HEC MONTRÉAL

L'impact de l'immersion collective sur l'apprentissage et l'expérience d'apprentissage

Par

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(Option Expérience Utilisateur en contexte d'affaires)

Mémoire présenté en vue de l'obtention
du grade de maîtrise ès sciences en gestion
(M. Sc.)

Octobre 2020

HEC MONTRÉAL

Comité d'éthique de la recherche

Le 21 mai 2019

À l'attention de : Pierre-Majorique Léger
Technologies de l'information
HEC Montréal

Objet : Approbation éthique de votre projet de recherche

 # Projet : 2020-3464

Titre du projet de recherche : Etude de l'impact sur le potentiel éducatif et sensoriel d'une technologie immersive

Source de financement : MITACS (CCS à venir)

Votre projet de recherche a fait l'objet d'une évaluation en matière d'éthique de la recherche avec des êtres humains par le CER de HEC Montréal.

Un certificat d'approbation éthique qui atteste de la conformité de votre projet de recherche à la *Politique relative à l'éthique de la recherche avec des êtres humains* de HEC Montréal est émis en date du 21 mai 2019. Prenez note que ce certificat est **valide jusqu'au 01 mai 2020.**

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La présente atteste que le projet de recherche décrit ci-dessous a fait l'objet d'une évaluation en matière d'éthique de la recherche avec des êtres humains et qu'il satisfait aux exigences de notre politique en cette matière.

Projet # : 2020-3464

Titre du projet de recherche : Etude de l'impact sur le potentiel éducatif et sensoriel d'une technologie immersive

Chercheur principal :
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Date d'approbation du projet : 21 mai 2019

Date d'entrée en vigueur du certificat : 21 mai 2019

Date d'échéance du certificat : 21 mai 2020

Maurice Lemelin
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CER de HEC Montréal

HEC MONTRÉAL

Comité d'éthique de la recherche

Le 13 juillet 2020

À l'attention de :
Pierre-Majorique Léger
Technologies de l'information, HEC Montréal

Cochercheurs :
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Projet # : 2020-3464

Titre du projet :
Etude de l'impact sur le potentiel éducatif et sensoriel d'une technologie immersive

Ajout de financement : MITACS - CCS : R2451

Titre de la subvention :
Enrichissement sensoriel de la modélisation 3D de la ville historique de Paris, pour le projet SAT (été 2019).

Stagiaires MITACS : Salame, Youness; Merveilleux-Du-Vignaux, Maylis

Pour donner suite à l'évaluation de votre formulaire F8 - Modification de projet, le CER de HEC Montréal vous informe de sa décision :

Les modifications (ajout de financement) ont été approuvées et notées au dossier. Le certificat actuel demeure valide jusqu'au prochain renouvellement.

En vous remerciant cordialement,

Le CER de HEC Montréal

Maurice Lemelin
Président
CER de HEC Montréal

Résumé

Depuis quelques années, les technologies immersives sont devenues de plus en plus accessible, rendant leur utilisation dans le domaine de l'éducation plus courante. La littérature existante se concentre en majorité sur l'impact de ces technologies sur la performance de l'utilisateur et étudie rarement l'impact d'une utilisation collective. Ce mémoire vise à étudier l'impact de l'immersion collective sur l'apprentissage et l'expérience d'apprentissage. En nous appuyant sur la théorie de Bandura sur le Social Learning, sur la théorie de l'impact de la présence ainsi que sur les construits introduits par la théorie de l'apprentissage de Fredricks nous posons l'hypothèse que l'immersion collective a un impact positif sur la performance et sur l'engagement comportemental, émotionnel et cognitif. Pour cela nous avons effectué une expérience inter sujets en partenariat avec la Société des Arts Technologiques (SAT). Les 93 participants ont été attribués à l'une des 4 conditions qui suivent : haute immersion collective, haute immersion individuelle, faible immersion collective, faible immersion individuelle. Les participants étaient mesurés à l'aide de questionnaires, d'entrevues et d'outils physiologiques.

Les résultats nous ont permis d'observer que l'immersion a un impact positif sur l'engagement comportemental et émotionnel. L'impact de l'aspect collectif de cette immersion n'a cependant pas été vérifié par nos résultats. L'engagement cognitif semble avoir été positivement affecté par l'immersion collective tandis que la performance d'apprentissage ne semble pas avoir été impactée par l'immersion collective.

Ces résultats contribueront à combler le manque de littérature sur l'immersion collective et sur l'impact sur l'expérience d'apprentissage ainsi qu'à proposer une méthodologie pour étudier l'immersion collective en contexte d'apprentissage. De plus, ils pourraient servir d'appui lors du lancement de certaines initiatives éducatives visant à incorporer des technologies immersives et collectives afin d'engager les étudiants.

Mots clés : immersion collective, technologie immersive, expérience d'apprentissage, engagement, expérience utilisateur.

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Liste des abréviations

SAT = Société des Arts Technologiques

CER = Comité d'éthique de la recherche

EDA = Activité électrodermale

ECG = Electrocardiogramme

SAM = Self-Assessment Manikin

HEC = Haute Ecole de Commerce

HMD = Head mounted display

CAVE = Cave Automatic Virtual Environment

VR = Virtual Reality

AR = Augmented Reality

AV = Augmented Virtuality

MR = Mixed Reality

HRV = Heart rate variability

Avant-propos

Ce mémoire a été rédigé sous forme d'une revue de littérature et d'un article scientifique, suivant l'autorisation de la direction administrative du programme de Maîtrise en gestion de HEC Montréal. Le premier chapitre étudie la littérature existante tandis que le second chapitre détaille l'étude effectuée en partenariat avec la Société des Arts Technologiques (SAT) avec le soutien de l'organisme Mitacs. Cet article s'efforce de détailler la méthodologie et les résultats de l'étude de l'impact de la collectivité de l'immersion sur l'engagement et la performance. Cet article sera soumis au journal Computers in Human Behavior Reports après la complétion du mémoire. L'accord de tous les co-auteurs a été obtenu afin de présenter cet article dans ce mémoire. Ce projet de recherche a été validé par le Comité d'Éthique en Recherche (CER) en date du 21 mais 2019 (projet n° 2020-3464).

Remerciements

Ce projet qui aura duré un an et demi a pu finalement aboutir et ce grâce à l'aide et au soutien de plusieurs personnes que j'aimerai remercier. Je tiens tout d'abord à remercier l'équipe de la SAT, Emmanuel Durand ainsi que Nicolas Bouillot et le reste de l'équipe du MetaLab sans qui ce projet n'aurait jamais vu le jour. Leur patience et leur disponibilité ont été d'une aide précieuse pour la mise en place des expériences.

En intégrant le Tech3Lab je savais que j'y trouverai une équipe incroyable et un projet intéressant mais mes co-directeurs, Pierre-Majorique Léger et Patrick Charland ont réussi à dépasser ces attentes en m'offrant une l'opportunité de travailler sur un projet merveilleux qui allie ma passion de l'art et mon domaine d'étude. Je leur serai à jamais reconnaissante de m'avoir permis de travailler si tôt dans ma vie sur un projet aussi passionnant, et ce en étant constamment accompagnée de leur confiance et de leurs encouragements.
L'équipe opérationnelle du Tech3Lab mérite des remerciements pour leur assistance et leur aide tout au long de la préparation, de la collecte ainsi que l'analyse. Je remercie tout particulièrement Shang Lin, François, Amine, David, Emma, Brendan ainsi que Bertrand. Vous étiez toujours prêts à répondre aux moindres questions et à prendre le temps de gérer les problèmes de collecte. Un salut tout particulier à Youness qui a participé à ce projet à mes côtés et avec qui les heures de meeting se sont enchaînées pour gérer ce projet jusqu'à sa complétion. J'aimerai aussi remercier les étudiants du Tech3Lab qui étaient là pour répondre à mes questions et me donner de précieux conseils, tout particulièrement Ariane, Félix, Raphaëlle et Benjamin.

Enfin je remercie mes amis Nathalie, Alice, Fanny, Lucas et toute la team Acrosport de leur soutien sans faille et de m'avoir supportée dans les moments où je les forçais à m'écouter parler de ce projet. Plus spécialement merci à Josué, Maman et la plus incroyable des fratries ; Perrine, Claire et Aymeric. Sans vous je ne serais pas la personne que je suis aujourd'hui, j'ai beaucoup de chance de vous avoir dans ma vie. J'ai une pensée toute particulière à mon papa qui aurait été si fier de moi.

Introduction

Mise en contexte de l'étude

Dans les dernières années, les technologies immersives ont connu un développement qui a permis leur démocratisation dans beaucoup de domaines tel que celui de l'éducation. Profitant de cette croissance, un grand nombre d'études a été effectué pour mesurer et comprendre l'impact de l'utilisation de ces technologies sur l'apprentissage et l'expérience d'apprentissage. Ces études ont été menées dans des contextes variés en étudiant diverses facettes de l'apprentissage. L'utilisation de ces technologies dans l'éducation a deux applications principales : celle de la formation pour adultes et celle de l'éducation en lycée ou en universités (Freina, 2015). L'utilisation dans les formations pour adultes dites formations professionnelles sont souvent motivées par fait que les situations simulées soient dangereuses ou difficilement accessibles. On retrouve notamment ces formations dans les domaines de l'aviation, du médical ou encore du militaire. Dans un contexte d'éducation en secondaire ou en université, la motivation principale semble plutôt de donner plus de contrôle à l'étudiant et de stimuler sa motivation. Encore une fois, la recherche met en évidence une utilisation plus fréquente de ces technologies dans le domaine médical.

Beaucoup étudient l'apprentissage uniquement par le biais d'une évaluation de la performance mais de plus en plus d'études se forcent à inclure le concept d'engagement comme étant aussi important que la performance dans l'étude de l'apprentissage. Ce concept, détaillé par Fredricks comme étant composé de trois dimensions : cognitive, comportementale et émotionnelle, est manipulé assez librement dans la littérature. Certaines études ne considèrent qu'une seule ou deux des trois dimensions.

