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Article

An Exploratory Study on the Impact of Collective Immersion on Learning and Learning Experience

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Abstract: This paper aims to explore the impact of a collective immersion on learners' engagement and performance. Building on Bandura's social learning theory and the theory on the sense of presence, we hypothesise that collective immersion has a positive impact on performance as well as cognitive, emotional and behavioural engagement. Ninety-three participants distributed in four conditions took part in the experiment. The four conditions manipulated the collective and individual dimensions of the learning environment as well as the high and low immersion of the learning material. The two conditions that offered a high immersion setting used two types of the novel immersive dome: a large one for collective immersion and a small one for individual use. All participants were presented with the same stimuli, an 8-min-long video of a virtual neighbourhood visit in Paris in the 18th century. The participants' reactions were measured during and after the task. The learning outcome, as well as the cognitive, emotional and behavioural engagement, were measured. Final results showed that collective immersion learning outcomes are not significantly different, but we find that collective immersion impacts the cognitive, emotional and behavioural engagement of learners.

Keywords: collective immersion; learning engagement; spherical dome screen; psychophysiology

1. Introduction

Over the past few years, immersive technologies such as augmented reality and virtual reality have become more affordable and accessible on a large scale [1]. With the commercialisation of portable virtual reality headsets, immersion is now becoming increasingly accessible in many domains, such as education and training [2]. Meta-analysis reveals that virtual reality can be an effective learning environment for teaching in K-12 and higher education [3–6].

However, there is limited research on a more recent phenomenon: the educational use of a collective immersion environment. Collective immersion is made possible via a visually immersive spherical dome screen (as shown in Figure 1). An immersive dome can entertain hundreds of spectators and provide them with an immersive experience in a 360° virtual environment. While domes were initially adapted for cinematic purposes, new audio video technologies brought in domes are used for various applications such as art performances and pedagogical purposes. Immersive domes are more and more popular as more immersive domes are conceived and built throughout the world [7].

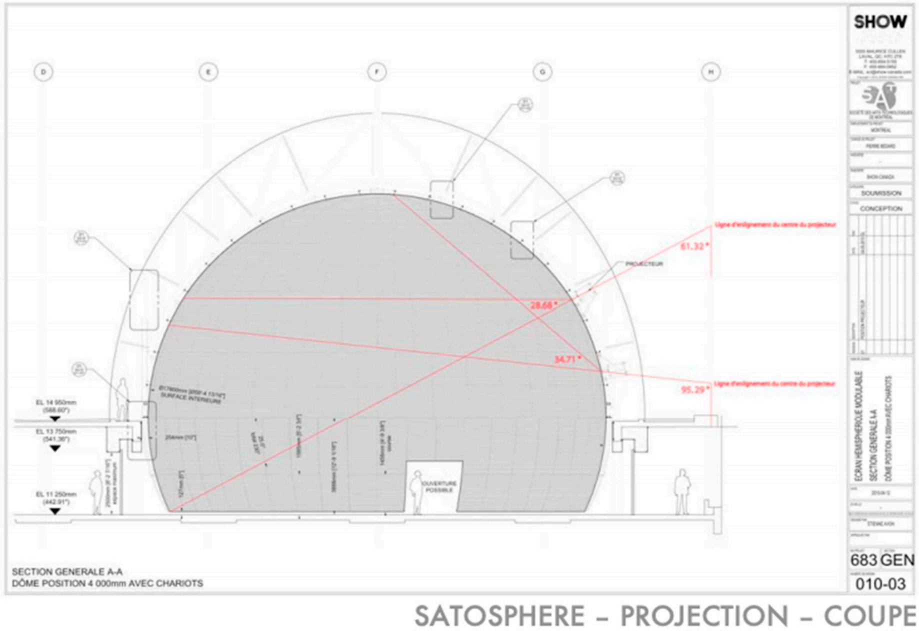

Figure 1. Plan of the dome used for the collective immersion.

This article explores the extent to which immersive dome impacts learning outcome as well as engagement in a collective pedagogical setting. Building on Bandura's social learning theory [8] and the theory on the sense of presence, we hypothesise that collective immersion has a positive impact on performance as well as cognitive, emotional and behavioural engagement. To test this hypothesis, we have conducted a two-factor experiment, namely use context (individual vs. collective) and immenseness (high or low). Ninety-three participants distributed in four conditions took part in the experiment: (1) collective—high immersion, (2) collective—low immersion, (3) individual—high immersion, and (4) individual—low immersion. The two conditions that offered a high immersion setting used two types of the novel immersive dome: a large one for collective immersion and a small one for individual use. All participants were presented with the same stimuli, an 8-min-long video of a virtual neighbourhood visit in Paris in the 18th century. The participants' reactions were measured during and after the task. The learning outcome, as well as the cognitive, emotional and behavioural engagement, were measured.

