predict a higher presence [5, 11, 12].

Despite that, each individual has its own immersive tendencies, which is the propensity to experience immersion [11]. It refers to an individuals' tendency to become involved in situations and maintain focus on current activities [12]. People with high immersive tendencies can more easily ignore external distractions and focus on their experiences, becoming unaware of the immediate environment and the passage of time. Studies have shown that its relation with the sense of presence is also positive, in that high immersive tendencies lead to higher levels of presence [13].

Nevertheless, which role do these variables really play when the goal is to use VR for learning? Schrader & Bastiaens [6] hypothesise that immersive tendencies function as a moderator on the relationship between the sense of presence and performance. In spite of that, although they found that the immersive tendencies were a predictor of the sense of presence, it did not significantly influence learning outcomes.

Aiming to contribute with this discussion, we investigate the effects of immersive tendencies and sense of presence in the learning gain while performing a comparison across three different media formats: a control Video one, and two experimental of immersive VR, Interactive and Non-interactive. Following the work of Makransky, Borre-Gude & Mayer [14], learning is defined as the demonstration of declarative knowledge, including basic facts and terminology related to the subject, assessed by means of objective retention tests.

2 Related Work

Few studies have added both the immersive tendencies and the sense of presence on the investigation of learning outcomes when VR is used as a media format. Notwithstanding, when the measuring of the variables does not obey a scientific rigour to enable a fair comparison, the results can be hindered, reducing the enthusiasm of teachers and researchers to invest in the costly job of developing instruction in VR. Parong & Mayer [15], for example, concluded that a slideshow group scored significantly better than a VR group on the overall performance. However, the following "a" and "b" variables were not properly controlled in their experiment.

a) *Format of instruction.* In the study of Parong & Mayer [15] the VR animation was automatically-paced and the slideshow presentation was self-paced, as the users determined the rhythm of access. Thus, participants were not in the same passive posture in both conditions. Also, although they ensured that both lessons contained the same words, one version had spoken and the other had printed format; and one version had dynamic graphics and the other graphics in static form.
b) *Measure of learning outcomes.* Instead of an objective pretest-posttest approach, Parong & Mayer [15] opted for a self-reported background knowledge questionnaire as a pretest, justifying they did not want to create a "testing effect", in which the pretest primes learners to construct answers before the instruction. Their posttest consisted of 20 questions based on the lesson, including 16 factual questions in multiple-choice format and four conceptual questions in short-answer format.

Lee, Wong & Fung [7], by their turn, although used a desktop-based VR setting, provide empirical evidence on the causality relationship between the sense of presence and learning outcomes, with students participating in a frog dissection simulator. Despite including the sense of presence and other personal aspects such as an individual's motivation and learning style, they did not investigate the immersive tendencies. Also, students did not participate in different conditions of media format.

Bulu [16], also using desktop-based VR, developed a virtual campus to examine the relationship among three types of sense of presence (social, place and co-presence), satisfaction and immersive tendencies, counting with the participation of preservice teachers. It was identified that the immersive tendencies were related to the sense of presence, which, in turn, was a predictor of satisfaction. Besides not comparing different conditions of media, learning outcomes were also not evaluated.

Schrader & Bastiaens [6] investigated if the sense of presence and learning were related to immersive tendencies in the outcomes from an educational computer game (desktop-based VR) in the area of Physics. Participants were students from high-school, and as a result, the immersive tendencies were positively related to the sense of presence and both trivial and nontrivial learning outcomes. However, the authors also did not test different conditions of media format.

Differently from these three studies and similar to Parong & Mayer [15], the work of Murray, Fox & Pettifer [17] did occur in an immersive VR setting. Participants used an HMD to navigate a virtual city. Among the variables measured, the immersive tendencies and the sense of presence, which, as a result, were not correlated. Thus, the authors suggest that other psychological factors such as dissociation might provide a better indication of the likelihood that the sense of presence will be experienced. Learning was not evaluated and a comparison of different media was not performed.

Allcoat & Mühlenen [1], on the other hand, did compare media formats: interactive immersive VR, passive video watching and traditional textbook. The learning materials were the same text and 3D model of a plant cell for all three conditions. They concluded that the VR condition showed better learning results, suggesting that the "active learning" model plays an important role. Although the emotional response was evaluated, immersive tendencies and sense of presence were not.