Bien que la majorité des études se rejoignent sur le fait que l'utilisation d'une technologie immersive permette de créer des conditions idéales dans le cadre de formations afin de stimuler l'engagement et la performance de l'utilisateur, il est important de mentionner que ces études utilisent le plus souvent des casques de réalité virtuelle. Ces technologies contraignent les chercheurs à se concentrer uniquement sur une utilisation individuelle. Il est cependant particulièrement intéressant de s'intéresser aux potentiels impacts d'une utilisation collective des

technologies immersives sur l'apprentissage et l'expérience d'apprentissage. Très peu d'études font l'utilisation d'une technologie permettant une haute immersion collective car ces technologies sont habituellement moins accessibles et plus coûteuses. Grâce au partenariat avec la Société des Arts Technologiques (SAT), l'étude au centre de ce mémoire fait l'utilisation de plusieurs technologies immersives. La première est un dôme immersif de 18 mètres de diamètre permettant une utilisation collective allant jusqu'à une capacité de 350 personnes mais qui, dans notre étude, ne sera occupé que par des groupes de 12 personnes. La seconde technologie immersive est un dôme immersif d'un diamètre de 3 mètres de diamètre permettant une utilisation individuelle.

Cette expérience fait suite à un projet débuté par Mylène Pardoen, le projet Bretez, dans l'objectif de reconstituer l'environnement d'un quartier de Paris au 18e siècle. Ce projet a ensuite été adapté par l'équipe de la SAT afin de prototyper une vidéo immersive dans l'objectif de populariser la connaissance historique. C'est suite à ce projet qu'une collaboration avec la SAT a été envisagée afin d'étudier l'impact d'une immersion collective sur l'apprentissage en utilisant leur vidéo comme stimuli.

Questions de recherche

L'utilisation des technologies immersives dans l'éducation étant de plus en plus répandue, de nombreuses expériences ont été menées afin de comprendre toutes les conséquences et impacts sur l'apprentissage. Cependant la littérature est souvent limitée en ce qui concerne l'étude d'une immersion collective et l'étude de l'expérience d'apprentissage.

L'étude se penche sur ces lacunes et vise à répondre à la question de recherche suivante : dans quelle mesure l'immersion collective impacte l'expérience d'apprentissage et l'apprentissage. Suivant la théorie de Fredricks cette question, impliquant des concepts complexes, a été décortiquée en 4 sous-questions permettant une meilleure compréhension de la visée de cette étude.

1. Dans quelle mesure l'immersion collective impacte l'engagement comportemental ?
2. Dans quelle mesure l'immersion collective impacte l'engagement émotionnel ?
3. Dans quelle mesure l'immersion collective impacte l'engagement cognitif ?

4. Dans quelle mesure l'immersion collective impacte la performance?

Afin de répondre à ces questions, les participants sont répartis en quatre conditions expérimentales. Chacune permettant respectivement une haute immersion collective, une basse immersion collective, une haute immersion individuelle et une basse immersion individuelle. Dans cette expérience les technologies utilisées sont un dôme immersif de 18 mètres de diamètres permettant une utilisation collective, un autre dôme de 3 mètres de diamètre pour une utilisation individuelle et enfin un écran plat permettant un visionnage collectif ou individuel. Dans chaque condition le ou les participants visionnent une vidéo d'une visite virtuelle de Paris au 18e siècle d'une durée de 8 minutes. Des données physiologiques, de questionnaires et d'entrevues sont ensuite collectées afin de mesurer l'impact sur l'engagement et la performance.

Contributions potentielles de l'étude

L'objectif de ce mémoire est de mettre en évidence l'impact d'une immersion collective sur l'expérience d'apprentissage et l'apprentissage. Plus précisément l'impact de l'immersion collective sur l'engagement comportemental, émotionnel et cognitif ainsi que sur la performance. En clarifiant cette relation, ce mémoire pourra contribuer à la littérature en comblant un manque d'étude sur l'immersion collective en contexte éducatif. Une contribution pratique serait ensuite de servir d'appui à certains organismes tels que la SAT afin de lancer des initiatives éducatives telles que des projections pour les étudiants ou des formations professionnelles en partenariat avec des universités ou des entreprises. Aussi les résultats présentés dans l'article permettront de contribuer à l'encouragement de l'intégration des technologies immersives dans les cursus éducatifs.

Structure du mémoire

Ce mémoire s'appliquera tout d'abord à étudier la littérature en rapport aux technologies immersives et les théories afférentes, puis à l'apprentissage et l'utilisation collective. Par la suite l'article couvrira l'expérience qui a été effectué en partenariat avec la Société des Arts Technologiques (SAT) afin d'étudier l'impact de l'immersion collective sur l'apprentissage et l'expérience d'apprentissage.

Contributions

Étape	Contributions
Formulation de la question de recherche	Identifier la question de recherche choisie - 60% - L'équipe de la SAT et les co-directeurs ont fortement contribué à la formulation de la question de recherche
Conception de l'expérience	Développement du design expérimental - 70% - Les co-directeurs ont contribué au développement du design expérimental - L'équipe de recherche du Tech3Lab a contribué à la sélection des outils de mesures Conception des plans de test - 100% Soumission Mitacs - 85% - Brendan Scully, de l'équipe de recherche du Tech3Lab a contribué à la relecture Soumission au comité d'éthique - 90% - L'équipe de recherche du Tech3Lab a contribué à la relecture
Revue de littérature	Étude de la littérature afin d'identifier les études effectuées sur le sujet - 90% - Les co-directeurs ont contribué à l'identification d'article pertinents Identification des construits et mesures à utiliser dans l'expérience - 80% - Les co-directeurs ont contribué à l'identification des construits à utiliser

	Écriture de la revue de littérature - 90% - Les co-directeurs ont fourni des commentaires et suggestions
Développement du stimulus	Conception du support visuel 0% - L'équipe de la SAT a entièrement assumé la conception du support visuel Enregistrement du support sonore - 50% - Elisa de Boisseuil-Baron, étudiante en histoire à l'UQAM a contribué à l'enregistrement du texte Conception du texte pour la narration - 20 % - Elisa de Boisseuil-Baron, étudiante en histoire à l'UQAM a contribué à la rédaction du texte Intégration du visuel, de l'audio et de la narration - 20% - L'équipe de la SAT a géré la majeure partie de l'intégration
Gestion des participants	Gestion du recrutement (annonce, contact, organisation de l'agenda) -100% Gestion des compensations - 50% - Emmanuel Durand et Nicolas Bouillot et le reste de l'équipe de la SAT ont contribué à la gestion des compensations
Collecte de données	Développement des questionnaires- 100% Conception des guides d'entrevues - 90 %

	- L’équipe de recherche du Tech3Lab a contribué aux tests et à la relecture des guides d’entrevue Test et réparation de l’équipement de collecte - 80% - François Courtemanche de l’équipe de recherche du Tech3Lab a entièrement pris en charge la réparation de l’équipement de collecte Gestion de la collecte pendant l’expérience - 100%
Extraction des données	Extraction et nettoyage des données physiologiques - 100% Retranscription des données d’entrevues dans le logiciel Optimal Workshop - 100% Extraction et nettoyage des données de questionnaires - 100%
Analyse des données	Formatage des données pour préparer à l’analyse - 20 % - Amine Abdessemed et Francois Courtemanche de l’équipe de recherche du Tech3Lab a géré la majorité du formatage des données Analyse statistique - 80% - Analyse statistique a été assistée par Shang Lin, de l’équipe de recherche du Tech3Lab
Rédaction de l’article	Écriture de l’article - 100% - Les co-directeurs ont fourni des commentaires et suggestions tout au long de l’écriture

Rédaction du mémoire	Écriture de l'article - 100% - Les co-directeurs ont fourni des commentaires et suggestions tout au long de l'écriture

Revue de la littérature

In the last years, immersive technologies have evolved into different forms, from Cave Automatic Virtual Environment (CAVE), to Virtual reality (VR) glasses or other head mounted display (HMD), and 360° projected environments. More often than not, these technologies were expensive, hard to come by and not entirely reliable (with lack of complete synchronization between the user's movement and the virtual movements). However recently, the commercialization of the Oculus Rift offered an accessible, portable and reliable version of a VR technology which enabled its use in many domains such as education and training (Frein, 2015). Within the last few years immersive technologies have experienced an increase in popularity and an increasing impact on society and business, however still little research has been done to explore and understand its impact (Suha, 2018). This literature review will cover the definition of an immersive technology and their different forms and applications as well as the definition of the terms associated. We will then review the existing theoretical foundation and experiments associated with the concepts of immersion, learning and collective use.

Immersive technologies

Immersive technology is a vast term that regroups all technologies that show the user a virtual environment while either shutting down physical reality or integrating it to the virtual environment. It is defined in literature as a technology that blurs the line between physical, virtual and simulated environments (Freina, 2015).

Immersive technologies can be situated on a reality-virtuality continuum. On this continuum are situated the Augmented Reality (AR), the Virtual Reality (VR) and the Augmented Virtuality (AV). When AR shows virtual elements in the physical environment, AV shows physical elements in a virtual world. They are often referred together as Mixed Reality (MR). VR is a representation of a complete virtual world (Suh, 2018).

Immersive technologies have evolved into various forms. The most popular are head mounted displays, such as the oculus rift that offers a VR experience, or the google glasses that offer an AR experience. Another well-known technology is the CAVE system, which is a room where all the walls, floors and ceilings are flat displays, such as used by the TeamLab or the Artechouse.

360° projected environments - such as the one used in our study - are a fairly unique type of immersive technology that has not been subject to many experiments. Hence this literature review will focus on experiments involving VR and AR as they create a virtual environment close to a 360° projection. The main difference separating a 360° projected environment - as used in this study - from AR and VR is the social aspect of the technology.

Usually AR, AV and VR can be used by one individual at a time, making these technologies isolating as each individual is seeing a unique sight by wearing a helmet or glasses. However, the 360° projected environment is accessible to groups, showing them the same display without the use of isolating devices.

The motivation for the use of immersive technologies are multiple. Literature identify a few such as inaccessibility (e.g. exploring freely the galaxy, imaginary worlds or previous/future time periods), ethic-related and/or dangerous situations (e.g. performing a plane landing for a novice pilot, when hundreds of lives are at stake, decision making simulation for firefighters' training in situation) (Freina, 2015). Other motivations are found in the positive outcome that can be triggered from the use of these technologies. These outcomes can be a learning effectiveness, learning engagement, learning attitude, task performance or reduced disease symptoms in psychotherapy (Suh and al., 2018; Welch et. Al, 1996).