The article is structured as follows. We first present a literature review on the impact of immersion on learning outcome and engagement, followed by our hypothesis development. We then present our experiment and expose the results we obtained. We conclude by discussing our results and the implications for both the research in education and practice.

2. Literature Review and Hypothesis Development

Immersive technology is a vast term that regroups all technologies that expose a user or a group of users to a virtual environment while either shutting down physical reality or integrating it into the virtual environment. Immersive technologies blur the line between physical, virtual and simulated environments [2]. All immersive technologies are situated on a reality–virtuality continuum [9] which includes Augmented Reality (AR), Virtual Reality (VR) and Augmented Virtuality (AV). There is a wide range of use of immersive technologies in the field of education. Immersive technologies can help train learners in inaccessible situations (e.g., exploring freely the galaxy, imaginary worlds, or previous/future time periods) and even dangerous educational contexts (e.g., performing a plane landing for a novice pilot, decision-making simulation for firefighters' training) [3]. Most popular immersive technologies such as the VR head-mounted display or AR glasses only allow for individual use. The technology used in this study is unique in the aspect that it provides for a collective immersion.

Presence and immersion are often used together in the literature, and their definition often overlaps. Browns and Cairns [10] define presence in VR as the point to which the mind is tricked into believing that the simulated environment is real. According to Suh [11], the sense of presence is a multidimensional constructs that includes the four following dimensions: the physical sense of presence, which refers to objects, the spatial presence, which refers to locations, the social presence, which refers to the sense of being together with someone, and the temporal presence, that refers to the perceived time. Suh [11] also defines immersion using two dimensions: the mental immersion and the physical immersion.

Mental immersion is a "state of mind" during which a player feels absorbed and engaged within the virtual environment. The physical immersion is relative to a user's capacity to interpret the virtual environment (visual, auditory and haptic cues) to navigate and control virtual objects. Slater and Wilbur [12] define immersion as the technological capacity to make one have a sense of presence by offering a vivid virtual environment while shutting out the physical environment. In the context of this research, we will define learning immersion as the feeling of being transported in a simulated educational environment.

Most studies in education on the impact of immersion on learning and learning experience are focused on the individual level of analysis [13]. The interest in individual learning is likely to be related to the relatively easier access to mass market immersive technology that is becoming widely available. Overall, this literature suggests a positive impact of immersive technologies on both learning outcomes and the experience of the learners [3]. For example, in Webster's study [14], researchers investigated the impact of VR in military training and compared it to a more traditional lecture-based training. The results showed that even though both training conditions were judged effective, VR-based learning produced higher exam scores by trainees. Alhalabi [15] tested the impact of three types of immersive technology and one non-immersive technology in engineering education. Results suggest that students performed significantly better when immersive technology was used.

While most studies focus on performance, Merchant et al. [3] remind that fewer studies impact the learning experience. For example, Bindman [16] reports a study on the emotional impact of immersive technology in film viewing. The study suggests that participants in the three-dimensional (3D) VR headset condition are experiencing a stronger sense of presence. The study reports that participants felt as if they were part of the movies and demonstrated a higher empathy level. In another study, Parong and Mayer [17] investigated the impact of immersion on interest, motivation and performance. The study contrasted the effectiveness of teaching scientific content through immersive technology in comparison with a desktop slideshow. Their results suggest that students who were exposed to the slideshow felt less motivation, interest and engagement than students who experimented with the immersive version of the content. It should be noted that, while most studies seem to suggest an overall positive role of immersive technologies, some authors dispute the positive impact of immersive technologies on performance and engagement and conclude on a non-existent impact [18] or even on a negative impact due to distraction or to a cognitive overload [19–21].

In the literature on immersive learning, the concept of learning is often limited to the performance of the learners. However, in this paper, our intention is to investigate more broadly the learning experience in the immersive setting, while still taking into account the learning outcome. Thus, we mobilise the theory of learning engagement proposed by Fredricks et al. [22]. According to this theory, learning engagement is a multidimensional construct that covers three dimensions: behavioural engagement, cognitive engagement and emotional engagement [23]. Behavioural engagement is defined as the positive conduct, involvement and participation manifested by a learner in an educational situation. Cognitive engagement refers to a more academic engagement and involves learning strategy and the mobilisation of the cognitive resources by the learner in the educational situation. Emotional engagement relates to the learners' affective reactions during the educational task and includes the motivation aspect of the learner's engagement.