Olmos-Raya et al. [18] also compared different media formats, that varied in levels of immersion: high, with HMD device, and low, with tablet and no additional device. Participants received animated contents about History and were evaluated regarding knowledge retention. As a result, better learning outcomes were obtained in the high immersive condition. The authors also evaluated the student's emotional response and motivation, but the immersive tendencies and sense of presence were not considered.

Khashe et al. [13], conversely, found no significant difference in participants' sense of presence and performance while interacting with two different platforms that varied levels of immersion. Although there was a strong positive relationship between immersive tendencies and presence, the same was not found for immersive tendencies and performance. The VE focused on pro-environmental behaviours and performance was measured by means of office-related tasks (time spent on reading passages and reading comprehension). That is, they did not investigate learning as the demonstration of declarative knowledge, assessed through objective retention tests [14].

Finally, in the study of Makransky, BorreGude & Mayer [14], the consequences of learning the same instructional content (safety training) through different instructional media (text, desktop-based VR and immersive VR) were examined. Similar to the previous studies, they confirmed the idea that learning in VR was more motivating than conventional media (text), and the more immersive setting obtained better learning outcomes. Sense of presence and immersive tendencies were also out of their scope.

Table 1 summarises the different aspects investigated in each of the related studies, highlighting a research gap when considering all five aspects/variables that are scoped by this paper.

Table 1. Comparison of the related work

	Immersive VR setting	Sense of presence	Immersive tendencies	Learning outcomes	Media comparison
Lee, Wong & Fung [7]	No	Yes	No	Yes	No
Bulu [16]	No	Yes	Yes	No	No
Schrader & Bastiaens [6]	No	Yes	Yes	Yes	No
Murray, Fox & Pettifer [17]	Yes	Yes	Yes	No	No
Parong & Mayer [15]	Yes	No	No	Yes	Yes
Allcoat & Mühlenen [1]	Yes	No	No	Yes	Yes
Olmos-Raya et al. [18]	Yes	No	No	Yes	Yes
Khashe et al. [13]	Yes	Yes	Yes	No	Yes
Makransky, Borre-Gude & Mayer [14]	Yes	No	No	Yes	Yes
Present study	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**

In addition to including both the immersive tendencies and the sense of presence in the investigation of learning outcomes, the difference of this study lies in seeking for a fairer analysis, by means of:

a) comparing a Non-interactive VR animation to a Video format, delivering the content in an automatic continuous equal pace, ensuring both passive modes of instruction, adding a third Interactive VR condition, as the literature suggests benefits from promoting more active learning [1];
b) performing an objective assessment of learning, by means of equal pre and posttests, allowing to infer learning indexes that can be directly associated with the intervention.

According to Stanney, Mourant & Kennedy [19], it is essential to control for such factors so that it is not erroneously concluded that performance is enhanced by immersion (or other factors) when the improvement might be directly related to the fact that subjects received more or different training time or training trials, for example.

3 Materials and Method

This study has an experimental between-subjects design, in which the independent variable is the media format (Interactive VR (IVR), Non-interactive VR (NVR) and Video (V)), and the dependent variables are the learning gain and the sense of presence. The immersive tendencies are collected for studying a possible correlation with the sense of presence and the learning gain. Participants were equally and randomly assigned to one of three conditions of media format.

In this sense, the following hypotheses are tested, divided into three main axes.

Media and Learning Outcomes (MLO)
MLO1. The learning gain is higher in Interactive VR than in Non-interactive VR.
MLO2. The learning gain is higher in Non-interactive VR than in Video.
MLO3. The learning gain is higher in Interactive VR than in Video.
Sense of Presence (SP)
SP1. The sense of presence is higher in Interactive VR than in Non-interactive VR.
SP2. The sense of presence is higher in Non-interactive VR than in Video.
SP3. The sense of presence is higher in Interactive VR than in Video.
SP4. The sense of presence is positively correlated with the learning gain.
Immersive Tendencies (IT)
IT1. The immersive tendencies are positively correlated with the sense of presence.
IT2. The immersive tendencies are positively correlated with the learning gain.

