Usability of An Immersive Authoring Tool: An Experimental Study for the Scenarization of Interactive Panoramic Videos

Daniel Xuan Hien Mai, Guillaume Loup, Jean-Yves Didier
IBISC Lab
Univ Evry, Université Paris Saclay
Evry, France
e-mail: danielxuanhien.mai@univ-evry.fr, guillaume.loup@univ-evry.fr, jeanyves.didier@univ-evry.fr

***Abstract*— The need for remote education and reduced learning costs has led to rapid development of virtual immersive learning environments. However, creating these environments using authoring tools still requires trainers to have a range of technical skills. Recently, a new approach has been developed that allows trainers to construct educational scenarios using panoramic video-based immersive authoring tools. This approach demands fewer technical skills compared to the modeling of 3D environments. To evaluate the usability of the Human-Computer Interaction (HCI) of this approach between two different types of interfaces, our experimental study was conducted. This study compared a Virtual Reality (VR) interface, which consists of a Head-Mounted Display (HMD) and its controllers, to a traditional Windows, Icons, Menus, Pointer (WIMP) interface in creating interactive scenarios. Both quantitative and qualitative measures were collected and later quantified to evaluate effectiveness, efficiency, user satisfaction, and motivation towards the interfaces. The results of the study showed that: (1) there was a better correlation between the trajectories of 3D objects positioned by the user (in this study, the trainer) and the entities targeted in the panoramic video using an immersive interface; (2) there was a significant difference in task execution time between the VR interface and the traditional WIMP interface; (3) trainers had greater satisfaction and motivation towards the VR interface compared to the traditional WIMP interface, despite symptoms of cybersickness.**

Keywords- panoramic videos; authoring tools; virtual reality; WIMP interface; immersive environments; interaction techniques.

I. INTRODUCTION

Investment by major technology companies in recent years, and growing demand for immersive environments in the domains of entertainment, communication, and education have created a strong impetus for the development of Virtual Reality (VR). Additionally, new technological breakthroughs have made VR hardware devices, such as VR headsets and omnidirectional cameras more accessible to the public. However, the development of VR applications in general and immersive environments for human learning in particular still presents many challenges, both in terms of processes and production tools, requiring the participation of a multidisciplinary team ranging from designers, artists, programmers and so forth [1]. These tools often require trainers to have certain expert knowledge for effective use to achieve the desired results.

Depending on the interaction needs, immersive environments will be designed differently, where each interaction scenario is a sequence of user interactions with the environment [2]. Therefore, interaction design methods and different forms of information representation will impact user experience as well as interaction outcome. Immersive environments based on panoramic videos are thus the proposed solution that simulates interactive scenarios close to the real environment, and enhances users' sense of presence when they use Head-Mounted Display (HMD) [3]. The panoramic video can be enriched by adding interactive elements such as text information, sounds, 2D/3D objects, as well as questions, in order to not only improve the user experience [4], but also integrate narrative and educational elements into the interactive scenarios. These additional elements require a particular structure tailored to the spatial and temporal dimensions of the panoramic video [5]. While 2D video editing tools primarily focus on the temporal dimension, creating interactive panoramic videos requires a more comprehensive set of tools that handle both spatial and temporal dimensions.

A suitable authoring tool will actively aid trainers in constructing the learning content [6]. New requirements for authoring tools for interactive scenarios based on panoramic videos have led to the concept of an exclusively immersive tool. Thanks to this approach, trainers, instead of using the traditional Windows, Icons, Menus, Pointer (WIMP) interface, can now use the VR interface to create and modify the content of the interactive scenario. This immersive environment will allow trainers to have learner-like access to quickly obtain a set of information and to self-assess the results of their work throughout the design process [7].

However, it remains to be determined whether the new interactive VR interface differs in terms of usability and user motivation compared to the traditional WIMP interface. To answer this question, our experiment was carried out to evaluate and compare the effectiveness and efficiency of trainer interactions with an authoring tool, based on a defined scenario, using both the traditional WIMP interface and the VR interface. The satisfaction and motivation of trainers towards the tool were assessed through questionnaires collected after the experiment.

It is worth noting that conducting experiments on usability and motivation are important for evaluating the effectiveness of the tool and identifying any potential issues that may arise when using the tool in real-world scenarios.

In Section II, we present a discussion of related work. Section III presents our research hypotheses. Section IV details the method, then Section V presents the results of the experiment. Our conclusions and future work are presented in sections VI and VII. The references close the article.