To our knowledge, there seems to be a lack of research on the effect that immersive environments have on learning in collective settings and scholars are calling for research on the collective use of technology in contexts such as education [24]. Building on Bandura's social learning theory [8], we theorise that a collective immersion could lead to positive learning outcomes and higher engagement from the participants. According to Bandura [8], people learn from one another by observing, imitating and modelling. This theory suggests that people can monopolise their attention, memory and motivation to learn effectively in a collective environment in a way that is not possible in individual learning conditions. Following this theory, we posit that a collective immersive environment is likely to generate a higher learning engagement and learning outcome than other non-collective and non-immersive learning situations.

Specifically, we state the following hypotheses:

Hypothesis 1 (H1). *Collective immersion has a positive impact on behavioural, emotional and cognitive engagement and performance.*

Hypothesis 1a (H1a). *Collective immersion has a positive impact on behavioural engagement.*

Hypothesis 1b (H1b). *Collective immersion has a positive impact on emotional engagement.*

Hypothesis 1c (H1c). *Collective immersion has a positive impact on cognitive engagement.*

Hypothesis 1d (H1d). *Collective immersion has a positive impact on performance.*

3. Materials and Methods

3.1. Experimental Design

To answer the research question and test our hypotheses, we conducted a two-factor experiment manipulation: use context (individual vs. collective) and immersiveness (high or low). Specifically, the experiment compared learning engagement and learning outcomes in four different experimental conditions: (1) collective—high immersion (Coll_Exp), (2) collective—low immersion (Coll_Cont), (3) individual—high immersion (Ind_Exp), and (4) individual—low immersion (Ind_Cont). The ethics committee of our institution authorised this experiment. All participants signed a consent form before their participation.

3.2. Experimental Setup

Condition 1 (Coll_Exp) was conducted in a 360° immersive dome (Montréal, Qc, Canada) of 18 m diameter and a height of 13 m, filled with 157 speakers for the collective high immersion (see Figure 2). In Condition 2 (Coll_Cont), a wall projector was used to present the stimulus (4 m diagonal projection), therefore allowing a large group of participants to watch the stimuli in a large room (see Figure 3). In condition 3 (Ind_Exp), the highly immersive individual condition, the experiment was conducted in a 360° immersive dome of 3 m diameters (Montréal, Qc, Canada) (see Figure 4). Finally, in condition 4 (Ind_Cont), the experiment was presented on a regular flat screen (139 cm diagonal) (see Figure 5).

Figure 2. The immersive projection in the collective setting with 12 participants (Coll_Exp).

Figure 3. The projection in the collective and low-immersion setting, with 12 participants (Coll_Cont).

Figure 4. The immersive projection in the individual setting (Ind_Exp).

Figure 5. The flat screen viewing in the individual and low-immersion setting (Ind_Cont).

3.3. Experimental Stimulus

The experimental stimulus used for this study takes its roots in the Bretez project [25], aiming to recreate a Parisian neighbourhood's visual and sound environment in the 18th century.

A 3D model of the Grand-Chatelet neighbourhood and the sounds was recreated by Pardoen [26] and adapted by SAT (Montréal, QC, Canada) to fit a 360° immersive dome technology format. This stimulus was presented using a platform that could support visual, sound and 3D model assets in the immersive dome. The platform can adjust the localisation of the sounds in the 3D model and create a dynamic virtual scene of the neighbourhood. A narrative was written and reviewed by the designers of the Bretez Project. This narration was then recorded and included in the scene. The final stimulus is an 8-min video of a virtual visit to Paris in the 18th century with a narration and ambient sounds.

The stimulus adapted to all experimental conditions of this experiment (i.e., high immersive and low immersive technologies). Two versions of the final scene were recorded. The first one was a recording of the first-person point of view 360° video walking around the recreated neighbourhood for the Condition 1 (Coll_Exp) and Condition 3 (Ind_Exp)—this version was adapted for a project in an immersive dome. The second recording was a regular first-person point of view video for Condition 2 (Coll_Cont) and Condition 4 (Ind_Cont)—this version was adapted for a flat (non 360°) viewing.

3.4. Sample

A total of 93 participants were recruited for this experiment. Requirements were to be 18 years old or older, with no pregnancy nor any cardiac or epileptic condition. In our sample of participants, 48 identified as men, 43 as women and 2 two as non-binary (age range from 18 to 64 years old—mean (M) = 25.9, standard deviation (SD) = 7.8). Out of all the 93 participants, 28 had no experience with immersive technologies (VR headset, AR glasses and immersive domes were example given for immersive technologies), the rest having experience ranging from a one-time experience (50 participants) to regular use (15 participants).

