Why 360° and VR headsets for movies? Exploratory study of Social VR via Hyve-3D

Tomás Dorta
Hybridlab, School of Design
University of Montreal
H3T 2B1, Montreal, Canada
tomas.dorta@umontreal.ca

Davide Pierini
Hybridlab, School of Design
University of Montreal
H3T 2B1, Montreal, Canada
davide.pierini@umontreal.ca

Sana Boudhraâ
Hybridlab, School of Design
University of Montreal
H3T 2B1, Montreal, Canada
sana.boudhraa@umontreal.ca

RÉSUMÉ
Le but principal de la Réalité Virtuelle (RV) dans le domaine du cinéma est d'immerger le spectateur dans la scène. Les derniers visiocasques de RV essayent d'atteindre cet objectif en utilisant des vidéos à 360°. Cependant, la narration et l'expérience sociale du cinéma peuvent être affectées car les spectateurs qui utilisent des visiocasques doivent regarder tout autour continuellement pour explorer la scène. De plus, les visiocasques limitent les utilisateurs à une expérience individuelle, dans laquelle la plupart de communications non verbales (expressions faciales, gestes et postures) sont obstruées. Cela perturbe potentiellement la présence sociale et l'expérience partagée de regarder des films. Cet article explore pour la première fois ces problèmes potentiels en comparant un système de RV social (Hyve-3D) avec un visiocasque de papier carton durant le visionnement de films avec ou sans narration. Les résultats suggèrent que le système de RV social est plus adapté pour l'expérience cinéma de type RV.

Mots Clés
Cinéma RV ; RV sociale ; Narration ; Expérience du cinéma.

ABSTRACT
The main goal of Virtual Reality (VR) in cinema is to immerse the spectator inside the scene. Recent VR headsets are trying to attain this goal using 360° videos. However, the storytelling and the cinema experience can be hindered because spectators using VR headsets have to continuously look around in order to explore the scene. Moreover, VR headsets restrict users to an individual experience, in which a big part of the non-verbal communication (i.e. facial expressions, gestures, and postures) is precluded. This potentially disrupts the shared and social experience of watching movies. This paper explores for the first time these potential issues by comparing a social VR system (Hyve-3D) with a cardboard VR headset during the vision of short movies including or not a storyline. Results suggest that the social VR system is more adapted for VR cinema experience.

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INTRODUCTION

Human kind is used to listen to stories. Since primitive times, people get together after hunting or picking activities, and share stories around a meal. Restaurants and cinemas are social spaces and when people are alone in those places they feel uncomfortable because those behaviours and habits are usually social and the experience is shared. Nowadays stories are still told around the table or transferred by media like novel books and movies, and they are considered leisure activities.

Watching movies and playing video games are two different leisure actions, compared to work where the users are confronted to achieve specific tasks with different degrees of interaction and effort. In the case of movies, users watch them to enjoy and relax. Focusing principally on the narrative, spectators take a passive role compared to active interaction roles of video games. Even if stories are presented in video games, like in the famous graphic adventure puzzle video game Myst - 1993 (Cyan Inc.), the storyline is cut with moments of interaction where users have to interact with the game, resolving enigmas or activating triggers in the 360° surrounded environment. In movies people enjoy the story, getting deeply in it. In videos games people are active and engaged in the interaction they have to achieve to pass to the next level or chapter of the story/game.

Standard cinemas experiences make the user watch the movie from the outside of the scene, which is observed through a frame (the shape and the ratio of the display). This setup does not lead to an immersive experience since the audience feels being in the movie theatre or in the living room instead of feeling to be in the scene and the story among characters. The "flat screen" is a window into another reality where the stereoscopic vision provides a display in relief. Nowadays, movie theatres are

designed as tunnels where some decorations are present on the sidewalls. Making the field of view or the screen bigger (like IMAX) to make users feel they are inside the action is not the solution: it is not the size of the screen that matters, but the effect of the display on the user to make them feel immersed, like anamorphic images or the *trompe-l'oeil* effect.