3.1 Participants

Participants were 36 students (20 male, 12 female) from Universidade de Trás-os-Montes e Alto Douro, located in Portugal. Their ages ranged between 16 and 49 years old (M = 23.86, SD = 6.85), with a distribution very proximal on each of the three experimental groups (M = 23.67, M = 22.83, M = 25.08). They were enrolled in a graduate (n = 14, ~39%) and undergraduate courses (n = 18, 50%) in knowledge areas distinct from Natural Sciences, which is the area of the instruction used in the study (e.g. Multimedia and Engineering). Some participants (n = 4, ~11%) were from the secondary school of the same University.

Participants were asked to rate their experience with computers. Approximately 47% (n = 12) affirmed having an intermediate experience. The remaining were divided into specialists (n = 11, ~31%) and individuals with basic experience (n = 8, ~22%). Regarding knowledge on VR, they were divided in basic (n = 13, ~36%), intermediate (n = 11, ~30%), specialist (n = 7, ~20%), and a small parcel indicated having no knowledge on VR (n = 5, ~14%). However, the majority affirmed having previous experience with immersive VR, meaning they have tried HMD before (n = 29, ~80%).

3.2 Materials

For the purpose of this study, a 12-min Biology lesson in VR was selected: "The Body VR, a Journey Inside the Cell", freely available on the Steam repository [20]. In this animation, the user has a full 360-degree view and is "shrunk" to travel through the bloodstream, while a narrator explains the purpose and structure of cells within it (Fig. 1). The narration was translated from English to Portuguese and recorded in a new track, as the native language of the participants is Portuguese. The original background ambient sounds were maintained.

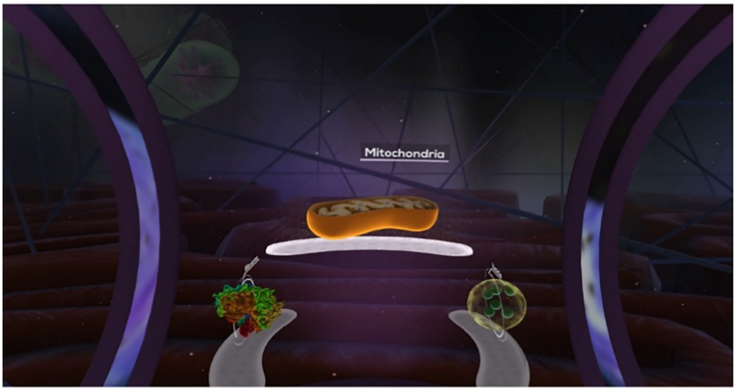

Fig. 1. Screenshot of "The Body VR, a Journey Inside the Cell".

Participants in the VR conditions received the visual stimulus using HTC Vive. This HMD features a 110° viewing angle and a resolution of 1080 × 1200 pixels per eye and allows the real-time tracking of the head position. As for the Interactive VR (IVR) condition, it was added the possibility of interacting with some of the 3D objects presented in the screen using the hand controllers (touching, moving, rotating and changing size).

In the Video (V) condition, it was used a 2D recording of the central view of the VR animation, which was displayed in a conventional computer screen. In all conditions, participants were not allowed to navigate the animation (play, pause, fast forward or rewind), ensuring that all three groups had the same pace of information and visuals to learn with, with the only difference being the media format. Thus, all formats had the same duration (12 min).

The laptop configuration, in short, consists of Intel Core i7-7700HQ processor, NVIDIA GeForce 1070 graphics card, 16 GB of RAM, with a 17″ Full HD (1920 × 1080) IPS screen and Windows 10 operating system. The headphones were Bose QuietComfort 25 with noise-cancelling. The same laptop and headphones were used in all three experimental conditions.

3.3 Instruments

Three instruments were used for data collection, all presented to participants in paper-based printed format: Immersive Tendencies Questionnaire (ITQ), knowledge test and ITC Sense of Presence Inventory (ITC-SOPI).

ITQ. Immersive tendencies were measured using the questionnaire from Witmer & Singer [11]. It contains 18 items with 7-point Likert scale response options (e.g. 1 = never, 4 = sometimes, 7 = very often). The sum of the points corresponds to an individual's immersive tendency. Thus, the range of possible scores is 18–126, and the samples' mean score was 76.66 in the original study.