- Three groups of 12 participants were assigned to Condition 1 (Coll_Exp). Out of these 36 participants, one abandoned the study halfway. In each group, 3 participants were randomly picked to be measured with physiological equipment. After each experiment, one extra participant was randomly selected to join the other three measured participants and partake in semi-guided interviews. A total of 12 participants were interviewed.
- In Condition 2 (Coll_Cont), two groups of 12 participants took part in the experiment. Three participants per group were also randomly picked to be measured with physiological equipment, leading to a total of 6 participants measured with physiological equipment. Also, 1 extra participant was randomly selected to join the three measured participants in a semi-guided interview.
- Condition 3 (Ind_Exp) tested individual use of highly immersive technology. Eighteen participants were measured and interviewed. Out of all these participants, we experienced 2 equipment malfunctions, resulting in a total of 16 participants.
- Condition 4 (Ind_Cont) tested the individual use of a low immersion setting. Sixteen participants were measured physiologically and interviewed, however two experienced equipment malfunctions, leading to fourteen participants.

3.5. Procedure

Participants were recruited via a short online survey. They were randomly assigned to a condition depending on their availability. Upon the arrival of the participant, one of the researchers explained the procedure. All participants signed a consent form before beginning the study.

In the collective experimental condition (Condition 1), participants were instructed to stand at the dome's centre and watch the immersive projection (Figure 2). For the individual experimental condition (Condition 3), participants were to sit on a revolving office chair at the centre of the dome (Figure 3), so that they could quickly turn around and see the immersive projection while staying at the recommended height to avoid any sound echo and anomalies.

In both collective and individual control conditions (Conditions 2 and 4), participants were asked to sit in a chair and watch the media on a regular television or projector (Figure 4). For the individual conditions (Conditions 3 and 4), the physiological reaction of participants during the experiment was measured with physiologic devices (see measures section). A head-mounted GoPro camera HERO4 (Montréal, Qc, Canada) was used to film where the participant is looking during the experiment. For the collective conditions (Conditions 1 and 2), 3 participants per group of 12 were randomly selected in advance, and the physiological reaction of those participants was measured using the BITalino (r)evolution Freestyle Kit (Montréal, Qc, Canada) (see measures section). A camera also filmed the collective conditions.

Following the experiment, all participants answered a questionnaire divided into 6 sections: Likert scales on the perceived usefulness, attitude towards the technology and cognitive load, Self-Assessment Manikin (SAM) scale, test on the sound content, test on the narrative content, test on the visual content (see measures section).

After answering the questionnaire, all participants for the individual conditions (Conditions 3 and 4), and the 20 randomly selected participants for the collective conditions (Conditions 1 and 2), participated in a semi-conducted interview with one of the researchers, during which open questions were asked to the participants. In the collective conditions (Conditions 1 and 2), as only two researchers were conducting the interviews, two participants were randomly assigned per researcher, and the interviews were conducted by one researcher for two participants at a time. In the individual conditions (Conditions 3 and 4), the interviews were conducted one on one. Before exiting, all participants signed the compensation form.

3.6. Measures

The three dimensions of engagement and the learning performance are operationalised through independent variables and constructs and measured with the following tools. Table 1 presents the psychometrics scales that we have adapted in this study to measure the various constructs.

Table 1. Independent variables and their corresponding constructs, measuring tools and their sources.

Independent Variables	Constructs	Tools	Source
Behavioural Engagement	Interest to renew the experience	Interview	
	Perceived usefulness	Likert scale (6 items) Interview	Adapted from Yang [27], Parong and Mayer [17] and Davis [28]
	Attitude towards technology	Likert scale (3 items)	Adapted from Parong and Mayer [17], Brooke [29]
Emotional Engagement	Measured emotional engagement (measured through arousal)	Electrodermal activity (EDA) Electrocardiography (ECG)	Charland et al. [30], Riva [31] and Tsianos [32]
	Perceived emotional engagement (measured through valence and arousal)	SAM scale Interview	Peacok [33], Bradley and Lang [34]
Cognitive Engagement	Perceived cognitive engagement (measured through cognitive load)	Likert scale (6 items) Interview	Adapted from Yang [27], Brooke [29] and Parong and Mayer [17]
Learning outcome	Measured Learning	Questionnaire (30 items)	
	Perceived learning	Likert scale (3 items) Interview	Adapted from Yang [27] and Parong and Mayer [17]

In addition to the psychometric scale, we have measured implicit emotional engagement with psychophysiological instruments [35]. Building on previous research [30,36,37], we have monitored electrodermal activity (EDA) and cardiovascular activity (electrocardiogram, ECG) during the experiment to evaluate the emotional arousal of participants. The device consisted of a BITalino (r)evolution Freestyle Kit (PLUX Wireless biosignals S.A.) [38] installed in a 3D-printed box that hung on the belt of the subjects (see Figure 6) [39,40].