The limitations of the use of immersive technologies are found in their costs, accessibility and the negative responses they may trigger such as motion sickness, physical discomfort, cognitive overload or distracted attention (Suh and al., 2018). With the developments of these technologies, users experienced new feelings that had to be described. A new range

of terms were adapted to enable the expression of these feelings such as the sense of presence, the immersion and the flow.

Immersion, presence and flow

The term presence has many definitions in literature and is often used synonymously or confused with the terms immersion and flow (Brown and Cairns, 2004 ; Cummings and al., 2012) but it is defined by Wirth & colleagues (2017) as ‘‘a binary experience, during which perceived self-location and, in most cases, perceived action possibilities are connected to a mediated spatial environment, and mental capacities are bound by the mediated environment instead of reality’’.

Some of the most common definitions are those of Cummings and al. (2012), Slater and Wilbur (1997) and Suh (2018). Cummings and al (2012) refers to the term presence as the psychological feeling of being somewhere else than the real environment while as Slater and Wilbur (1997) define it, the term immersion refers to the technological aspect of the system and the capacity it has to make one have a sense of presence by offering a vivid virtual environment while shutting out the physical environment. Suh (2018) also defines flow as a state of focus, control and interest that is accompanied by a loss of self-consciousness in the human-machine interaction.

Some authors such as Suh (2018) go further in the definition of the terms and identify different dimensions in these concepts. They differentiate four types of sense of presence: the physical sense of presence, that 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. They also define immersion using two dimensions: the mental immersion and the physical immersion. The mental immersion is a “state of mind**”** in which a player feels absorbed and engaged within the virtual environment. The physical immersion is relative to the capacity of a user to interpret the virtual environment (visual, auditory and haptic cues) to navigate and control virtual objects.

However, these terms and their dimensions are often redefined depending on the context in which they are being used. In VR presence is considered by Brown and Cairns (2004) as the concept of "the extent to which a cognitive and perceptual system is tricked into believing they are somewhere other than their physical location". Yet, in video games Brown and Cairns (2004) considers the terms of immersion and relates it to the realism of the game world, or the atmospheric sounds, immersion is also said to have depth. However, it is not always clear what immersion is and what causes it. There can be games with high realism and atmospheric sounds that don't achieve immersion. In a similar manner, Ermi and Mäyrä (2005) define immersion in video games using three different dimensions. The sensory dimension that relates to the audiovisual aspect of games. This dimension can be altered by elements such as the size of the screen, the speaker system or the graphics quality. The challenge-based dimension of immersion refers to the gameplay experience of the player challenging his motor and mental abilities against the game. The imaginative dimension of immersion is linked to the way a player identifies with the character or is absorbed by the narrative which Ermi and Mäyrä (2005) consider as a synonym of feelings of empathy. The dimension seems to be the most relevant in role-playing games.

Murray J. (2017), however, considers that the medium is not relevant to the capacity of feeling in immersion. A stirring and compelling narrative can be registered by our brain as virtual reality and reach an intensity as to obliterate the world around us. Murray considers the experience of "being transported to an elaborately simulated place" as immersion and links it to the initial meaning of immersion: to be submerged in water. As we seek the same sensation of being surrounded by a simulated environment, another reality the same way we are surrounded by water when submerged.

Considering these numerous definitions of either presence, flow and immersion and their extremely intertwined and contextual use, we will consider the most important aspects of these definitions and describe it as such. One's sense of immersion or presence or flow reflects the feeling of being transported in a simulated environment. Immersion/ presence/flow is a fluid scale, one can be more or less immersed or have a stronger, weaker sense of presence/flow.

Measuring immersion has been a recurrent topic in this literature. Over the last few years authors have used the same tools to measure immersion. They are most often self-reported measures, but some technological tools now allow an objective measure of immersion. Self-reported measurements often refer to questionnaires, self-reports of interviews (Jennett (2008), Slater (2009); Bian (2017)), whereas objective measurements often refers to physiological measures such as electrocardiogram activity (ECG) and electrodermal activity (EDA) (Slater (2009), Martey (2014)) or heart related physiological measurements such as heart rate, heartbeat interval, heart rate variability (HRV), low-frequency HRV, high frequency HRV and respiratory rate (Bian (2017)) and other observation measurements such as task completion, eye fixations etc. (Jennett (2008).)

These new technologies make the user experience strong feelings and enable the user to access a large variety of environments, making it a tool of great potential in training and education. The rise of the concepts of presence, flow and immersion created an increase in the studies of the impact of such concepts on learning. As of today, many theories have emerged to explain this phenomenon, however we will use the theory of the impact of presence as the supporting theoretical framework for our experiment as it applies the best to our context.

Theory of the impact of presence

The literature references a few theories and speculations on the impact of presence as defined by Wirth & colleagues (2007). Welch & al. (1996) considers that the impact of the sense of presence is behavioral as it has the bigger impact on task performance. Ke and al. (2016) and Von der Pütten and al. (2012) define the impact of presence as a stimulation to motivation, learning engagement and learning achievements as presence allows natural and dynamic interaction with the learning material (Suh, 2018).

The following studies rely on this theory to measure the impact of immersion on learning and learning experience. In Tang (2020) study, a design class was assisted with a Mixed

reality environment. Pretests and posttests were conducted to measure the impact of the use of this technology. Results showed that students' ability in geometric analysis and creativity increased in a Mixed Reality Environment assisted lecture compared to a traditional lecture.

Building on the theory of the impact of presence, Stavroulia (2017) study used a VR role-based scenario to try and help teachers understand and experience student's positions, disabilities and problems as well as identify bullying related activities. Preliminary results showed that the use of VR technology in the teacher's training had a high potential in helping them perform better and achieve a better understanding of students' problems.

As e-learning is becoming an increasingly important tool for education studies such as FRANCESCHI, Katherine (2009) try to measure the impact of adding immersion and interaction through the use of shared virtual space. Results show that the virtual environment increased the sense of presence of the students and enhanced their engagement in their group learning interactions.

In an online class in university (Carver, 2018), students used mixed reality technology and through a simulated middle school classroom environment and avatars to interact. Results were positive as students and teachers were able to conduct successful focus groups and witness an increase in engagement during these meetings.

In these studies, the learning and learning experience are not clearly defined and while some studies only focus on the learning outcome, some focus on some kind of engagement. There are many ways the existing literature studies learning and learning experience. Performance is the most commonly used to assess learning in literature as well as in society, from performance reviews at work to test scores and gpa in schools and university. To further our study of the learning and learning experience we will also rely on Fredricks' theory of engagement.

Theory of engagement

Fredricks and al. (2004) details the theory of engagement in learning and identifies three types of engagement, the behavioral, cognitive and emotional engagement. Behavioral engagement is defined as the positive conduct, involvement and participation noticed when learning. Cognitive engagement refers to a more academic engagement such as involvement in learning or strategic thinking in learning. Emotional engagement relates to the affective reactions. These engagements can be measured with many specific scales and the outcomes of a positive and strong general engagement manifests itself in the achievements of the student.

Many studies rely on this theoretical foundation to study learning and learning experience and they use various tools to measure the engagement. Key findings suggest that an increased engagement promotes better learning performance and learning experience, such as discovered by Blasco-Arcas, Lorena (2013) in their study in a university science class. Chi, Michelene TH (2014)'s study supports the same conclusion but goes further as to study what can impact the engagement and their finding suggests that more interactive and active classes encourage students to become more engaged which in turn leads to an increased learning. Other authors such as *Hamari (2016)*, suggest that in a learning game-based environment the challenge of the game has a positive effect on learning both directly and via the increased engagement, while *Blumenfeld (2006)*'s study considers motivation a setting stone to cognitive engagement. According to them, motivation is reflected by situational interest, which is influenced by novelty, variety, incongruity of grabbing attention challenges and experiences; value which is defined as long term interest; competence; autonomy and relatedness. According to this study, if one impacts motivation, one impacts cognitive engagement.

Engagement in education has been studied for a long time and literature has used many constructs to investigate it. While some studies focus on motivation as a prime indicator of engagement (*Blumenfeld, 2006),* some measure engagement through elevated concentration, interest and enjoyment (Hamari, 2016), and some article have the sole

objective to list and reference the most commonly used ways of measuring engagement (HENRIE, Curtis R. and al, 2015). As for the tools used to properly measure these constructs, scales and other self-report instruments are commonly used in literature to measure the engagement of the participants. Articles such as Bindman's (2018), Goldspink (2013) validate and put into practice the use of such tools. Henrie (2015) assesses the strength and limitations of qualitative and quantitative self-reported measures but also includes the use of physiological data. Others refer to physiological data as a way to measure the engagement such as Charland and Leger (2015).

Immersion and learning

Taking a global approach on the literature on the impact of immersion on learning experience, we realize that existing studies consider mostly individual contexts and the use VR. Outcomes are varied but most support a positive impact of immersive technologies on either performance or cognitive, emotional or behavioral engagement.

Many of these studies focus on the impact on performance. In Webster's study (2016) the researchers investigated the impact of VR in the training of the US army and compared it to a more traditional lecture-based training. The results showed that even though both forms of training were effective, VR-based learning produced significantly higher scores on the exam. Following a similar model, Spoehr (1994) study compared two history classes, one had access to the academic content, while the other had a hypermedia corpus they could interact with. Results showed the class with the hypermedia corpus performed better on the test and essay but also demonstrated deeper understanding of the concepts. Alhalabi's (2016) experiment tested the use of three types of immersive technology and one non-immersive technology in engineering education. Astronomy, Transportation, Networking and Investors were the tested topics in this study. Results revealed that students performed significantly better in quizzes when any type of immersive technology was used.