In order to adapt the instrument to the Portuguese language, the back-translation method was used [21, 22]. First, it was translated from English into Portuguese by two of the researchers together. Then, the Portuguese version was individually translated back to English by two Computer Science doctorates specialising in VR, without knowing the original version. They were all Portuguese natives and fluent in the English language. Subsequently, each researcher demonstrated their agreement or disagreement with the back translation of each item, by calculating the percentage of agreement in a 10-point scale, where 1 = not agree and 10 = extremely agree. The results allowed the inclusion of all the items, as the calculated values were all above 80% of agreement.

Knowledge Test. According to the content presented in "The Body VR, a Journey Inside the Cell" [20], the researchers elaborated a test consisting of 10 multiple-choice questions. Each question had five answer options, with 1 point given for each correct answer (0 for an incorrect answer). Thus, the total score range from 1 to 10. It was initially constructed in English and then translated to Portuguese.

The test was designed to examine participants' knowledge of basic Biology concepts and procedural information involved in the animation, and it was validated by a Natural Sciences professor (Portuguese native, English fluent), who analysed the correspondence and adequateness of each question in both languages.

The same test was applied before and after the intervention (pretest and posttest); the only difference was the order the questions appeared to avoid bias. In the pretest, the questions followed the logic of events described in the animation, and in the posttest, it did not. Improvement from pretest to posttest was used as a measure of learning gain.

ITC-SOPI. In order to assess participant's sense of presence, a validated 44 item 5-point Likert scale (ranging from 1 to 5) questionnaire originated from Lessiter et al. [5] was selected, due to its cross-media comparison capabilities. The instrument is divided into four factors, described as follows, with one item not inserted in none of them (item B6).

a) Spatial Presence (SP) (19 items): the ability to physically control and manipulate aspects of the displayed environment (even using unsophisticated control devices);
b) Engagement (E) (13 items): a measure of a user's involvement, interest in the content of the displayed environment, and their general enjoyment of the experience;
c) Ecological Validity/Naturalness (EVN) (5 items): related to the believability, realism of the content, naturalness and solidity of the environment;
d) Negative Effects (NE) (6 items): headache, eye strain, tiredness, and other negative effects that may be associated with the media format.

We used a reduced validated 35-item Portuguese version from Vasconcelos-Raposo et al. [23], which maintains these four factors.

3.4 Procedure

Upon arrival, participants were welcomed at the facilities of the MASSIVE (acronym for Multimodal Acknowledgeable multiSenSory Immersive Virtual Environments) laboratory and were randomly assigned to one of the three experimental conditions. They were briefly explained the general educational purpose of the study, and started by filling the consent form with demographic questions. Then, the ITQ and the knowledge pretest were filled in the sequence.

The intervention was conducted individually, in a dim and controlled room, where participants were isolated from external variables. They remained seated in the centre of the room, which corresponds to the centre of the animation. In the VR conditions, the researchers helped the participants equipping the HMD, ensuring that it was properly fitted and that they were comfortable with it.

Immediately after the experience, participants filled the knowledge posttest. Then, the ITC-SOPI and, finally, were thanked and dismissed.

3.5 Analysis

Descriptive and inferential statistics were measured using SPSS 18 software, with a confidence level of 95% and Bonferroni adjustment within each simple main effect. Wilcoxon Signed-Rank Test was used in paired-samples tests and the correlation tests were performed using the Spearman's test. To assess the normal distribution of the data, a Shapiro Wilk's test was applied.

When a normal distribution was verified, the homogeneity of variances was analysed using the Levene's test and, if it was not violated, an One-way ANOVA test was performed for three groups and an independent samples t-test was run for two groups. When a normal distribution was not verified or the assumptions of the One-way ANOVA were not met, a Kruskal-Wallis H test was performed for three groups and a Mann-Whitney's U test was run for two groups.

4 Results

Results for the normality tests indicated the use of non-parametric tests in most cases ($p < 0.05$), except with the scores of the ITQ ($p = 0.876$) and the factors Spatial Presence and Ecological Validity/Naturalness of the ITC-SOPI, which have a normal distribution ($p = 0.722$, $p = 0.117$).

In the following section, we perform a sample characterisation to evaluate if there was bias introduced by the participant's immersive tendencies or previous knowledge.