Three sensors were positioned on the participant's torso to measure the ECG. Two other sensors were positioned on the palm of the non-dominant hand to measure the EDA. The ECG sensors record the heart rate beat per minute (BPM), enabling us to analyse the change in the heart rate at the post-processing stage. The EDA sensors record the tonic activity (the baseline) and the phasic activity. The latter represents the variations in skin conductivity caused by sweat gland activity. These variations are indicators of change in arousal [41]. A baseline was recorded at the beginning of the experiment [42]. During this baseline, the participant was expected to sit and relax so that the sensors could record his average EDA and ECG.

Figure 6. Electrodermal activity (EDA) sensors and the BITalino box.

Similar to our previous work [37,43], to synchronise the projected video with the EDA and ECG data, a Bluetooth Low Energy (BLE) (Montréal, Qc, Canada) sent signals to a lightbox and all the BITalino devices in range. The camera was able to capture the signal numbers displayed by the lightbox. The same numbers were saved into the EDA and ECG data file, following the synchronisation technique developed by Courtemanche et al. [30,44–47].

Learning performance was measured with a quiz composed of three sections:

- 5 questions referring to the visual dimension of the projection
- 11 questions referring to the narrative content
- 14 questions on the acoustic stimuli in the simulation

This quiz was created following Charland et al.'s [48] method. The questions were prepared and reviewed by a team of history experts affiliated with the research team.

Finally, perceived immersion was operationalised as a manipulation check. The sense of presence was measured by four items adapted from Falconer [49] (Cronbach's Alpha of 0.748).

3.7. Data Preparation and Analysis

Data was analysed using a regression including all the control variables with either a normal or multinomial distribution. Each condition's data was compared to another to measure the impact of immersion on learning experience in a collective environment (1 vs. 2) as well as in an individual environment (3 vs. 4) and of the impact of collective immersion on learning experience in a highly immersive environment (1 vs. 3) as well as in low immersion (2 vs. 4).

This baseline mean was subtracted to each value of the recorded EDA and ECG from the experiment, revealing peaks in physiological data [50]. These peaks represented the emotional arousal variation felt by the participant during the experiment. Data was then analysed using linear regression with a random intercept model and a normal distribution.

As for the qualitative data, the information collected in Reframer (Optimal Workshop, Wellington, NZ) was then transcribed. Following guidelines from Boeije [51], each entry was labelled with tags to help the analysis and filter the information according to need. The two researchers organised the tag system and the first entries were cross-checked by each researcher, so the entries were tagged similarly.

4. Results

The following section presents results according to each hypothesis. It must also be noted that a synthesis of the results is shown in two graphs (Figures 7 and 8) at the end of the results section.

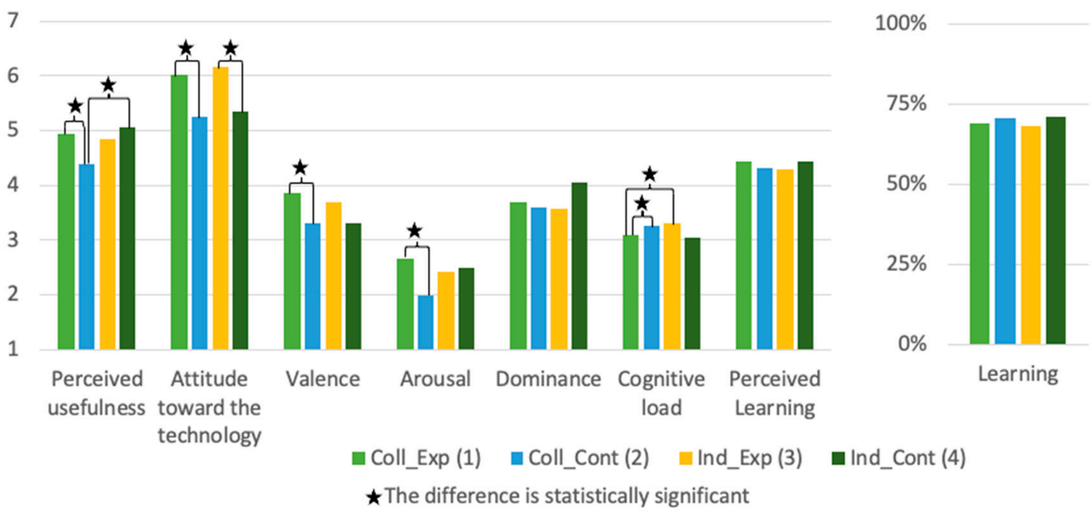

Figure 7. Graph of the average value of all but physiological variables and their statistical significance ($p < 0.05$).