II. Background And Related Work

A. Authoring tools and interactions with panoramic videos

The interactive design that complements panoramic videos presents not only technical challenges (with respect to video asset management, video environment fidelity, and natural navigation) but also design challenges [8]. These issues include designing non-intrusive and non-distracting user interfaces, creating effective navigation and orientation mechanisms, and incorporating engaging elements into the design.

In addition, the feeling of immersion can affect the difference in visual navigation effectiveness between the traditional WIMP and VR interfaces [9]. One of the main tasks of the designers is to overlay a 3D object upon the panoramic video. To ensure consistency between these two entities, a predetermined trajectory based on the timeline of the panoramic video [5] must be defined. This requires capturing the spatiotemporal motion of the designers, which allows them to specify the movements of the 3D object.

For user interaction studies, in the absence of a specific classifier, the object of research is usually the end user or, in this context, the learner. Research work in the context of panoramic videos is most often devoted to the effect of motion parallax [10][11] the perception of content, as well as different methods of rendering and displaying panoramic videos and incorporating 3D entities to improve user experience [12].

Recently, several studies have been dedicated to designing panoramic video tools in VR, where users act as trainers. T. Adão et al. performed an experiment to evaluate the usability of a rapid prototyping tool [13] through tasks such as adding and removing 3D objects in space and time. Another experiment was carried out to evaluate the continuity of integrating video animations, 3D objects as well as 3D sounds [14] by utilizing non-complex interaction techniques.

Pakkanen et al. proposed a comparison of three models of interaction techniques (remote control, pointing with head orientation, and hand gestures) in VR for controlling panoramic video playback [15]. The results of this study showed that the participants experienced a reduction in nausea on their second attempt. This suggests that cybersickness survey results may be influenced by participants' previous experience (working time) in the VR environment. Regarding the usability of the three types of interactions, the remote control was found to be more accurate and users liked it more than the other two types of interactions.

The Fonseca & Kraus experiment [16] evaluated learners' attitudes and behaviors after watching panoramic videos in both VR and mobile platforms, making it one of the few studies that cover multiple platforms. The conclusion of this research mentioned a more positive emotional impact on the user when they viewed panoramic videos in a virtual reality environment compared to an equivalent environment on a tablet. The experiment did not assess participants' interactive behaviors, but only focused on behavioral analysis of perception after receiving narrative information.

As a case study of panoramic video authoring tools, the research by Coelho & Melo [7] is remarkable when it comes to evaluating the usability of three different types of interfaces: WIMP, VR, and tangible. Results showed that participants' gender had no effect on dependent factors. Regarding the usability, the VR and tangible interfaces had a higher level of satisfaction than the WIMP interface. However, the WIMP interface had the lowest task execution time and the authors concluded that this was due to participants' greater familiarity with the keyboard and mouse. The effectiveness was not determined conclusively as the experimental procedure only took into account the number of performed errors, which was not statistically significant.

These experiments have shown that running the same interaction technique on different types of environments or interfaces will have different usability results. The requirement for spatiotemporal coherence in interaction is a critical element of panoramic video-based immersive environments. It is thus necessary to compare the interaction technique specific to authoring tools on panoramic videos, between the traditional WIMP interface and the VR interface, through a new experimental study.

B. The immersive authoring tool Wixar[17]

To accurately compare the usability of two types of interfaces, the analysis and evaluation of interaction techniques must be performed on the same authoring tool to balance the workload between the two types of interfaces and ensure uniformity of statistical data.

Most authoring tools support the WIMP interface, but a limited number support the VR interface [6]. In order to limit differences in statistical data of two different interfaces, we chose the Wixar authoring tool for our experiment. Wixar is a multi-platform authoring tool already on the market, offering a range of options for creating scripted content for interactive panoramic videos. It aims to empower trainers without programming skills to design immersive learning environments using panoramic videos.

The selected interaction techniques for this experiment, including visual perception (head movement or camera rotation with keyboard buttons), navigation (joystick or mouse movement), and selection and manipulation, are commonly used in panoramic video contexts.

Wixar offers both a PC version and a VR version with the same user interface (UI). The PC version uses a mouse for navigation instead of a joystick and keyboard buttons for rotation instead of head movement, making it a suitable comparison to the VR version. These standard human-computer interfaces do not negatively affect the outcome of the experiment. The selected user interfaces (Figure 2) will not negatively impact the results of the experiment.