Most studies focus as such on the performance and test results, but fewer study the impact on cognitive, emotional or behavioral engagement. Bindman (2018), study focused on the emotional impact of immersive technology in film viewing. It was reported that participants in the 3D VR headset condition were more inclined to think of themselves as a character of the film rather than an observer. The study reports that participants who thought themselves as a character reported significantly more empathy, hence VR condition seems to be fostering empathy on a higher level than the less immersive option that is the viewing on a smartphone (2D).Studying the cognitive engagement and performance, Spoehr (1994)'s study tested an interactive and immersive hypermedia corpus on students. Results showed that those who had access to the hypermedia corpus performed better, wrote better essays and demonstrated a richer understanding of the concepts. More recently, and focusing on the behavioral aspect of engagement, Parong and Mayer (2018)'s study compared the effectiveness of teaching scientific content through immersive technology or a well-made desktop slideshow. It was exposed that students who viewed the slideshow performed better but mentioned feeling less motivation, interest and engagement than students who experimented with the immersive version of the content.

In summary, literature fosters few articles that study the impact on emotional, cognitive and behavioral engagement as well as performance, as most focus solely on performance. The results are overall positive but some studies dispute the positive impact of immersive technologies on performance and engagement and conclude on a non-existent impact such as Moreno and Mayer (2002) or even on a negative impact due to distraction or to a cognitive overload such as Makransky an al (2017), Richards and Taylor (2015) or Schrader, Claudia (2012).

In addition, these studies, and most of the literature on immersive learning, only consider an individual use of the immersive technology. The sole notion of collective immersion is little present in literature as very few technologies allow such a use. Yet, in other technological domains, the collective use of a technology has been an increasing subject of interest. For example, as information systems have evolved from individual use, to

enterprise use, to distributed use, the need for a deeper understanding of such a collective use has risen (Negoita, 2018).

The collective use of an immersive technology is a key concept that needs to be addressed. The investigation of a collective use would encourage the implementation of immersive technologies in education or training as an established use in education would more often than not require a collective use. The current education and training systems are organized by classes and groups of students, which is why a collectively used immersive technology would be a better match than individually used ones, that is, if results show a positive impact of the collective use of immersive technologies on learning.

Social learning theory

As literature is little developed on the subject, no precise theoretical foundation has been identified, which is why we will rely on Bandura's Social Learning Theory as it suggests that people learn from one another. By observing, imitating and modeling, people are able to monopolize their attention, memory and motivation to learn. This learning is dependent upon the quality and quantity of interaction people have with one another. Also, according to Dunleavy (2014), the use of immersive technologies is aligned with Bandura's social learning theory as it places the user in a simulated physical and social environment encouraging active observations, peer coaching and authentic inquiry.

The few studies that rely on Bandura's theory to investigate the collective use of a technology in education. In 2008, KE F. study tested a computer game-based learning on 5th grade students. A math related tournament took place with different categories in play in which students were randomly assigned. The categories were collaborative tournament, interpersonal competitive tournament, individualistic tournament and a control group. A standardized math exam and an inventory on attitude towards math was used as a pretest and post test to measure student's improvements. Results showed that the pre-set goal (collaborative, competitive or individual) did not impact the overall performance, however the collaborative goal was the most effective in promoting a positive math

attitude. Later and in a higher education level, Breland (2009) study found that in an architectural university class, collaborative virtual environment yields better results than individual virtual environment. Students that participated in the collective virtual environment were more productive, made less errors, reported a decrease in stress and an increase in positive thinking.

Conclusion

This literature review had two purposes. The first one was to help us reach an understanding of the relationship between immersive technologies and learning. To accomplish that, we defined what immersive technologies refer to and what the concept of immersion is. This enabled us to identify the theoretical foundation to support the impact of immersion on learning (Suh, 2018). We then furthered our understanding of the concept of learning following Fredricks (2004) theory of engagement. We then reached the second purpose of this literature review that was to show the evidence of a lack of literature on the collective use of immersive technologies and its impact on learning outcomes and engagement as defined earlier.

Experiments that study the impact of individual immersive technologies such as VR HMD on either learning outcome or engagement are very numerous (FRANCESCHI, Katherine (2009), Carver, 2018, Spoehr (1994), Bindman (2018), Parong and Mayer (2018)). However, to our knowledge there are no studies that consider a collective immersion and that study the three types of engagement - as defined by Fredricks, 2004 - as well as learning outcomes.

This is explained by the fact that the majority of experiments only focus on the learning outcomes as performance is the universal way of measuring progress in education and training. The experiments that study the impact of immersion on engagement usually focus on one type of engagement at a time, either cognitive (Spoehr, 1994), behavioral (Parong and Mayer (2018), Vishwanath and al (2017)) or emotional (Bindman (2018), Visch and al. (2010)) engagement. The lack of literature on collective immersion is

justified by the fact that most immersive technologies only allow for an individual use. Collective immersive technologies are more expensive and need a particular infrastructure, which makes them less accessible to study.

Based on past studies on the impact of immersion of either performance or engagement we have found that most literature supports some kind of positive impact on either performance, engagement or sometimes both. There is no particular trend as to what is most impacted, as each study has very specific settings that justify such a variety of findings. Depending on the material presented, the technology used, the demographics and what is studied, some find a very positive impact on performance, while some find no strong impact on performance but an impact on engagement. Finally, some articles dispute these findings and expose a negative impact of immersion on learning outcomes and cognitive engagement, explained by phenomenons of cognitive overload and distraction (Moreno and Mayer (2002), Makransky an al (2017), Richards and Taylor (2015)).

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The impact of collective immersion on learning and learning experience

Abstract

As technologies have an increasing role in education, questions arise concerning the impact of these technologies on student's performance and engagement. The objective of this paper is to explore the impact of immersion and collectivity on learner's engagement and performance. Building on Bandura's social learning theory and the theory on the sense of presence, we hypothesize that collective immersion has a positive impact on performance as well as cognitive, emotional and behavioral engagement. 93 participants distributed in 4 conditions took part in the experiment. The four conditions manipulated the collective and individual aspect of the environment as well as the high and low immersion aspect of the environment. The two conditions that offered a high immersion setting used two types of dome, one for a collective use and the other for an individual use. These domes are part of the Société des Arts Technologiques (SAT)'s infrastructure. All participants were presented to the same stimuli, an 8 minutes long video of a virtual visit of a neighborhood in Paris in the 18th century. The participants were measured during the task and after the task answered a questionnaire were interviewed. The learning outcome as well as the cognitive, emotional and behavioral engagement were measured. Final results showed no impact on learning outcomes but a positive impact on cognitive engagement and mixed impacts on behavioral and emotional engagement.

Introduction

In the last years immersive technologies such as augmented reality and virtual reality have become more affordable and accessible on a large scale *(Yuen, 2011*). With the commercialization of the oculus rift (a virtual reality headset), immersion is now starting to be accessible in many domains such as education and training (*Freina, 2015*). The scientific community has, since then, become very eager to understand in depth the impact of the use of immersive technologies on the education and training of students and professionals. As the most accessible technology at hand - the oculus

rift - only allows for an individual use, the vast majority of the existing literature relies on studies made in an individual context. Most of these studies also focus on studying the impact on learning outcomes while engagement has been understudied.

The lack of literature on collective immersion and its impact on engagement and learning outcome combined with the partnership with the Société des Arts Technologiques (SAT) was the perfect opportunity to study this subject. The SAT had been beforehand involved with the Bretez project (Pardoen, 2018) to study the popularization of historical knowledge through an immersive video (Puget, 2019). For this project a prototype of a 3D mockup of a Parisian neighborhood in the 18th century was adapted to be fit to be projected in an immersive dome. The sounds were also manipulated to simulate the acoustic environment. With the support of the team from the SAT, this prototype was used in our study as our stimuli and the immersive domes from the SAT's infrastructure was made available to us to conduct the experiments.

To investigate the impact of collective immersion on learning outcome and engagement we randomly distributed the 93 participants in 4 conditions. The first condition used an immersive dome of 18m diameters to allow a collective and immersive viewing of the stimuli. The second condition employed a regular flat screen to provide a collective and lowly- immersive viewing of the material. The third condition took place in a smaller immersive dome of 3 meters diameter made for individual viewing of the stimuli. Finally, the last condition utilized a regular flat screen to show the stimuli in an individual context. In all conditions we measured the behavioral, emotional and cognitive engagement as well as the learning outcome.

Literature review

Immersive technologies and immersion

Immersive technology is a vast term that regroups all technologies that show the user a virtual environment while either shutting down physical reality or integrating it to the virtual environment. It is defined in literature as a technology that blurs the line between physical, virtual and simulated environments (Freina, 2015). All immersive technologies can be situated on a reality-virtuality

continuum. On this continuum are situated the Augmented Reality (AR), the Virtual Reality (VR) and the Augmented Virtuality (AV). When AR shows virtual elements in the physical environment, AV shows physical elements in a virtual world. They are often referred together as Mixed Reality (MR). VR is a representation of a complete virtual world (Suh, 2018). The purpose of the use of immersive technologies are multiple. Literature identify a few such as inaccessibility (e.g. exploring freely the galaxy, imaginary worlds or previous/future time periods), ethic-related and/or dangerous situations (e.g. performing a plane landing for a novice pilot, when hundreds of lives are at stake, decision making simulation for firefighters' training in situation) (Freina, 2015). 360° projected environments - such as the one used in our study - are a fairly unique type of immersive technology that has not been subject to many experiments as they require a particular infrastructure and equipment. Hence this literature review will focus mostly on experiments involving VR as they create a virtual environment close to a 360° projection.

The terms presence and immersion are often used together in literature and their definition often overlap. *Browns and Cairns (2004)* defines the term presence in VR as the point to which the mind is tricked into believing that the simulated environment is real. They also define the term immersion as, in video games, the realism of sounds, graphics and overall environment. According to this literature, immersion is also said to have depth (meaning it is not binary).
Suh (2018) goes further and differentiates four types of sense of presence : the physical sense of presence, that 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 (2018)* also defines immersion using two dimensions: the mental immersion and the physical immersion. The mental immersion is a "state of mind" in which a player feels absorbed and engaged within the virtual environment. The physical immersion is relative to the capacity of a user to interpret the virtual environment (visual, auditory and haptic cues) to navigate and control virtual objects. *Slater and Wilbur (1997)* defines the term immersion as the technological aspect of the system and the capacity it has to make one have a sense of presence by offering a vivid virtual environment while shutting out the physical environment.