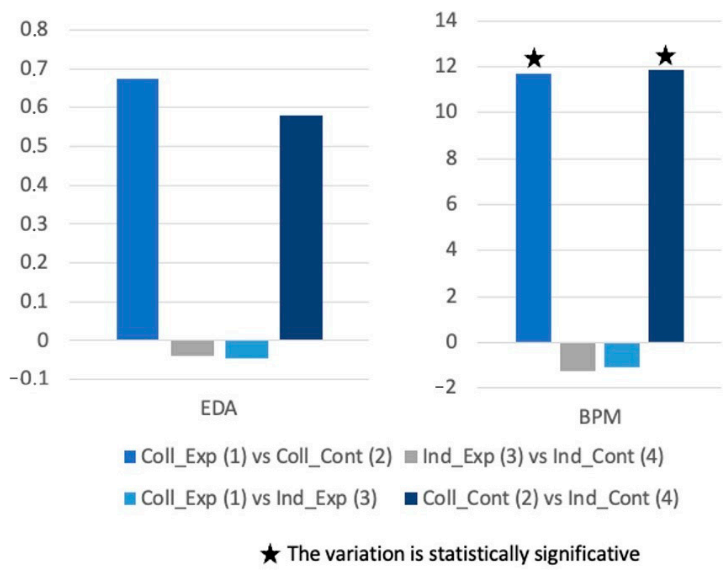

Figure 8. Graph of the variation estimates for the physiological variables and their statistical significance ($p < 0.05$).

Collective immersion has a positive impact on behavioural engagement (H1a).

Table 2 suggests a positive impact of immersion on attitude toward the used technology as well as a positive impact of collectivity on perceived use. In a collective environment, it would seem that a lowly immersive environment (Condition 2) favours a higher perceived use than a highly immersive environment (Condition 1).

Table 2. Impact of immersion and collectivity on behavioural engagement.

	Coll_Exp (1) vs. Coll_Cont (2)		Ind_Exp (3) vs. Ind_Cont (4)		Coll_Exp (1) vs. Ind_Exp (3)		Coll_Cont (2) vs. Ind_Cont (4)	
	Estimate	***p*-Value**	**Estimate**	***p*-Value**	**Estimate**	***p*-Value**	**Estimate**	***p*-Value**
Perceived usefulness	0.533	0.038 *	−0.314	0.345	0.225	0.410	−0.669	0.034 *
Attitude toward the technology	−1.648	0.003 *	−1.505	0.038 *	−0.335	0.531	0.044	0.941

* statistically significant.

However, the information gathered in the interview points otherwise, with 10 interviewees out of 12 in Condition 1 (Coll_Exp) mentioning that the format and content seemed useful as is, and in Condition 2 (Coll_Cont), only 2 out of 8 found it useful as-is and 3 mentioned not finding it useful at all. In both conditions, some interviewees agreed it had more potential.

We can also observe in Table 2 that in a lowly immersive environment, a collective setting (Condition 2) favours a higher perceived use than an individual setting (Condition 4). This is supported by the information gathered in the interviews.

Regarding the interest to renew experiment, results suggest a positive impact of immersion on interest to renew experiment in a collective setting (8/12 firm yes, 0/12 no in Condition 1 (Coll_Exp) vs. 2/8 firm yes and 2/8 firm no in Condition 2 (Coll_Cont)) but a seemingly negative impact of collectivity in a highly immersive context (8/12 firm yes in Condition 1 (Coll_Exp) vs. 16/18 firm yes in Condition 3 (Ind_Exp)).

It seems that high immersion favours a high interest to renew the experience in both collective (Condition 1) and individual settings (Condition 3). None of the highly immersive conditions (Conditions 1 and 3) triggered a negative response from participants when asked if they were interested in renewing the experience and the large majority were positive and enthusiastic about repeating the experiment.

In short, this hypothesis is partly supported, as immersion seems to positively impact the interest to renew the experiment and the attitude towards the used technology. However, the collective use does not have any significant impact on any of these constructs. According to our measurements, it has come to light that, in a collective environment (Conditions 1 and 2), immersion has a negative impact on the perceived use. It is essential to mention that these results are in contradiction with the findings from the interviews. Lastly, in low immersion, collectivity (Conditions 2 and 4) positively impacts the perceived use

Collective immersion has a positive impact on emotional engagement (H1b).

Results in Table 3 show a partial positive impact of immersion on perceived emotions. A highly immersive environment (Condition 1) favours stronger and more positive perceived emotions in a collective setting than in a low immersive setting (Condition 2). The information gathered from qualitative interviews also supports this finding, as in a highly immersive environment, 6 interviewees out of 12 mentioned feeling awed and impressed, when none mentioned it in Condition 2 (Coll_Cont).