Hence, Wixar is a suitable authoring tool for evaluating the usability of WIMP and VR interactive interfaces, as it satisfies the requirements and purpose of this experiment.

III. RECHEARCH HYPOTHESIS

Our first hypothesis (H1) is that the difference in navigation (viewpoint changing) and selection and manipulation (trajectory recording) actions during task execution between the VR and WIMP interfaces will lead to a difference in usability between them. In the context of this experiment, operations requiring spatiotemporal coordination of panoramic videos are supposed to have better accuracy and execution time in VR compared to WIMP.

Our second hypothesis (H2) is that the use of a VR headset for the authoring tool will not significantly increase mental load or symptoms of cybersickness compared to a traditional WIMP interface.

Our third hypothesis (H3) is that participants using the VR interface will exhibit higher motivation than those using the WIMP interface in this experiment.

IV. METHOD

A. Participants

The participants in the experiment ranged in age from 20 to 50 years old, with an average age of 30.7 years. Both groups, VR and WIMP, had 15 participants each and were evenly distributed in age. All participants had a good command of French, enabling them to comprehend information presented in the language and engage in conversations throughout the experiment. The informed consent form, which included details on withdrawal rights, confidentiality rights, benefits, and potential risks of the study, was understood by all participants.

This study was approved by the Paris-Saclay research ethics committee and participants signed the consent form after being fully informed of the progress of the experiment.

B. Wixar Authoring Tool

We utilized Wixar version 1.4, which was released in July 2021, that offers both WIMP and VR interfaces. The main steps of using Wixar are outlined in Figure 1. The trainer's process of designing an application was divided into three phases: 1) Adding media resources, such as panoramic videos, audios, and 360 images, 2) Integrating and configuring the interaction techniques offered by Wixar, and 3) Releasing a new immersive educational environment.

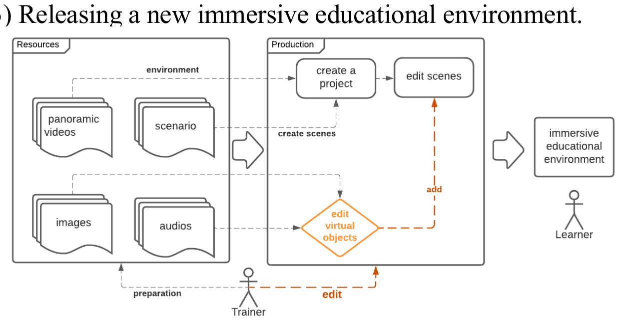

Figure 1. Wixar Operation Process

In this experiment, different panoramic video scenes were provided and a preview of the scenario to be enacted was presented to the participant beforehand.

C. Material

Devices used in this experiment included: a laptop computer equipped with the Wixar 1.4 PC authoring tool; an Oculus Quest 2 headset equipped with the Wixar 1.4 VR authoring tool. To ensure hygiene, the equipment was thoroughly cleaned before each participant's session and participants were instructed to sanitize their hands and wear a respiratory protection mask throughout the entire procedure.

D. Measurements

Our team had developed an algorithm which was then integrated into Wixar 1.4 to gather quantitative data on user behavior during task performance.

Questionnaires were used to collect demographic information (identified only by participant number) and data on cybersickness (SSQ [18], NASA-TLX [19]), satisfaction (SUS) [20], and motivation (SIMS) [21].

The obtained data was then analyzed to evaluate the usability of two different types of interfaces during participant interactions. Usability, as defined by ISO 9241-11 [22], is “the extent to which a system, product or service can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use”. This definition highlights three criteria that must be considered during the construction of the experiment so that the results obtained can be analyzed with precision afterwards: (1) Effectiveness: accuracy and completeness with which users achieve specified goals (2) Efficiency: relationship between the results and the resources used to achieve them. (3) Satisfaction: comfort and subjective evaluation of user interaction.

Specifically in this experiment, effectiveness was linked to the precision of the participant's manipulation, efficiency was measured by the time it took to perform tasks and finally, satisfaction was assessed through questionnaires.

E. Scenarios & Procedure

The participants were divided into two groups, each corresponding to a different interface (WIMP and VR). Participants were asked to position themselves in front of a PC or to wear an Oculus Quest 2 headset. After starting the Wixar 1.4 application, the participant faced 5 task sequences. The main tasks involved positioning and configuring a virtual object on a fish in a panoramic video by superimposing a virtual marker on the fish. The fish had different, increasingly complex trajectories step by step, such as linear movement, slight wave, underfoot, around space variable acceleration, and vertical movement (Figure 2).