As supported by *Cummings and al (2012) and Browns and Cairns (2004)* we can conclude that the terms immersion and presence rarely have a clear definition and are often confused with each

other. Hence, we will consider only the term immersion and sense of presence for this research and they will be considered as synonyms. Both terms will be used throughout the experiment as some participants who are less experienced with technology seem to connect and understand the term presence more than the term immersion. Their definition will be as follows: one's sense of immersion/presence reflects the feeling of being transported in a simulated environment. Immersion/presence is a fluid scale as one can be more or less immersed.

Immersive technologies and learning

Most of the studies on the impact of immersion on learning and learning experience are in an individual context as they the most accessible immersive technology on the market which is a VR headset (the oculus rift). Outcomes are varied but most support a positive impact of immersive technologies on either learning outcome or learning experience.

Many of these studies focus on the impact on performance. In Webster's study (2016) the researchers investigated the impact of VR in the training of the US army and compared it to a more traditional lecture-based training. The results showed that even though both forms of training were effective, VR-based learning produced significantly higher scores on the exam. Following a similar model, Spoehr (1994) study compared two history classes, one had access to the academic content, while the other had a hypermedia corpus they could interact with. Results showed the class with the hypermedia corpus performed better on the test and essay but also demonstrated deeper understanding of the concepts. Alhalabi's (2016) experiment tested the use of three types of immersive technology and one non-immersive technology in engineering education. Astronomy, Transportation, Networking and Investors were the tested topics in this study. Results revealed that students performed significantly better in quizzes when any type of immersive technology was used.

As most studies focus on the performance and test results, fewer study the impact on the learning experience. Bindman (2018)'s study focused on the emotional impact of immersive technology in film viewing. It was reported that participants in the 3D VR headset condition reported feeling a stronger sense of presence and were more inclined to think of themselves as a character of the film

rather than an observer. The study reports that participants who thought themselves as a character reported significantly more empathy, hence VR condition seems to be fostering empathy on a higher level than the less immersive option that is the viewing on a smartphone (2D). Parong and Mayer (2018) studied the impact of immersion on interest, motivation and performance. The study compared the effectiveness of teaching scientific content through immersive technology or a well-made desktop slideshow. It was exposed that students who viewed the slideshow performed better but mentioned feeling less motivation, interest and engagement than students who experimented with the immersive version of the content.

The results are overall positive but some studies dispute the positive impact of immersive technologies on performance and engagement and conclude on a non-existent impact such as Moreno and Mayer (2002) or even on a negative impact due to distraction or to a cognitive overload such as Makransky an al (2017), Richards and Taylor (2015) or SCHRADER, Claudia (2012).

The literature shows split opinions, but most studies use VR technologies that only allow individual environments and most often only measure the impact on the performance. Thus, we aim to study the impact of a different technology that allows for a collective setting and the impact of this technology on learning as well as learning experience.

Hypothesis development

In the literature on immersive learning, the concept of learning has often been reduced to the performance and learning outcome, however our desire is to study the learning outcome as well as the learning experience. Fredricks and al. (2004) details the theory of engagement in learning and identifies three types of engagement; the behavioral, cognitive and emotional engagement. Behavioral engagement is defined as the positive conduct, involvement and participation noticed when learning. Cognitive engagement refers to a more academic engagement such as involvement in learning or strategic thinking in learning. Emotional engagement relates to the affective reactions. These dimensions of engagement can be measured with many specific scales and the outcomes of a positive and strong general engagement manifests itself in the achievements of the

student. Hence, we define the participant learning experience we study as the association of cognitive, emotional and behavioral engagement.

Fredrick's theory of engagement suggests the existence of a mediation effect of engagement on performance. However, the existing literature on the impact of immersive technology on engagement and performance rarely relies on a model with a mediation. Most often immersive technologies directly impact engagement and performance, which is why our model will not rely on a mediation effect.

Many theories can be used to understand the relationships between collective immersion and learning and learning experience. First to understand the impact of immersion on learning, the theory on the impact of presence, such as defined by multiple authors such as Welch & al. (1996) and Ke and al. (2016). Welch & al. (1996) considers that the sense of presence has the bigger impact on task performance. Ke and al. (2016) define the impact of presence as a stimulation to motivation, learning engagement and learning achievements as presence allows natural and dynamic interaction with the learning material (Suh, 2018). Building on existing literature and the theory of presence we can hypothesize that participants in a highly immersive environment will perform better and be more engaged than participants that are in low immersion.

To understand the impact of collective use, as very few studies consider a collective environment, Bandura's social learning theory will be the foundation of the hypothesis that a collective immersion favors a better learning outcome and higher engagement from the participants. Bandura's (1977) Social Learning Theory, suggests that people learn from one another. By observing, imitating and modeling people are able to monopolize their attention, memory and motivation to learn. This learning is dependent upon the quality and quantity of interaction people have with one another. Following this theory, we aim to study if a collective environment will yield better engagement and performance results than an individual environment in both high immersion and low immersion.

Hence from Fredricks engagement theory, the theory on the impact of presence and bandura's social learning theory as well as the present literature we predict that:

H1: Collective immersion has a positive impact on behavioral, emotional and cognitive engagement as well as performance.

H1a: Collective immersion has a positive impact on behavioral engagement.

H1b: Collective immersion has a positive impact on emotional engagement

H1c: Collective immersion has a positive impact on cognitive engagement

H1d: Collective immersion has a positive impact on performance

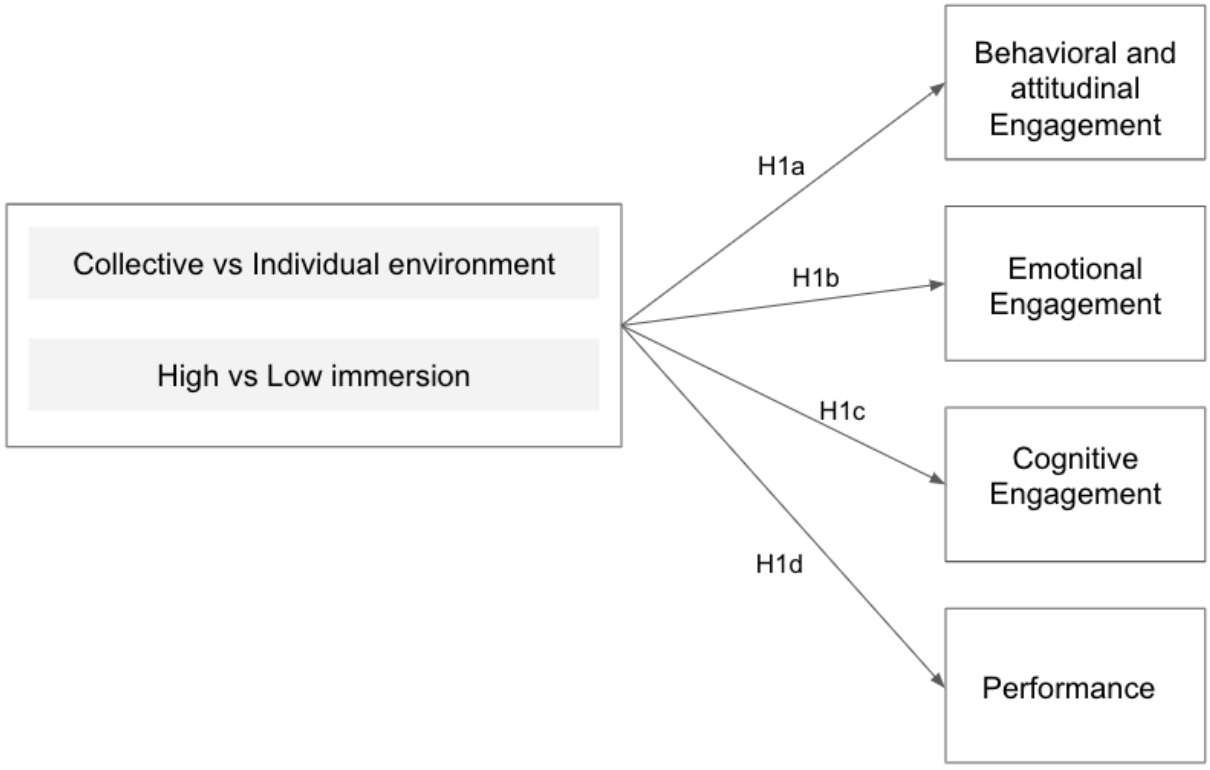

Fig.1 Model and hypotheses

Methodology

Experimental design

The study manipulated the collective use and the immersion by studying four conditions. Two of the conditions were individual (n=30, 15 per condition) and two were collective (n=60, 5 group of 12 participants). A highly immersive (experimental) and a lowly immersive (control) environment were tested in both individual and collective settings. The experimental design is inter-subject.

The first condition tested the collective use of a highly immersive setting. Three groups of 12 participants were assigned to this condition. In each group, 3 participants were randomly picked to be measured with physiological equipment, however out of the projected 9 total participants measured, 2 had corrupted data, leading to 7 physiologically measured participants in condition 1. After each experiment, the three measured participants plus another randomly chosen participant took part in an interview conducted by the researchers. Each researcher was assigned two participants and conducted collective semi-guided interviews. A total of 12 participants were interviewed in the first condition. The second condition focused on the collective use of a lowly immersive setting. In this case only two groups of 12 participants took part in the experiment, and one abandoned. In the same manner, 3 participants per group were randomly picked to be measured with physiological equipment, leading to a total of 6 participants measured with physiological equipment. Following the same selection methods as for condition 1, each group had 4 participants taking part in interviews.

Condition 3 tested to individual use of a highly immersive technology. 18 participants were measured and interviewed. Out of all these participants, 2 experienced equipment malfunction resulting in a total of physiologically measured participants of 16. Condition 4 tested the individual use of a low immersion setting. 16 participants were measured and interviewed, however 2 experienced equipment malfunction, leading to 14 participants being physiologically measured.

HEC Montreal's ethic committee authorized the use of this experimental design for our experiment.