In both conditions, the participants reported feeling calm and neutral. However, in Condition 1 (Coll_Exp), these reactions were considered positive as it was in a calming sensation (4 out of 12 interviewees), while in Condition 2 (Coll_Cont), it was often associated with a feeling of boredom or lack of interest. Physiological data revealed a positive impact of immersion on arousal in a collective setting (Condition 1 vs. Condition 2), but in the individual setting, low immersion favours higher arousal (Condition 2 vs. Condition 4).

The ECG recorded a higher BPM (adjusted to baseline) for the highly immersive condition (Condition 1) than for the control condition (Condition 2). It appears that, in collectivity, high immersion (Condition 2) induces higher emotional arousal. However, in a low immersive setting, the ECG recorded a higher BPM (adjusted to baseline) for the individual condition (Condition 4) than for the collective condition (Condition 2). It suggests that solitude might induce higher emotional arousal in a low immersion setting.

Table 3. Impact of immersion and collectivity on learning experience.

		Coll_Exp (1) vs. Coll_Cont (2)		Ind_Exp (3) vs. Ind_Cont (4)		Coll_Exp (1) vs. Ind_Exp (3)		Coll_Cont (2) vs. Ind_Cont (4)	
		Estimate	***p*-Value**	**Estimate**	***p*-Value**	**Estimate**	***p*-Value**	**Estimate**	***p*-Value**
Perceived learning experience	Valence	−1.225	0.029 *	−1.582	0.046 [1]	−0.358	0.526	−0.113	0.858
	Arousal	−1.543	0.007 *	−0.208	0.763	−0.355	0.513	0.654	0.314
	Dominance	0.195	0.714	0.804	0.284	0.161	0.771	0.43	0.534
Objective learning experience	ECG (BPM)	11.69	0.011 *	−1.240	0.733	−1.065	0.773	11.87	0.007 *
	EDA (phasic)	0.673	0.171	−0.039	0.925	−0.449	0.31	0.26	0.579

* statistically significant. [1] This *p*-value becomes non-significant in the regression model without the control variable, collinearity is suspected, thus not taken into account.

Results enable us to partially support this hypothesis as perceived emotions are more intense and more positive in a highly immersive environment. However, this result applies only in a collective setting. Psychophysiological arousal appears to be stronger in a high immersive environment in a collective setting (Condition 1). Also, in low immersion, a collective (Condition 2) environment favours higher emotional arousal.

Collective immersion has a positive impact on cognitive engagement (H1c).

Results in Table 4 suggest a positive effect of immersion and collectivity on cognitive load. It seems that in a collective setting, a highly immersive environment (Condition 1) creates a lower perceived cognitive load than a lowly immersive environment (Condition 2). In the highly immersive condition (Condition 1), the interview revealed that 7 participants out of 12 reported having no problem concentrating on the stimuli. However, in the low immersive condition (Condition 2), 4 interviewees out of 8 found it very hard to focus and were at some point completely distracted. In Condition 2 (Coll_Cont), 6 interviewees found the environment distracting (mentioning either the lights, the surrounding noises, or the other participants). It is also revealed that a highly immersive setting in a collective environment (Condition 1) favours a lower perceived cognitive load than in an individual environment (Condition 3). In the collective environment (Condition 1), 7 out of 12 interviewees found it easy to focus, when in the individual environment (Condition 3), only 1 participant mentioned this ease and 4 out of 18 were distracted by the environment. Twelve interviewees in Condition 3 (Ind_Exp) mentioned that the low quality of the visuals and overlap of narration and sounds made it hard for them to focus correctly.

Table 4. Impact of immersion and collectivity on cognitive engagement.

	Coll_Exp (1) vs. Coll_Cont (2)		Ind_Exp (3) vs. Ind_Cont (4)		Coll_Exp (1) vs. Ind_Exp (3)		Coll_Cont (2) vs. Ind_Cont (4)	
	Estimate	***p*-Value**	**Estimate**	***p*-Value**	**Estimate**	***p*-Value**	**Estimate**	***p*-Value**
Cognitive load (Likert 3 items)	−0.648	0.028 *	−0.071	0.86	−0.680	0.048 *	0.095	0.763

* statistically significant.

The results support an overall lower cognitive load in the collective immersive environment, which can potentially be interpreted as a tendency for participants to have less trouble concentrating and be less distracted, therefore increasing their cognitive engagement. Hence, our results enable us to support our hypothesis as a collective immersion generates a higher cognitive engagement. In a highly immersive environment, collective use leads to a higher cognitive engagement, and in a collective environment, a high immersion favours a higher cognitive engagement.

Collective immersion has a positive impact on performance (H1d).

The last hypothesis suggested a positive impact of collective immersion on the learning outcome. The results displayed in Table 5 did not enable us to verify this hypothesis. No significant results were found for the impact of immersion and collective use on learning outcomes, either perceived or real. The participants' commentary in the interviews were mitigated. In a high immersion setting, participants mentioned learning only about some details, about the environment and everyday life. The learning was defined as anecdotal. Participants mentioned that there was a high learning potential that was not totally exploited. In a low immersion setting, participants also mentioned anecdotal learning, however, there was no mention of unexploited potential.