4.1 Sample Characterization

Regarding immersive tendencies, the One-way ANOVA test has revealed no statistical significances between the three groups for $p < 0.05$ ($F(2,36) = 2.275$, $p = 0.119$, 0.429, O.P = 0.429), as presented in Table 2. Due to the moderate-to-large effect ($\eta p^2 < 0.119$) and considerable O.P. (<0.40), post hoc tests were applied to verify the possible occurrence of a Type II error, which was not confirmed. Thus, the sample can be considered homogeneous in relation to immersive tendencies.

Table 2. One-way ANOVA of the Immersive Tendencies Questionnaire

ITQ Score	Groups						p-value	η_p^2	Observed power
	IVR		NVR		V				
	M	SD	M	SD	M	SD			
	79.67	14.32	89.83	10.92	90.33	14.19	0.119	0.121	0.429

Regarding the pretests, the Kruskal-Wallis' test maintained the null hypothesis of equality between groups ($\chi^2(2) = 0.796$, $p = 0.672$, $\eta^2 = 0.036$) (see Table 3).

In this sense, it can be verified that the sample is homogeneous: all participants start on an equal footing regarding previous knowledge and immersive tendencies, allowing to assume that these factors will have no influence on the results presented in the following sections.

4.2 Media and Learning Outcomes

Table 3 allows observing that all the groups performed better on the posttest, with a positive learning gain. When comparing all the pretest and posttest scores via a

Wilcoxon Signed-Rank Test (z = 2.18, p = 0.29), it can be verified that the learning gain was statistically significant after the intervention.

Concerning the analysis by group, participants in the NVR condition obtained the highest mean score on the posttest (M = 6.83, SD = 2.52), followed by the V (M = 6.33, SD = 2.67) and the IVR group (M = 6.17, SD = 2.17), respectively. This is a preliminary indication that learning performance might be better in the Non-interactive VR condition, with an average knowledge increase of 1.25 points, leaving behind the Interactive VR (1.17) and the Video (0.42) conditions.

Table 3. Results for the knowledge tests and learning gain

Knowledge	Groups					
	IVR		NVR		V	
	M	SD	M	SD	M	SD
Pretest	5.00	2.86	5.58	2.31	5.92	2.39
Posttest	6.17	2.17	6.83	2.52	6.33	2.67
Learning gain	1.17	2.76	1.25	2.01	0.42	1.83

In the sequence, the MLO hypothesis tests are presented.

MLO1. The learning gain is higher in Interactive VR than in Non-interactive VR
The results show that the IVR group did not outperform the NVR group (1.17 of learning gain in comparison to 1.25). Also, the Mann-Whitney's U test did not reject the null hypothesis of equality between groups, considering the values of learning gain (U = 63.00, z = −0.531, p = 0.595). Thus, we cannot confirm the MLO1 hypothesis.

MLO2. The learning gain is higher in Non-interactive VR than in Video
Although the results show that the NVR group did outperform the V group (1.25 of learning gain in comparison to 0.42), the Mann-Whitney's U test did not reject the null hypothesis of equality between groups, considering the values of learning gain (U = 52, z = −1.178, p = 0.239). In this sense, we cannot confirm the MLO2 hypothesis.

MLO3. The learning gain is higher in Interactive VR than in Video
Although the results show that the IVR group did outperform the V group (1.17 of learning gain in comparison to 0.42), the Mann-Whitney's U test did not reject the null hypothesis of equality between groups, considering the values of learning gain (U = 61.500, z = −0.620, p = 0.535). In this sense, we cannot confirm the MLO3 hypothesis.

4.3 Sense of Presence

According to the authors of the ITC-SOPI [5], the scores for each factor cannot be combined into one overall sense of presence; it must be analyzed individually. They also clarify that the item referring to characters being aware of the user's presence

(B23 from the original version, B20 from the Portuguese version) has to be ignored when the evaluated VE does not contain characters, which was the case of the tested animation.

Considering these assumptions, Table 4 presents the results of the ITC-SOPI factors for each research group. It allows observing that the mean scores for the IVR group were the highest for all factors, followed by the NVR and the V groups, respectively. This result indicates that participants in the Interactive VR condition achieved a higher sense of presence than the other two groups. Also, participants in the Non-interactive VR achieved a higher sense of presence than in the Video condition, which was the less stimulating in this regard.