Condition	**EXPERIMENTAL (High immersion)**	**CONTROL (Low immersion)**	Phenomenon studied
Collective use	**Condition 1** 3 groups of 12 participants	**Condition 2** 2 groups of 12 participants	Impact of immersion in a collective environment
Individual use	**Condition 3** 18 participants measured and interviewed	**Condition 4** 16 participants measured and interviewed	Impact of immersion in an individual environment
Phenomenon studied	Impact of the collective use in high immersion	Impact of the collective use in a low immersion	

Table 1 – Overview of the experimental design

Experimental stimulus

The media used for this study takes its roots in the Bretez project (Puget, 2019) aiming to recreate the visual and sound environment of a Parisian neighborhood in the 18th century. The 3D model of the Grand-Chatelet neighborhood and the sounds recreated by Mylène Pardoen were adapted by the Metalab team from the SAT to fit their 360° immersive dome's technology format. The Metalab created a platform that could support visual, sound and 3D model assets. The new platform created enabled the Metalab team to adjust the localization of the sounds in the 3D model and create a virtual scene of the neighborhood. In collaboration with the UQAM department of history, a narrative was written with the help of a history student and reviewed by Mylène Pardoen, the conceptor of the Bretez Project. This narration was then recorded and included in the scene. The final stimulus is an 8 minutes video of a virtual visit of Paris in the 18th century with a narration and ambient sounds, that has been adapted to fit both high immersive and low immersive technologies. Two versions of the final scene were recorded. The first one was a recording of a first-person point of view 360° video walking around the recreated neighborhood for the condition 1 and 3 to be projected in an immersive dome. The second recording was a regular first-person point of view video for the condition 2 and 4 to be shown on a flat screen. The SAT gave us access

to a 360° immersive dome of 18 meters diameter and a height of 13 meters, filled with 157 speakers for the collective high immersion; and a 360° immersive dome of 3 meters diameters for the individual high immersion condition (3). The collective control condition (2) used a wall projector to enable the viewing of the material and the individual control condition (4) used a regular flat screen.

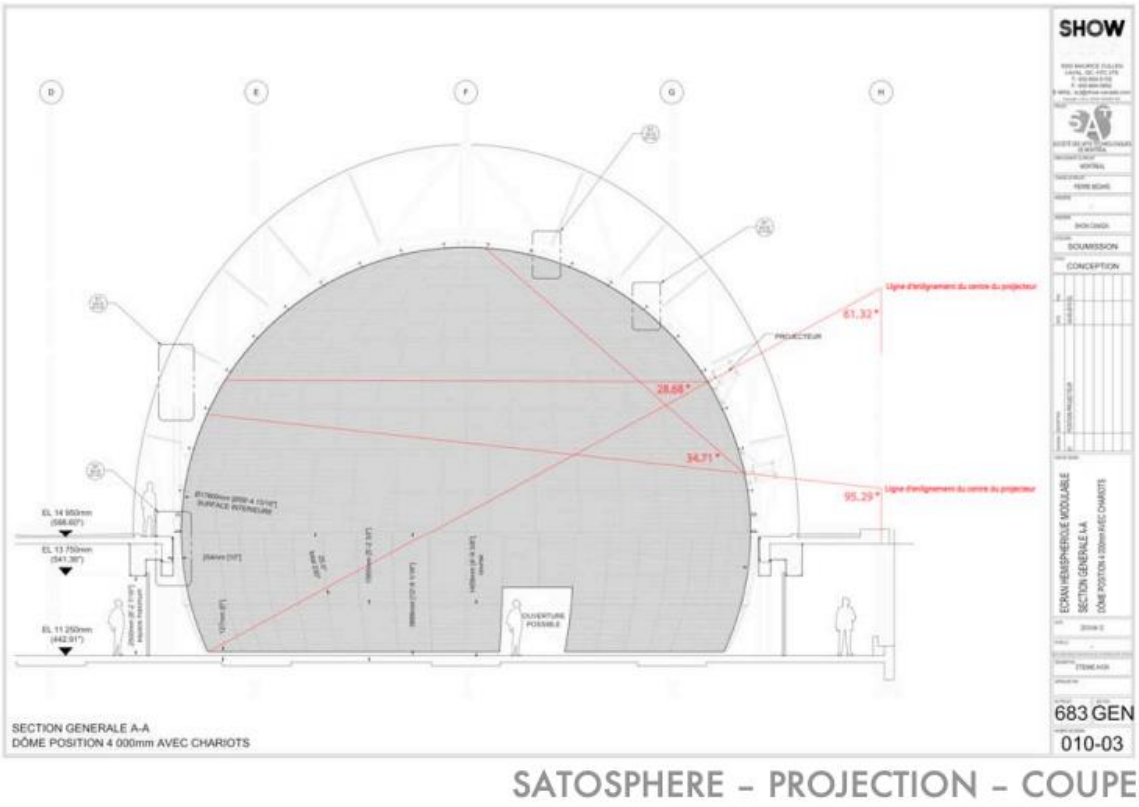

Figure 1 - Plan of the dome used for the collective immersion

Figure 2 - The immersive projection in the collective setting with 12 participants

Figure 3 - The immersive projection in the individual setting with 1 participant

Figure 4 - The projection in the individual and low-immersion setting with 12 participants

Demographics

A total of 93 participants were recruited for this experiment using SAT's website, university mailing list and Facebook. 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, 1 as other and 1 would rather not say. All participants were aged between 18-64 years old, for both women and men the average age was between 18 and 24 years old. 4 participants were high school graduates, 20 were College graduates, 46 participants had a bachelor's degree, 22 participants had a master's degree and 1 was a Ph.D. graduate. Out of all the participants, 28 had no experience with immersive technologies, 50 had little (once or twice) experience with immersive technologies, 12 had some (from time to time) experience with immersive technologies, 3 had experience (often) with immersive technologies and no participant had a lot of experience (very frequently) with immersive technologies

Procedure

For the recruitment, participants answered a short online survey to register for the experiment, enabling a screening process. They were randomly assigned to a condition depending on their availability. Upon the arrival of the participant, one of the researchers explained the procedure. Participants were to sign an agreement form prior to beginning the study.

In the collective experimental condition, participants were to stand at the center of the dome and watch the immersive projection (Figure 2). For the individual experimental condition, participants were to sit on a revolving office chair at the center of the dome (Figure 3), so that they could easily turn around and see the immersive projection while staying at the recommended height to avoid any sound echo and anomalies. In both individual and collective control conditions, participants were to sit in a chair and watch the media on a regular television (Figure 4).

For the individual conditions all participants were measured with physiologic equipment: EDA, ECG and a camera to film where the participant is looking during the experiment.

For the collective conditions, 3 participants per group of 12 were randomly selected in advance. These 3 participants were measured with physiologic equipment and camera during the experiment. Following the experiment, all participants answered a questionnaire divided in 6 sections; a Likert scale, Short development, SAM scale, Test on the sound content, Test on the narrative content, Test on the visual content. After answering the questionnaire – all participants for the individual conditions and the 3 selected participants plus one randomly selected participant for the collective conditions – participated in a semi-conducted interview with one of the

researchers, during which open questions were asked to the participants. In the collective conditions, as only 2 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 the interviews were conducted one on one. Before exiting, all participants signed the compensation form.

Operationalization of research variables

The three dimensions of engagement and the performance are operationalized through independent variables and constructs and measured with tools that are the following.

Independent variables	Constructs	Tools	Source
Behavioral Engagement	Interest to renew xp	Interview	
	Perceived use	Likert scale (6 items) Interview	DEEP Parong & Mayer 2018 PU scale Davis 1989
	Attitude toward technology	Likert scale (3 items)	Mayer SUS
Emotional Engagement	Objective learning xp (valence arousal)	EDA ECG	Charland, Leger 2015 Riva, 2003 Tsianos, 2010
	Perceived learning xp (valence, arousal)	SAM scale Interview	Peacok, 1990
Cognitive Engagement	Perceived learning experience (cognitive load)	Likert scale (6 items) Interview	DEEP SUS Parong & Mayer 2018

Learning outcome	Learning	Questionnaire (30 items)	
	Perceived learning	Likert scale (3 items) Interview	DEEP Parong & Mayer 2018

Table 2. Independent variables and their corresponding constructs, measuring tools and their sources

Cognitive engagement data were collected through the perceived learning experience represented by the perceived cognitive load measured in the interview and through 6 Likert items gathered from the DEEP questionnaire (Yang 2012), SUS questionnaire (Brooke 1986) as well as Parong & Mayer (2018) study. The items were adjusted to fit the immersive technology studied. To measure the reliability of these items the Cronbach's Alpha was computed for this construct and was lower than the recommended 0,7. Three out of the six items were disregarded as to raise the Cronbach's Alpha coefficient up to 0,708.

Behavioral engagement data were collected through three different constructs. First, the interest of the participant in re-experiencing a similar environment measured in the interview. Second, the perceived use of the experience measured through Likert and in the interview. The Likert items were gathered from the DEEP questionnaire, Parong & Mayer 2018 study and the PU scale (Davis 1989). The Cronbach's Alpha for this construct was 0,78 allowing us to keep all six items. And last, the attitude toward the used technology measured through Likert with 2 items borrowed and adapted from Parong and Mayer (2018) study and the SUS questionnaire (Brooke 1986). The Cronbach's Alpha for this construct was of 0,669 which was lower than the recommended 0,7, however since this construct's scale was only composed of two items, we decided not to remove any.

Emotional engagement data were collected through two constructs. Lang (1993) defines emotion on an arousal/valence coordinate space, with the dimension of valence going from pleasant to unpleasant, and the dimension of arousal going from excited to calm. The first construct is the objective learning experience represented by the valence and arousal measured by physiological (EDA and ECG) data with a portable equipment to enable participants to move freely. This device

was a BITalino (figure 5) (r)evolution Freestyle Kit (PLUX Wireless biosignals S.A.) (Diana Batista and al. 2019). Three sensors were positioned on the torso of the participant to measure the ECG and two other sensors were positioned on the palm of the non-dominant hand to measure the EDA.

To synchronize the projected video with the EDA and ECG data, a Bluetooth Low Energy (BLE) sent signals to a lightbox and to all the BITalino devices in range. The camera was able to capture the signal numbers displayed by the lightbox and the same numbers were saved into the EDA and ECG data file, following the synchronization technique developed by Courtemanche et al.