Table 5. Impact of immersion and collectivity on learning outcomes

	Coll_Exp (1) vs. Coll_Cont (2)		Ind_Exp (3) vs. Ind_Cont (4)		Coll_Exp (1) vs. Ind_Exp (3)		Coll_Cont (2) vs. Ind_Cont (4)	
	Estimate	***p*-Value**	**Estimate**	***p*-Value**	**Estimate**	***p*-Value**	**Estimate**	***p*-Value**
Learning (Total test)	−0.015	0.662	−0.03	0.359	0.015	0.591	0.012	0.721
Perceived learning (Likert 3 items)	0.148	0.624	0.124	0.746	0.108	0.739	0.032	0.928

Collective immersion has a positive impact on behavioural, emotional and cognitive engagement and performance (H1).

5. Discussion and Conclusions

This study contributes to the literature by exploring the pedagogical impact of a new immersive technology on the learner's engagement and performance. To our knowledge, this is the first time that the impact of two different immersive domes was studied to understand their education relevance.

As this study contributes to the literature by offering a new environment of experiment enabling us to study the impact of collectivity and immersion, it also studies the impact of such variables on both performance and engagement. Our results have partially supported the hypothesis that collective immersion has a positive impact on engagement and performance. On the effect on behavioural engagement, previous literature reveals a tendency to a positive impact on learning and interest from the participants [17,52]. In accordance, our results show a generally positive impact of immersion on behavioural engagement, although the hypothesis of a positive impact of collective immersion has not been supported. Similar results were also observed in the literature as no trends are being reported [3].

Similarly, the positive impact of collective immersion on emotional engagement has not been supported, but a positive impact of immersion on emotional engagement has been highlighted. This finding is largely supported by the literature [16,53] and often justified on the basis that immersion leads to a higher sense of presence, which helps the participants relate more to the content and feel more empathy.

Most of the literature on cognitive engagement focuses on the performance and learning outcome of the participant. However, a few studies consider the cognitive engagement as defined by Fredricks et al. [22] and, in accordance with our results [54], we observe a positive impact of immersion on cognitive engagement. Moreover, our results enable us to support the hypothesis of a positive impact of collective immersion.

The lack of impact on the learning outcomes, in this context, may be interpreted as a positive result, as it shows that collective immersion does not impair the performance of the student as some articles have suggested [19,20,55]. These articles often emphasise the negative impact of cognitive overload and other distractors in the virtual environment. Chang et al. [56] explain this phenomenon with the notion of distracted attention. However, it is a possibility that this same phenomenon may explain why the participants are not performing better when in a collective immersion. Our results are aligned with previous studies that have also reported a lack of impact of immersion on performance [14].

Participants have also suggested a few modifications that could improve the experiment's quality. Many participants in all conditions mentioned that the quality of the visuals were below their expectations. Considering their previous exposure to either video games, animated movies, special effects as seen in movies, or VR games, they were very distracted by the media's quality that reminded them of an unfinished prototype. They suggested adding more colours and textures to the visuals. Some also mentioned the lack of "life" and activity in the streets visited in the media, making it look like a "ghost town". Some participants also suggested a less monotonous voice for the narration. These elements were repeatedly reported to be part of why participants could not feel completely immersed in the media.

There are still unanswered questions with regards to the impact of collective immersion on learning, and more research is needed. In the future, building on Cronan [57] and Charland [48], this experiment would benefit from more efficiently studying the learning outcome. In this experiment, participants were of different ages, education levels, and overall knowledge about Paris and France's history. The media was made to be accessible to a large range of participants. Hence, the information delivered was basic enough to be understood by all participants and so it might have been too simple for some. Following Caya [58], it would be relevant to study the impact on a group's performance with the same level of knowledge about the subject. Using a more extended media with a more considerable amount of information would also help see the real impact of immersion and collectivity on performance. Testing the long-term retention of knowledge should also be incorporated in the performance evaluation. Considering interaction with the media was also a recurrent suggestion from the participants.

Finally, this research contributes to helping art and educational institutions open their collective immersive infrastructure to the public for educational purposes. It also brings empirical support for designers to invest in developing collective immersive material for educational purposes. Our results suggest that immersive artifacts can play a role in engaging learners into pedagogical contexts in which immersion has the potential to convey the required sensory understanding to engage appropriately large groups of students. This exploratory research and future related research also open the possibility to support collaboration between educational infrastructures, such as universities or formation centres, and organisations offering the collective immersive technologies.

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