Table 4. Results for the ITC-Sense of Presence Inventory

ITC-SOPI factors	Groups					
	IVR		NVR		V	
	M	SD	M	SD	M	SD
Spatial presence	3.62	0.50	2.67	0.60	2.24	0.62
Engagement	3.52	0.54	3.33	0.47	3.02	0.81
Ecological validity/naturalness	3.80	0.62	3.40	0.68	3.13	0.78
Negative effects	1.57	0.96	1.47	0.67	1.36	0.33

On the other hand, the score for the Negative Effects factor was also higher in the IVR group (M = 1.57, SD = 0.96), which means that participants in this condition experienced more uncomfortable feelings like headache, eyestrain, dizziness and nausea. Following the same logic, the NVR group was the second-highest (M = 1.47, SD = 0.67), and the V group had the lowest mean score for Negative Effects (M = 1.36, SD = 0.33). However, the overall scores were low in all conditions, indicating that this factor did not have a significant impact on participants' sense of presence. In the following, the SP hypothesis tests are presented.

SP1. The sense of presence is higher in Interactive VR than in Non-interactive VR
The results show that the ITC-SOPI score was higher in the IVR group than in the NVR group for all factors, and the independent samples t-test also rejected the null hypothesis for Spatial Presence ($t(22) = 4.006$, $p = 0.001$). However, the Mann-Whitney's U test and the t-test, respectively, maintained the null hypothesis for Engagement ($U = 60.000$, $z = -0.703$, $p = 0.482$) and Ecological Validity/Naturalness ($t(22) = 1.442$, $p = 0.163$). The Mann-Whitney's U test also maintained the null hypothesis for Negative Effects ($U = 63.500$, $z = -0.207$, $p = 0.612$). Thus, we can partially confirm the SP1 hypothesis, that the sense of presence is higher in the IVR than in the NVR condition, in what concerns spatial presence.

SP2. The sense of presence is higher in Non-interactive VR than in Video
Although the results show that the ITC-SOPI score was higher in the NVR group than in the V group for all factors, the independent samples t-test and the Mann-Whitney's U test, respectively, did not reject the null hypothesis for Spatial Presence ($t(22) = 0.855$, $p = 0.113$) and Engagement ($U = 60.500$, $z = -.670$, $p = 0.503$). For the factors Ecological Validity/Naturalness and Negative Effects, the independent samples t-test and the Mann-Whitney's U test, respectively, also maintained the null hypothesis ($t(22) = 1.653$, $p = 0.402$, $U = 65.000$, $z = -0.412$, $p = 0.680$). In this sense, we cannot confirm the SP2 hypothesis.
SP3. The sense of presence is higher in Interactive VR than in Video
The results show that the ITC-SOPI score was higher in the IVR group than in the V group for all factors, and the independent samples t-test did reject the null hypothesis for Spatial Presence ($t(22) = 5.732$, $p < 0.001$). However, for Engagement, the Mann Whitney's U test maintained the null hypothesis ($U = 51.000$, $z = -1.232$, $p = 0.218$). The independent samples t-test also rejected the null hypothesis for Ecological Validity/Naturalness ($t(22) = 2.231$, $p = 0.036$), but the Mann-Whitney's U test maintained the null hypothesis for Negative Effects ($U = 60.500$, $z = -0.681$, $p = 0.496$).

Therefore, we can partially confirm the SP3 hypothesis, that the sense of presence is higher in the IVR than in the V condition, in what concerns spatial presence and ecological validity/naturalness.

SP4. The sense of presence is positively correlated with the learning gain
Considering the values of learning gain and the scores of the ITC-SOPI factors from the three research groups, the Spearman's test maintained the null hypothesis for the factors Spatial Presence ($r_s = 0.177$, $p = 0.301$), Engagement ($r_s = 0.080$, $p = 0.641$), Ecological Validity/Naturalness ($r_s = 0.163$, $p = 0.341$) and Negative Effects ($r_s = -0.135$, $p = 0.433$). Thus, we cannot confirm the SP4 hypothesis.

4.4 Correlation of Immersive Tendencies with the Sense of Presence and Learning

In the sequence, the IT hypothesis tests are presented.