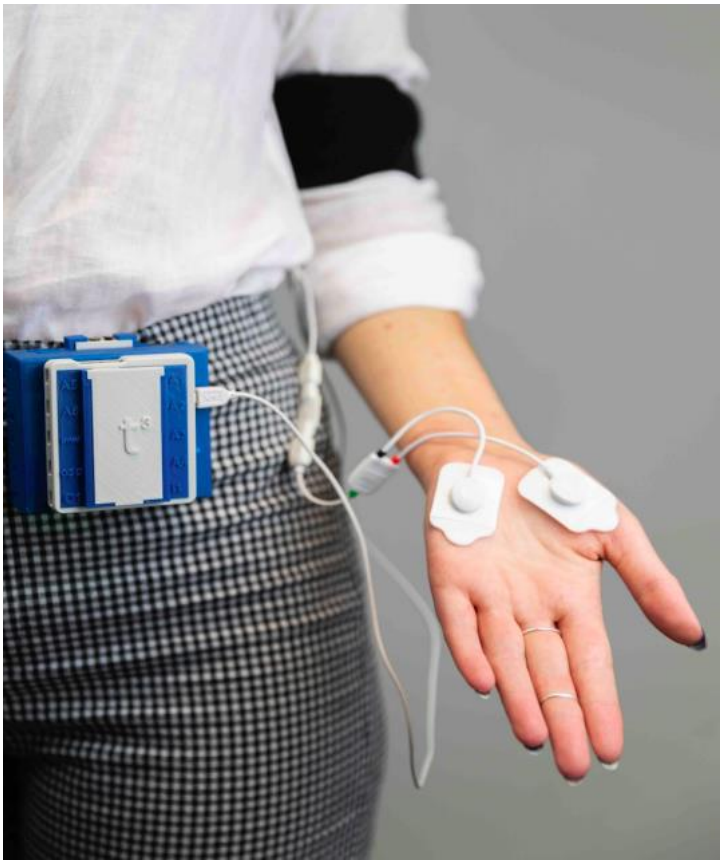

Figure 5 - EDA sensors and the BITalino box

The second construct is the subjective learning is represented by the perceived valence, arousal and control and measured by SAM scale.

Performance data were collected through the learning measured with a test composed of three sections. A section of 5 questions referring to the visual aspect of the projection, a section of 11 questions referring to the narrative aspect and a last section of 14 questions referring to the sounds

of the projection. This questionnaire was created following Charland and al. (2016) method and asking the reviews of the history student who was in charge of creating the narrative for the projection. The performance data is also collected through the perceived learning measured with a Likert scale composed of 3 items which were sourced and adapted from the DEEP questionnaire and Mayer study (2018). The Cronbach's alpha was 0,73.

A for the dependent variables, immersion was operationalized to make a manipulation check. The sense of presence was measured by Likert scale and in the interview. The Likert scale was composed of four items borrowed from Brewin (2014) study and had a computed Cronbach's Alpha of 0,748 after removal of one item. Collectivity is naturally operationalized through the number of participants in the condition (alone or a group of 12)

Data Analysis

All collected quantitative data was made anonymous and compiled in one excel file. The data was analyzed 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 (3vs 4) and of the impact of collective immersion on learning experience in a highly immersive environment (1vs3) as well as in low immersion (2vs4).

Physiological data (EDA and ECG) was recorded throughout the experiment with a BITalino. A baseline was recorded at the beginning of the experiment. During this baseline the participant was expected to sit and relax so that the sensors could record his average EDA and ECG. This baseline mean would then be subtracted to each value of the recorded EDA and ECG from the experiment revealing peaks in physiological data (JJ Braithwaite and al. 2015). These peaks represented the emotional arousal variation felt by the participant during the experiment.
This data was then analyzed using linear regression with a random intercept mode and a normal distribution. The data was also tested for mediation; however, none was found.

As for the qualitative data, the two researchers randomly and equally distributed the interviews amongst themselves and then transcribed the information collected in a software called Optimal Workshop. Each entry was labeled with tags to help the analysis and filter the information according to need. The tag system was organized by the two researchers and the first entries were cross checked by each researcher, so the entries were tagged in a similar manner. Each participant's interview had around 12 entries, each corresponding to a question, or a point made by the interviewee.

Results

H1a: Collective immersion has a positive impact on behavioral engagement.

	1 vs 2		3 vs 4		1 vs 3		2 vs 4	
	estimate	p-value	estimate	p-value	estimate	p-value	estimate	p-value
Perceived use (6 items)	.533	**.038**	-.314	.345	.225	.410	-.669	**.034**
Attitude toward technology (2 items)	-1.648	**.0034**	-1.505	**.038**	-.335	.531	.044	.941

Table 3 - Results on the impact of immersion and collectivity on behavioral engagement (Likert scale)

Results suggest a positive impact of immersion on attitude toward technology as well as a positive impact of collectivity on perceived use. In a collective environment it would seem that a low immersive environment (condition 2) favors a higher perceived use than a highly immersive environment (condition 1). However, the information gathered in the interview points otherwise with 10 interviewees out of 12 in condition 1 mentioning that the format and content seemed useful as is and in condition 2, 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 that in a low immersive environment a collective setting (condition 2) favors a higher perceived use than an individual setting (condition 4). This is supported by the information gathered in the interviews. In condition 2, out of 8 interviewees, 5 found it useful and with some potential of being even more useful; whereas in condition 4, 8 out of 16 interviewees found it useful and 2 mentioned

the future potential if applied to a more immersive technology (VR was a given example). In a collective as well as in an individual environment a highly immersive environment (condition 1 and condition 3) favors a more positive attitude toward technology than a low immersive environment (condition 2 and condition 4).

	Condition 1	Condition 2	Condition 3	Condition 4
Yes	8 out of 12	2 out of 8	16 out of 18	12 out of 16
Yes, if the quality evolves	4 out of 12	2 out of 8	2 out of 18	1 out of 16
No	/	2 out of 8	/	3 out of 16
Unsure	1 out of 12	2 out of 8	/	/

Table 4 - Interview results about wanting to renew the experiment

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 vs 2/8 firm yes and 2/8 firm no in condition 2) but a seemingly negative impact of collectivity in a highly immersive context (8/12 firm yes in condition 1 vs 16/18 firm yes in condition 3). It seems that high immersion favors a high interest to renew the experience in both collective and individual settings. None of the highly immersive conditions 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.

This hypothesis is partly supported, as immersion seems to have a positive impact on the interest to renew the experiment and on the attitude towards 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, immersion has a negative impact on the perceived use. It is important to mention that these results are in contradiction with the findings from the interviews. Lastly, in low immersion, collectivity has a positive impact on the perceived use.

H1b : Collective immersion has a positive impact on emotional engagement

		1 vs 2		3 vs 4		1 vs 3		2 vs 4	
		estimate	p-value	estimate	p-value	estimate	p-value	estimate	p-value
Perceived learning experience	Valence	-1.225	**.029**	-1.582	.0462*	-.358	.526	-.113	.858
	Arousal	-1.543	**.007**	-.208	.763	-.355	.513	.654	.314
	Dominance	.195	.714	.804	.284	.161	.771	.43	.534
Objective learning experience	ECG (BPM)	11.69	**.011**	-1.240	.733	-1.065	.773	11.87	**.0074**
	EDA (phasic)	0.6732	.1713	-.039	.925	-.449	.31	0.26	.5798

Table 5 - Results on the impact of immersion and collectivity on emotional engagement (SAM scale and physiological data adjusted to baseline)

**this p-value becomes non-significant in the regression model without the control variable, a collinearity is suspected, thus not taken into account*

Results found a partial positive impact of immersion on perceived emotions. In a collective setting, a highly immersive environment (condition 1) favors stronger and more positive emotions than in a low immersive setting (condition 2). The information gathered from qualitative interviews supports this discovery, as in a highly immersive environment 6 interviewees out of 12 mentioned feeling awed and impressed when none mentioned it in condition 2. In both conditions the participants reported feeling calm and neutral, however in condition 1 these feelings were considered positive as it was in a calming sense (4 out of 12 interviewees), when in condition 2 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 2), but in the individual setting low immersion favors high arousal (condition 2 vs 4). The ECG recorded a higher bpm (adjusted to baseline) for the highly immersive condition than for the control condition in a collective setting. It seems that, in collectivity, high immersion induces a higher emotional arousal. However, in a lowly immersive setting, the ECG recorded a higher bpm (adjusted to

baseline) for the individual condition than for the collective condition. It seems that solitude induces a higher emotional arousal in low immersion setting.

Results enable us to partially support this hypothesis as perceived emotions are both more intense and more positive in a highly immersive environment. However, this result applies only in a collective setting. Measured emotional arousal is higher in a highly immersive environment in a collective setting. In addition, in low immersion, a collective environment favors a higher emotional arousal.

H1c : Collective immersion has a positive impact on cognitive engagement

	1 vs 2		3 vs 4		1 vs 3		2 vs 4	
	estimate	p-value	estimate	p-value	estimate	p-value	estimate	p-value
Cognitive load (Likert 3 items)	-.648	**.028**	-.071	.86	-.680	**.048**	.095	.763

Table 6 - Results on the impact of immersion and collectivity on cognitive engagement

Results suggest a positive effect of immersion and collectivity on cognitive load. It seems that in a collective setting a highly immersive environment (condition 1) favors a lower perceived cognitive load than a lowly immersive environment (condition 2). In the highly immersive condition, the interview revealed that 7 participants out of 12 reported having no problem focusing. However, in the lowly immersive condition, 4 interviewees out of 8 found it very hard to focus and were at some point completely distracted. In condition 2, 6 interviewees found the environment to be a distracting factor (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) favors a lower perceived cognitive load than in an individual environment (condition 3). In the collective environment 7 out of 12 interviewees found it easy to focus, when in condition 3 only one participant mentioned this ease and 4 out of 18 were distracted by the environment. 12 interviewees in condition 3 mentioned that the low quality of the visuals and overlap of narration and sounds made it hard for them to focus properly.