Figure 2. Fish with different trajectories

Following the 5 sequences, the participant was invited to complete the questionnaires. The total duration of each experiment was approximately 45 minutes.

F. *Quantitative data*

During the experiment, participant behavior data was automatically collected, including head movements, joystick or mouse movements, the operations concerning the creation, deletion and movement of objects, and the recording of movement of the virtual marker tracking the fish.

These data were subsequently analyzed to compare the effectiveness and efficiency between the two interface types.

G. *Questionnaires (qualitative data)*

1) *Before their activity*

The experiment used the NASA-TLX scale, translated into French by Ganier, F., Hoareau, C., & Devillers in 2013 [23], to assess the workload involved.

In virtual reality immersion research, cybersickness is frequently evaluated. The French questionnaire used in this study was proposed by Kennedy, R.S. et al. in 1993[18].

2) *After their activity*

The F-SUS scale is the French version of the SUS (System Usability Scale) proposed by Gronier, G., & Baudet, A. in 2021 [24]. This scale is widely used to measure the usability of interactive systems.

And finally, this experiment also assessed the participants' motivation through the SIMS situational motivation scale (French version suggested by Lambert-Le Mener, M. (2012) [25]).

H. *Analysis method*

The space of a virtual reality application that uses panoramic videos is usually designed using polar coordinates [5]. Thus, all the spatial parameters of the added virtual objects are saved as polar coordinates (quaternion rotation).

During the experiment, the movement of the virtual marker while tracking a fish in the video was recorded for each frame, and then resampled to a fixed frame rate of 50 FPS for ease of analysis.

At time *t* in the video, marker *m* had position p_m and fish f had position p_f. The distance d_t (p_m, p_f) represented the distance between the marker and the fish at time *t*.

The participants were instructed to place the marker on the fish, but we realized that the targeted part of the fish (e.g., head, body, tail) varied among participants. Consequently, we did not use the d_t index directly for the analysis. Instead, we used the relative distance between two consecutive periods $t+1$ and t, i.e. $\Delta_{t+1,\,t} = |\, d_{t+1} - d_t \,|$ with the goal of making the Δ as small as possible. Our objective was to measure and compare the variations and the stability of the recorded trajectories considering the targeted trajectory.

V. Results

The collected quantitative and qualitative data were normalized to select appropriate parameters and then analyzed with SPSS (version 25, IBM Corp).

A Student Test was performed for the bivariate correlation test if the sample met the covariance criteria. Conversely, if the sample did not meet the criteria, a Mann-Whitney non-parametric test was used.

Data were collected on two experimental groups, each with 15 participants, corresponding to two types of WIMP and VR interactive interfaces.

A. *Effect of interactive interface on effectiveness*

The average difference (Δ) used for the effectiveness tests on the 5 tasks (corresponding to 5 different trajectories in 5 scenes from s1 to s5). Effectiveness is inversely proportional to the Δ coefficient, so as seen in Figure 3, the VR group recorded more stable trajectories than the WIMP group. The results were consistent across all 5 trajectory types.

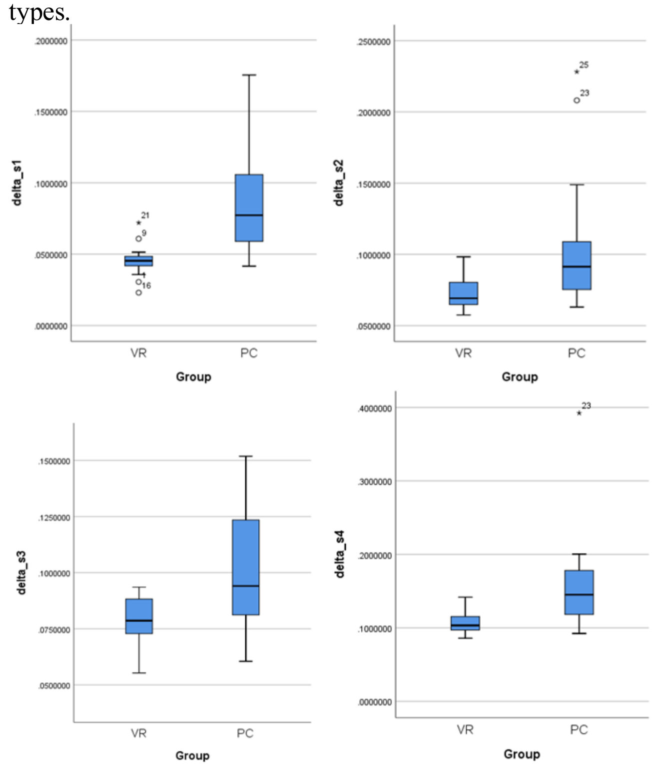

Figure 3. Distribution of Mean Trajectory Differences for VR and WIMP Groups per Sequence