IT1. The immersive tendencies are positively correlated with the sense of presence
Considering the ITQ and the ITC-SOPI scores, the Spearman's test maintained the null hypothesis for all factors: Spatial Presence ($r_s = -.081$, $p = 0.639$), Engagement ($r_s = 0.181$, $p = 0.290$), Ecological Validity/Naturalness ($r_s = 0.171$, $p = 0.319$) and Negative Effects ($r_s = 0.024$, $p = 0.890$). Therefore, we cannot confirm the IT1 hypothesis.
IT2. The immersive tendencies are positively correlated with the learning gain
Considering the values of learning gain and the scores of the ITQ from the three research groups, the Spearman's test maintained the null hypothesis of correlation ($r_s = -.079$, $p = 0.648$). In this sense, we cannot confirm the IT2 hypothesis.

5 Discussion

The discussion of results is organized by the three hypotheses axes that were tested.

5.1 Media and Learning Outcomes

The results show that all three research groups performed better on the posttest, achieving a statistically significant positive learning gain. This finding suggests that all conditions have actually contributed to knowledge retention, allowing to agree with the study of Allcoat & Mühlenen [1], when concluding that VR can be a compelling alternative to traditional didactic approaches, with similar performance levels and improved engagement.

However, the supposition that learning outcomes would be higher in the Interactive VR condition was rejected. Contrary to expected, participants in the Non-interactive VR condition obtained a higher knowledge increase, meaning it was the most successful format, although not statistically proven. It means that when comparing both passive modes of instruction delivered in an automatic continuous equal pace (Non-interactive VR animation to Video), the VR was more prominent.

This fact suggests that learning is not a result of graphics or visuals, as these were the same in both conditions. Instead, it appears to be attributable to immersion [1]. Students in the immersive conditions (VR) could see around just naturally moving their heads, giving them a 180º of vision that Video condition students didn't have. The possibility to visually examine their surroundings more naturally in the VE allowed them to better acquire the information they needed to understand concepts. In this sense, we can extend the findings of Olmos-Raya et al. [18], in which better learning outcomes were obtained in the VR condition as compared to a tablet, and of Makransky, Borre-Gude & Mayer [14], in which the same occurred while comparing VR to a textbook.

On the other hand, we cannot corroborate with Allcoat & Mühlenen [1] when they associate VR to the pedagogic model of active learning, suggesting that it plays an important role. That is, at least the way our more active condition was modelled (Interactive VR), with the use of hand controllers. Additional explanations for this result can be linked to the instructional design theories of Cognitive Load [24] and Multimedia Learning [25]. Studies that endorse this finding are discussed as follows.

Cognitive Load. The extrinsic cognitive load associated with the use of a highly visual and interactive technology may have caused a "seductive detail" [26]. Makransky, Terkildsen & Mayer [27] identified that students learned less in the more immersive condition insofar as realism was a distraction not relevant to the instructional goal. According to Whitelock et al. [2], although "being there" is very motivating, it can take up too much of the users' attention and produce a cognitive overload when it comes to understanding conceptual notions. In the study of Schrader & Bastiaens [28], the high-immersion condition was more demanding in the working memory, and the consequent extrinsic cognitive load made learning more difficult.

Multimedia Learning. Parong & Mayer [15], while using the same lesson of this study [20], found that the slideshow format was more effective for learning than the immersive VR. They suppose that this could have been due to the coherence principle, which calls for eliminating extraneous material. As students were “placed” in the blood-stream, with various cells constantly moving past, being able to look in any direction to see these movements, their attention was diverted from the important material. In our case, the use of hand controllers might have contributed to exacerbating the coherence principle of multimedia learning, distracting students from the learning content.

In a similar perspective, there is also the novelty factor [26]. Although most participants affirmed having previous experience with VR, this technology is not part of the students’ daily life. That is, they were probably more dazzled by the novelty of the technology that didn’t pay so much attention to the lesson. And the use of hand controllers may have aggravated this perspective.

5.2 Sense of Presence

Results for the sense of presence dimension followed the expected logic: highest in the Interactive VR group, followed by the Non-interactive VR and the Video groups, respectively. However, the hypotheses tests to statistically prove these differences were partially accepted, concerning only two factors: a) spatial presence was higher in the Interactive VR than in the other two conditions; and b) ecological validity/naturalness was higher in the Interactive VR than in the Video condition.