Our results enable us to support our hypothesis as a collective immersion favors a lower cognitive load. In a highly immersive environment, collective use favors a lower cognitive load and in a collective environment, a high immersion favors a lower cognitive load.

H1d: Collective immersion has a positive impact on performance

	1 vs 2		3 vs 4		1 vs 3		2 vs 4	
	estimate	p-value	estimate	p-value	estimate	p-value	estimate	p-value
Learning (Total test)	-.015	.662	-.03	.3596	.015	.5915	.012	.721
Perceived learning (Likert 3 items)	.148	.6243	.124	.7461	.108	.7391	.032	.9282

Table 7 - Results on the impact of immersion and collectivity on learning outcomes

The last hypothesis suggested a positive impact of collective immersion on the learning outcome. The results 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 participant's commentary in the interviews were mitigated. In a high immersion setting participants mentioned learning only about some details, about the environment and the 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 an unexploited potential.

H1: Collective immersion has a positive impact on behavioral, emotional and cognitive engagement as well as on the learning outcome

To summarize, our principal hypothesis has been partially verified. Concerning the impact on behavioral engagement results are mitigated but tend towards a positive impact of immersion. However, the positive impact of a collective immersion is not supported. In an individual environment, immersion has a positive impact on the attitude toward technology. In a collective environment immersion has a negative impact on the perceived use, even though interviews with participants points otherwise. In both and individual and collective setting, immersion has a

positive impact on the interest to renew the experience. In a highly immersive environment, collectivity has a negative impact on the interest to renew the experience and in a lowly immersive environment collectivity has a positive impact on the perceived use. Results have shown that in a collective environment, immersion has a positive impact on emotional and cognitive engagement. In a highly immersive environment, collectivity has a positive impact on cognitive engagement. Results revealed no significant impact of immersion or collectivity on performance, either positive nor negative.

Discussion

This study contributes to the literature by offering a new environment of experiment enabling us to study the impact of collectivity as well as immersion. It also studies the impact of such variables on both performance and engagement. Our results have partially verified the hypothesis that collective immersion has a positive impact on engagement and performance.

On the effect on behavioral engagement, literature shows a tendency to a positive impact (Markowitz, 2018; Parong and Mayer, 2018) that is justified by an increase in interest from the participants. In accordance, our results show a general positive impact of immersion on behavioral engagement, although the hypothesis of a positive impact of collective immersion has not been supported. In this case literature on collective immersion is so underdeveloped that it shows no trends or possible justification for this result (Merchant and colleagues, 2014).

In a similar manner, the positive impact of collective immersion on emotional engagement has not been supported but a positive impact of immersion on emotional engagement has been revealed. This finding is largely supported by literature (Visch and colleagues, 2010; Bindman and al., 2018) and often justified by the fact that immersion leads to 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. A few studies however consider the cognitive engagement as defined by Fredricks and al (2004) and findings are in accordance with our own results (Spoehr, 1994) and

show 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 is, in this context, a positive result, as it shows collective immersion doesn't impair the performance of the student as some articles have suggested (Tost and Economou, 2009; Makransky and al., 2017; Richards and Taylor's, 2015). These articles often explain a negative impact by the phenomenon of cognitive overload and other distractors in the virtual environment. This phenomenon is explained by Chang and al.' (2014) distracted attention theory. It is a possibility however that this same phenomenon may be the explanation why the participants are not performing better when in a collective immersion.

However, because this research is exploratory a few possible biases have been identified. The dome used in the individual condition and in the collective conditions were not of the same size. This could have impacted our results. However, it would seem unrealistic to have an 18 meter diameter dome be used for an individual experience. Participants have also suggested a few modifications that could improve the quality of the experiment and reduce the biases. Many participants in all conditions have mentioned the quality of the visuals that were below their expectation. Considering their experience in video games, VR, animated movies or special effects as seen in movies, they were very distracted by the quality of the media that reminded them of an unfinished model. They suggested adding more colors and textures to the visuals. Some also mentioned the lack of "life" and activity in the streets visited in the media which made it look like a "ghost town". The narration was mentioning events and people that were not present in the visuals. Some participants also suggested a less monotonous voice for the narration. These elements were repeatedly reported to be part of the reasons why participants could not feel completely immersed in the media.

Conclusion

In the future this experiment would benefit from studying more efficiently the learning outcome. In this experiment participants were of different ages, education level and overall knowledge about the history of Paris and France. The media was made to be accessible to a large range of

participants, hence the information delivered was basic enough as to be understood by all participants and so maybe too simple for some. It would be more interesting to study the impact on the performance of a group that has the same level of knowledge about the subject. Using a longer media with a larger quantity 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. In parallel with this experiment another study was made to investigate the impact of interaction in immersion (Salame, 2020).

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Conclusion

Rappel du contexte

L'objectif de ce mémoire est d'étudier l'immersion collective et son impact sur l'apprentissage et l'expérience d'apprentissage. En premier lieu, la revue de littérature identifie le manque d'études sur l'apprentissage en contexte d'immersion collective. La seconde moitié de ce mémoire détaille la méthodologie et les résultats liés à l'étude effectuée en collaboration avec la Société des Arts Technologiques (SAT) et ce auprès de 93 participants.

Cette expérience inter-sujet a pris place pendant l'été 2019 à la SAT ainsi que dans les bâtiments du HEC à Montréal. Grâce à des entrevues, questionnaires et outils physiologiques nous avons pu tester nos hypothèses et répondre à notre question de recherche.

Rappel de la question de recherche et principaux résultats

Q1 : Quel est l'impact d'une haute immersion collective sur l'engagement comportemental, émotionnel et cognitif ainsi que sur l'apprentissage ?
Cette question de recherche combinée à une étude de la littérature associée nous a permis de développer ces quatre (4) hypothèses :

H1a : Une haute immersion collective a un impact positif sur l'engagement comportemental

H1b : Une haute immersion collective a un impact positif sur l'engagement émotionnel

H1c : Une haute immersion collective a un impact positif sur l'engagement cognitif

H1d : Une haute immersion collective a un impact positif sur l'apprentissage

Les résultats nous permettent de partiellement valider ces hypothèses. Nous avons pu confirmer que l'immersion a un impact positif sur l'engagement comportemental et émotionnel, cependant les résultats n'ont pas permis de confirmer l'impact positif de l'aspect collectif de cette immersion. Effectivement, dans le contexte de l'engagement émotionnel, aucun résultat significatif n'a été identifié, tandis que dans le cas de l'engagement comportemental les résultats mitigés ne nous ont pas permis de tirer une conclusion définitive. L'hypothèse sur l'engagement cognitif a été

entièrement supportée par nos résultats. Par ailleurs, les analyses n'ont donné aucun résultat significatif pour l'impact de l'immersion collective sur l'apprentissage.

Contributions (théoriques et pour l'industrie)

Il existe très peu d'études sur l'immersion collective et son impact sur l'apprentissage et l'expérience d'apprentissage. Ce mémoire permet de donner plus d'information sur cette relation ainsi que de lier la littérature sur l'apprentissage en contexte immersif et ainsi que celle sur l'apprentissage collectif. De plus, la littérature existante traite souvent de l'apprentissage sans considérer suffisamment l'expérience l'apprentissage. Notre étude se penche à la fois sur la performance d'apprentissage que sur l'engagement du participant. L'article propose donc une méthodologie qui allie des données rapportées par le participant (entrevues, questionnaires) à des données mesurées à l'aide d'outils physiologiques et ce pour étudier l'apprentissage autant que l'expérience d'apprentissage. Cette méthodologie est donc aussi accessible à l'industrie afin de permettre à certaines entreprises ou organismes de mener leurs propres expériences afin d'étudier le phénomène dans divers contextes éducatifs.

Dans un second temps, cette étude a permis de contribuer à l'industrie en fournissant les résultats nécessaires à certaines organisations telles que la SAT afin de développer des initiatives à visées éducatives. Ces résultats supportent l'utilisation de l'immersion collective dans les domaines de l'éducation. L'intégration d'une technologie immersive dans les universités ou dans les formations professionnelles permettrait aux étudiants de mieux comprendre le sujet afin d'éveiller l'intérêt et l'engagement des personnes visées et ce sans réduire la qualité de l'apprentissage. Puisqu'une telle technologie requiert une infrastructure de taille et de coût non négligeables, des organismes comme la SAT seraient donc en mesure de proposer leur infrastructure pour accueillir des initiatives éducatives en partenariat avec les entreprises, universités ou encore centres de formations.

Limitations et recherches futures

Les résultats proposés dans ce mémoire doivent être remis dans le contexte de leurs limitations. L'échantillon de la population utilisé pour la participation a été sélectionné sur une base volontaire.

Les niveaux de connaissances sur le sujet de Paris au 18e et le degré de familiarité avec les technologies immersives était varié. Il serait bénéfique de reproduire l'expérience avec un échantillon plus contrôlé. De plus, de nombreux participants ont mentionné avoir été perturbés par la qualité du média qui était en dessous de leurs attentes. Cette attente ayant été déçue, il est possible que cela ait impacté négativement les résultats. L'utilisation d'un média plus poussé graphiquement permettrait d'évaluer plus justement l'expérience du participant. Une autre limitation est en relation avec l'infrastructure utilisée. Bien que les deux dômes utilisés soient très semblables, l'échelle de grandeur est très différente étant donné que l'un fait 18m de diamètre tandis que l'autre n'en fait que 3m et cela est à prendre en compte dans les résultats.

Les études futures pourraient optimiser la méthodologie utilisée en intégrant plus de construits pour mesurer l'engagement comportemental, émotionnel et cognitif ainsi que l'apprentissage. Il est important de noter que le sujet étudié relevait de connaissances anecdotiques sur le quotidien dans la ville de Paris au 18e siècle et se reposait beaucoup sur l'aspect sensoriel de l'expérience puisque l'emphase était sur les bruits ambiants de la ville à l'époque. Cette étude gagnerait dans le futur à étudier un sujet plus en profondeur et d'une durée plus longue afin de donner au participant la chance d'en apprendre plus. Aussi cette étude gagnerait à se pencher sur la rétention sur le long terme des notions abordées pendant la projection ainsi que sur des domaines divers et variés d'apprentissage.

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