The Mann-Whitney U tests revealed significant differences between the WIMP and VR groups in the average Δ in 4 trajectories s1, s2, s4 and s5. A similar result was found in the Student Test on Δs3 (Table I) with a significant Levene's Test result of 0.001687. The hypothesis that there is a difference in variance between the two groups (WIMP and RV) was accepted, indicating a significant difference in the mean of the two groups (significant T-Test result of 0.01585).

TABLE I. STATISTICAL SIGNIFICANCE TESTS BETWEEN VR AND WIMP GROUPS FOR MEAN DIFFERENCE IN TRAJECTORY ACROSS 5 MISSIONS

	Group	Shapiro-Wilk	Mann-Whitney U	Levene Test	T-Test
Δs1	VR	0.379511	0.000841	--	--
	WIMP	0.037481			
Δs2	VR	0.181733	0.004494	--	--
	WIMP	0.001477			
Δs3	VR	0.527049	--	0.001687	0.01585
	WIMP	0.245281			
Δs4	VR	0.338854	0.000622	--	--
	WIMP	0.000542			
Δs5	VR	0.700370	0.005114	--	--
	WIMP	0.000039			

B. *Effect of interactive interface on efficiency*

Regarding execution efficiency, the group using VR completed tasks faster than the group using WIMP interface (Figure 4).

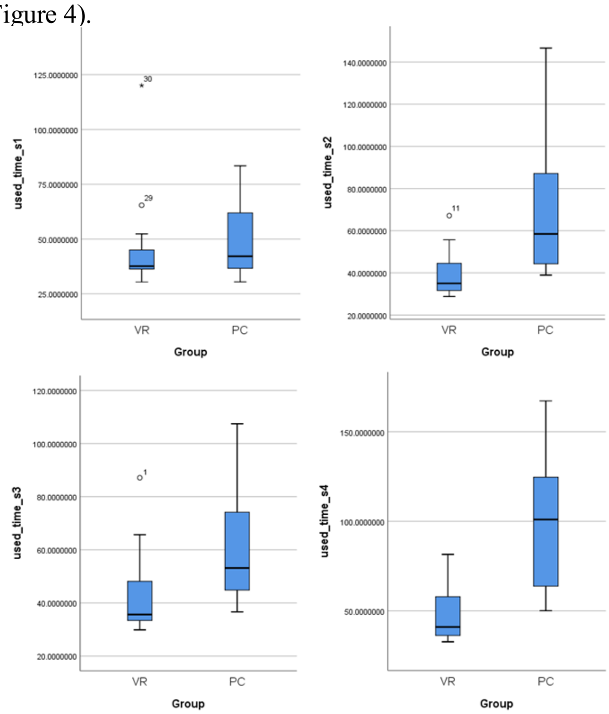

Figure 4. Distribution of Execution Time Differences for VR and WIMP Groups by Sequence

The Mann-Whitney U Tests (Table II) indicated significant differences between the WIMP and VR groups in terms of execution time for s2, s3, s4, and s5. The tests showed no significant difference for s1 (Sig.=0.351).

TABLE II. STATISTICAL SIGNIFICANCE TESTS BETWEEN VR AND WIMP GROUPS FOR MEAN DIFFERENCE IN TRAJECTORY ACROSS 5 MISSIONS

	Group	Sig. Shapiro-Wilk	Sig. Mann-Whitney U
Δs1	VR	0.000030	0.350688
	WIMP	0.023687	
Δs2	VR	0.021897	0.001130
	WIMP	0.020213	
Δs3	VR	0.001141	0.005114
	WIMP	0.043944	
Δs4	VR	0.010367	0.000125
	WIMP	0.169789	
Δs5	VR	0.000014	0.000205
	WIMP	0.574785	

However, when comparing data for scene s1 to other scenes, we observed that the VR group completed the task in a relatively shorter amount of time.

C. *Satisfaction*

Results of the F-SUS questionnaire to assess satisfaction rate showed no significant difference between the VR group (M=79.6, S.D.=11.7) and the WIMP group (M=76.8, SD=15.4). Despite the high diversity of opinions shown by the significant values of the standard deviations, the averages of the SUS [26] indicated that both systems resulted in an acceptable level of user satisfaction.