According to Tjon et al. [9], spatial presence is the most studied aspect of presence and is most directly related to the presence experience itself. Its importance is also highlighted by Riva, Waterworth & Murray [8], who suggest that it may be key to persuasion as it promotes a more natural interaction with the user’s surroundings. Persuasion, by its turn, is a communication strategy to induce someone to accept an idea, an attitude, or to perform an action; a fundamental key to learning. Conversely, the authors state that a low spatial presence may degrade the user experience, consequently hindering the expected outcomes.

Together with the significant difference in ecological validity/naturalness, this finding shows that the possibility of interacting with 3D objects in the VR animation, by means of hand controllers, added realism to the experience. It allows corroborating that the naturalness of the interactions and how closely it mimics real-world experiences affect how much presence is reported [11], and that this factor can be linked to the ability of individuals to adopt behavioral patterns similar to that observed in everyday life, and therefore to respond to it in a more realistic way [29].

However, the hypothesis that the sense of presence would be positively correlated with the learning gain was refuted. Thus, we cannot agree with the studies of Schrader & Bastiaens [6] and Lee, Wong & Fung [7], which showed that an increased sense of presence did lead to better learning outcomes. However, they did not compare different media formats. In our study, the fact that the Interactive VR condition was the highest at the sense of presence might have influenced this result. Linked to the previous section, the reasons for this result can be grounded in the theories of Cognitive Load [24] and Multimedia Learning [25].

5.3 Immersive Tendencies

Although participants in the Interactive VR condition had the lowest score for immersive tendencies, meaning they would be less inclined to feel the sense of presence, their scores were the highest in all ITC-SOPI factors. This result indicates that, contrary to the original study of Witmer & Singer [12], immersive tendencies were not a critical factor for the subjects to experience the sense of presence.

Therefore, the first hypothesis, that immersive tendencies would be positively correlated with the sense of presence, was rejected, allowing us to agree with the work of Murray, Fox & Pettifer [17], in which these variables were also not correlated. However, we cannot corroborate with studies of Schrader & Bastiaens [6], Khashe et al. [13] and Bulu [16], in which a positive relationship between immersive tendencies and sense of presence was identified.

The second hypothesis, that immersive tendencies would be positively correlated with the learning gain, was also refuted. In this sense, we can extend the results of Khashe et al. [13], which also did not find a positive association between immersive tendencies and performance. On the other hand, we cannot endorse the study of Schrader & Bastiaens [6], in which the immersive tendencies were positively related to both trivial and nontrivial learning outcomes.

It must be highlighted that our study has some differences from the ones mentioned in this discussion, as pointed out in the related work section. At the same time that it demonstrates the unprecedented character of the research, it also indicates that the results must be taken accordingly.

6 Conclusion

Creating educational applications for VR can be a laborious and costly endeavour [1]. In this sense, it is essential to investigate whether and in which ways these applications are useful for learning or not.

In order to contribute to understanding the potential of VR technology to support learning, this study analysed the sense of presence and the immersive tendencies of individuals across three different media formats of the same lesson, seeking for fair comparisons. We provide empirical evidence that immersion can really contribute to enhance learning, leading to better scores than a similar passive mode of instruction (Video). However, the supposition that adding interactivity to VR would result in better outcomes was rejected, and the findings were grounded on instructional design principles of Cognitive Load [24] and Multimedia Learning [25]. The sense of presence and the immersive tendencies appeared to be not critical factors in this equation.

As limitations of the study, it must be pointed out the small sample size, which did not allow the extraction of statistically significant differences in some cases, and the fact that it was a laboratory-controlled study. Field studies must be conducted to extend the findings in contexts of formal and non-formal educational.

Also, the use of knowledge retention tests as the only instrument to infer learning outcomes can be considered a limitation. Makransky, Borre-Gude & Mayer [14], for instance, added realistic measures of transfer, aimed to assess deep understanding and performance. The authors suggest that the evidence would not be found that if they had conducted only a retention test. Furthermore, a more in-depth study controlling the principles of the mentioned instructional design theories is needed, including the variables analysed in this study.

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