D. *Cybersickness*

The outcome of the Cybersickness Questionnaire (SSQ), which measured symptoms of nausea and oculomotor disorders, showed a significant difference between the VR and WIMP groups. The Shapiro-Wilk normality test led to a Mann-Whitney U evaluation, revealing that participants using the low-cost VR headset experienced significant cybersickness. These results were further confirmed by the questions regarding oculomotor disorders, where a Levene's Test and T-test established a greater feeling of oculomotor disorders among the VR group than the WIMP group (as shown in Table III).

TABLE III. EVALUATION OF CYBERSICKNESS SYMPTOMS

	Group	Shapiro-Wilk	Mann-Whitney U	Levene Test	T-Test
Nausea	VR	0.009	0.001	--	--
	WIMP	--			
Oculomotor	VR	0.150	--	0.447	0.023
	WIMP	--			

E. Motivation

Results of the SIMS questionnaire made it possible to identify the type of user motivation using the Situational Motivation Scale. Regarding intrinsic motivation, there was a significant difference between the VR group (M=23.8 and SD=2.9) and the WIMP group (M=19.7 and SD=5.4). A second significant difference was discovered between the VR group (M=8.9 and SD=4.6) and the WIMP group (M=13.9 and SD=7.1) for external regulation. These two differences highlighted a greater sense of autonomy for the VR group compared to the WIMP group (Table IV).

TABLE IV. STATISTICAL SIGNIFICANCE TESTS BETWEEN VR AND WIMP GROUPS FOR MEAN DIFFERENCE IN TRAJECTORY ACROSS 5 MISSIONS

	Group	N	Medium	S.D	T-Test
Intrinsic Motivation	VR	15	23.80	2.883	0.017
	WIMP	15	19.73	5.496	
Identified regulation	VR	15	20.73	5.663	0.121
	WIMP	15	17.53	5.276	
External regulation	VR	15	8.93	4.559	0.031
	WIMP	15	13.87	7.080	
Amotivation	VR	15	9.33	4.065	0.225
	WIMP	15	11.93	7.015	

Although differences in identified regulation and amotivation were not significant, the values remained consistent with the results for the other motivations.

VI. DISCUSSION

Our first hypothesis has been supported by the results of the study, which showed that the VR interface was more effective, efficient, and satisfactory than the WIMP interface in performing various tasks. This conclusion contradicted the findings of Coelho and Melo [7], who evaluated the usability of three different interfaces (WIMP, VR, and tangible). The difference between the two studies can be attributed to the nature of the interaction being tested. Indeed, our work focused on a particular interaction, the trajectory of objects and the spatiotemporal relationship in a panoramic video-based immersive environment. We collected quantified data, namely the trajectory and the duration of the missions. Conversely, whereas Coelho and Melo only counted the number of errors during task execution, which showed no statistically significant differences.

The analysis demonstrated that the marker-to-fish tracking using VR was more stable than the one using WIMP, resulting in higher effectiveness of VR interaction. This was due to better coordination of viewpoint change (navigation) and trajectory recording (selection and manipulation) in both spatial and temporal dimensions of the panoramic video. The VR interface allowed for better spatial perception and object movement speed compared to WIMP.

For object motion tracking, findings of our study also revealed that if coordination of spatial and temporal motion was not maintained at all times (which happened on the WIMP interface when the fish moved out of the viewing area), an interrupt action was necessary. This affected not only the recorded trajectory results but also the execution time of the experiment tasks. Spatial navigation (change of viewpoint) when combined with simultaneous and uninterrupted trajectory recording, resulted in better performance of the VR interface in terms of time and accuracy.

The assumption which can be made at this stage is that the mouse sensitivity (Dots Per Inch - DPI) on the WIMP interface was not adjusted to match participants' usage habits, which led to poor accuracy results. Indeed, feedback from left-handed participants and from the participants who were accustomed to using touchpads supported this assumption. Regardless, if true, it still highlighted the VR interface's advantage in better adapting to the user's natural movements.

According to the cybersickness analysis, levels of nausea and oculomotor disorder were more pronounced on the VR interface than on the WIMP interface. The experimentation process for the 5 tasks was long, so we did not detail this aspect as deeply as the study conducted by Pakkanen et al. [15] where participants repeated the tasks to assess their adaptation to the immersive environment over time.

The Situational Motivation Scale questionnaires showed a significant difference in intrinsic motivation and external regulation between the VR and WIMP groups, with the VR group exhibiting higher results. This indicated a higher sense of autonomy and better motivation to complete tasks in the VR group.

VII. CONCLUSION

The goal of our experiment was to evaluate and compare the usability of the VR interface of an HMD and its controllers to that of the classic WIMP interface by conducting the same set of tasks for designing interactive scenarios for panoramic videos. So as to fulfill this aim, evaluations of the effectiveness, efficiency and user satisfaction for each of the interfaces were carried out.

The experiment findings showed better results in terms of motion tracking as well as interaction execution time on the VR interface than on the WIMP interface. The level of satisfaction was comparable between the two groups and fell within acceptable range, with no significant difference observed. In terms of usability, the VR interface, thanks to its superior spatiotemporal coordination of interactions, seemed better suited than the WIMP interface.

Although the VR interface had its issues with cybersickness, trainers still reported a higher level of satisfaction and motivation while performing tasks in VR as compared to the traditional WIMP interface.

The immersive environment based on interactive panoramic videos not only includes space-time interactive objects, but also other objects, such as text and sound. Therefore, the creation of these objects using an authoring tool requires further evaluation of cross-platform usability.

In the future, we will examine and evaluate the system's adaptability to various scenarios, with the aim of developing a model for a scripting assistant to aid trainers in the process of building an immersive learning environment.

REFERENCES

[1] Sundström, Y. (2013). Game design and production: frequent problems in game development.

[2] J. L. Rubio-Tamayo, M. Gertrudix Barrio, and F. García García, "Immersive Environments and Virtual Reality: Systematic Review and Advances in Communication, Interaction and Simulation," *Multimodal Technologies and Interaction*, vol. 1, no. 4, Art. no. 4, Dec. 2017, doi: 10.3390/mti1040021.

[3] M. G. Violante, E. Vezzetti, and P. Piazzolla, "Interactive virtual technologies in engineering education: Why not 360° videos?," *Int J Interact Des Manuf*, vol. 13, no. 2, pp. 729–742, Jun. 2019, doi: 10.1007/s12008-019-00553-y.

[4] T. Chambel, M. N. Chhaganlal, and L. A. R. Neng, "Towards immersive interactive video through 360° hypervideo," in *Proceedings of the 8th International Conference on Advances in Computer Entertainment Technology*, New York, NY, USA, Tháng Mười Một 2011, pp. 1–2. doi: 10.1145/2071423.2071518.

[5] P. R. C. Mendes, Á. L. V. Guedes, D. de S. Moraes, R. G. A. Azevedo, and S. Colcher, "An Authoring Model for Interactive 360 Videos," in *2020 IEEE International Conference on Multimedia & Expo Workshops (ICMEW)*, Jul. 2020, pp. 1–6. doi: 10.1109/ICMEW46912.2020.9105958.

[6] M. Khademi, M. Haghshenas, and H. Kabir, "A Review On Authoring Tools," presented at the Proceedings of the 5th International Conference on Distance Learning and Education, IPCSIT, Sep. 2011, vol. 12, pp. 40–44.

[7] Coelho, Hugo, et al. "Authoring tools for creating 360 multisensory videos—Evaluation of different interfaces," *Expert Systems*, vol. 38, no. 5, p. e12418, 2021, doi: 10.1111/exsy.12418.

[8] L. Argyriou, D. Economou, V. Bouki, and I. Doumanis, "Engaging Immersive Video Consumers: Challenges Regarding 360-Degree Gamified Video Applications," in *2016 15th International Conference on Ubiquitous Computing and Communications and 2016 International Symposium on Cyberspace and Security (IUCC-CSS)*, Oct. 2016, pp. 145–152. doi: 10.1109/IUCC-CSS.2016.028.

[9] G. Robertson, M. Czerwinski, and M. van Dantzich, "Immersion in desktop virtual reality," in *Proceedings of the 10th annual ACM symposium on User interface software and technology - UIST '97*, Banff, Alberta, Canada, 1997, pp. 11–19. doi: 10.1145/263407.263409.

[10] A. Serrano *et al.*, "Motion parallax for 360° RGBD video," *IEEE Transactions on Visualization and Computer Graphics*, vol. 25, no. 5, pp. 1817–1827, May 2019, doi: 10.1109/TVCG.2019.2898757.

[11] B. Luo, F. Xu, C. Richardt, and J.-H. Yong, "Parallax360: Stereoscopic 360° Scene Representation for Head-Motion Parallax," *IEEE Transactions on Visualization and Computer Graphics*, vol. 24, no. 4, pp. 1545–1553, Apr. 2018, doi: 10.1109/TVCG.2018.2794071.

[12] T. Rhee, L. Petikam, B. Allen, and A. Chalmers, "MR360: Mixed Reality Rendering for 360° Panoramic Videos," *IEEE Transactions on Visualization and Computer Graphics*, vol. 23, no. 4, pp. 1379–1388, Apr. 2017, doi: 10.1109/TVCG.2017.2657178.

[13] T. Adão *et al.*, "A rapid prototyping tool to produce 360° video-based immersive experiences enhanced with virtual/multimedia elements," *Procedia Computer Science*, vol. 138, pp. 441–453, 2018, doi: 10.1016/j.procs.2018.10.062.

[14] K. Choi, Y.-J. Yoon, O.-Y. Song, and S.-M. Choi, "Interactive and Immersive Learning Using 360° Virtual Reality Contents on Mobile Platforms," *Mobile Information Systems*, vol. 2018, p. e2306031, Oct. 2018, doi: 10.1155/2018/2306031.

[15] T. Pakkanen *et al.*, "Interaction with WebVR 360° video player: Comparing three interaction paradigms," in *2017 IEEE Virtual Reality (VR)*, Mar. 2017, pp. 279–280. doi: 10.1109/VR.2017.7892285.

[16] D. Fonseca and M. Kraus, "A comparison of head-mounted and hand-held displays for 360° videos with focus on attitude and behavior change," in *Proceedings of the 20th International Academic Mindtrek Conference*, New York, NY, USA, Oct. 2016, pp. 287–296. doi: 10.1145/2994310.2994334.

[17] "Wixar - Your Human Resources Metaverse." https://www.wixar.io/ (accessed Mar. 13, 2023).

[18] R. S. Kennedy, N. E. Lane, K. S. Berbaum, and M. G. Lilienthal, "Simulator Sickness Questionnaire: An Enhanced Method for Quantifying Simulator Sickness," *The International Journal of Aviation Psychology*, vol. 3, no. 3, pp. 203–220, Jul. 1993, doi: 10.1207/s15327108ijap0303_3.

[19] S. G. Hart and L. E. Staveland, "Development of NASA-TLX (Task Load Index): Results of Empirical and Theoretical Research," in *Advances in Psychology*, vol. 52, P. A. Hancock and N. Meshkati, Eds. North-Holland, 1988, pp. 139–183. doi: 10.1016/S0166-4115(08)62386-9.

[20] J. Brooke, *SUS: A "Quick and Dirty" Usability Scale*. CRC Press, 1996, pp. 207–212. doi: 10.1201/9781498710411-35.

[21] F. Guay, R. J. Vallerand, and C. Blanchard, "On the Assessment of Situational Intrinsic and Extrinsic Motivation: The Situational Motivation Scale (SIMS)," *Motivation and Emotion*, vol. 24, no. 3, pp. 175–213, Sep. 2000, doi: 10.1023/A:1005614228250.

[22] I. ISO, "9241-11: 2018 Ergonomics of Human-System Interaction—Part 11: Usability: Definitions and Concepts," *International Organization for Standardization. https://www. iso. org/obp/ui/\# iso: std: iso*, vol. 9241, no. 11, 2018.

[23] F. Ganier, C. Hoareau, and F. Devillers, "Évaluation des performances et de la charge de travail induits par l'apprentissage de procédures de maintenance en environnement virtuel," *Le travail humain*, vol. 76, no. 4, pp. 335–363, 2013, doi: 10.3917/th.764.0335.

[24] G. Gronier and A. Baudet, "Psychometric Evaluation of the F-SUS: Creation and Validation of the French Version of the System Usability Scale," *International Journal of Human–Computer Interaction*, vol. 37, no. 16, pp. 1571–1582, Oct. 2021, doi: 10.1080/10447318.2021.1898828.

[25] M. L. L.-L. Mener, "The academic performance of university students in their first-year : influence of cognitive abilities and motivation," phdthesis, Université de Bourgogne, 2012. Accessed: Mar. 13, 2023. [Online]. Available: https://theses.hal.science/tel-00780578

[26] A. Bangor, "Determining What Individual SUS Scores Mean: Adding an Adjective Rating Scale," vol. 4, no. 3, 2009.