During the last years we witnessed the renaissance of VR thanks to the advent of a new generation Head Mounted Retina Displays (HMrD) or VR headsets using high resolution screens (Oculus Rift™). Even if VR headsets are not designed for cinema, nowadays there is an important trend of using HD small cameras (GoPro™) and stitching software (Kolor Eyes™), that allows 360° videos, and some companies (i.e. Jaunt) start to propose VR cinema content for VR headsets. This new content goes even forward of simple 360° videos, since the storytelling is challenged and the way those films are shot is different. The composition of the scene, the staging as well as the technical and direction support during filming have to be revised for the 360°. Moreover, the appearance and performance of characters need also to be adapted to that. All this because spectators using VR headsets have become able to look at any direction of the scene, since from their individual point of view, they can watch where they desire. But what are the intentions of the directors of these movies? How they can be sure the important facts and details of the story are well perceived? Moreover, users are cut from their bodies, including gestures and facial expressions compromising non-verbal communications during collective viewing. Since the sound of some VR headsets is individual, verbal communication could be further an issue.

The aim of this study is to explore the efficacy of the interaction and the user experience while watching short movies using two different VR systems: a VR headset (HMrD), individual in its nature, and a social VR system Hybrid Virtual Environment 3D (Hyve-3D), allowing a shared immersive visualization. We are not focused on comparing different kinds of VR displays and not even on comparing them to traditional cinema screens; it is rather to explore the impact of the VR headsets 1) on the social dimension of watching a movie with someone else and 2) on the vision of a movie with a storyline. In order to do this, we conducted a comparative study between cardboard VR headsets and Hyve-3D. Hyve-3D is a social VR system implemented for co-design (Figure 1) [8]. The immersive visualisation of this system consists in a spherical concave screen that is not 360° and produces immersion using anamorphic images without glasses. Results suggest that the freedom to explore the 360° environment disrupt the reception of the narrative and affect the social dimension of the cinema's experience.

RELATED WORK

The history of 360° projections goes back hundreds of years, from the use of *trompe-l'oeil* effect on the dome-paintings of baroque churches to the panoramas in 19th century World Fairs where the creation relied mostly on manual and sometimes photographic methods [13]. The anamorphic technique produces distorted projections that look normal when viewed from a particular position, projected on a spherical surface, or viewed through a curved mirror or lens. Spherical recording and projection of video content has also been explored recently [7], in which case the necessary anamorphic deformations were achieved either by employing optical methods or digital post-production of video content [3, 5]. Using cylindrical and spherical distorted panoramic images, the user can visualize the scene from the inside and feel being present in it. Spherical panoramas can be reproduced from multiple angle images [4, 9].

The project xTV (explorative television) [16] generated a series of explorative applications for television (i.e. sport events, documentary, fictional) in 360°. During brainstorming sessions with directors, event organizers and experts in immersive experiences, it emerged that contents in 360° could be intuitively explored without forcing users to participate. However, this project focused more on the production and the diffusion of this new kind of videos rather than studying the user's reception of these contents. In addition, they used traditional computer or TV screens and no innovation was explored about the visualization system.

McGinity et al. [12] proposed the AVIE, a cylindrical display theatre for immersive, interactive, and multi-user experience (up to 20 people). The AVIE combines a real-time 360° omnistereo projection with a surround audio and a marker-less motion tracking system. The screen is a 10 meters' diameter cylinder, standing 3.6 meters high. Even though it could be an interesting installation for cultural, educational or artistic institutions (i.e. museum), it seems hardly applicable in the context of cinema and home video especially because of the huge dimensions and because people have to stay standing.

Through a human-centred design approach Bleumers et al. [2] conducted a study aiming at understanding which characteristics make a TV-program suitable for the 360° video recording. In this study participants watched a fragment of a 360° video, then researchers collected data about user experience. In addition, by using the "laddering" technique they prompted users to envision possible opportunities for future usage of the new technology. Users pointed out both problems and opportunities of 360° videos: this type of visualization was thought to be suitable for videos that trigger the desire of exploration such as documentaries, touristic videos, programs featuring houses or interiors; moreover, 360° visualization was perceived as an opportunity when the spectator wants to experience the scene in the first-person perspective (i.e. watching a sport action from the perspective of our favourite player) or during social programs in order to perceive non-verbal communication cues (i.e. frowning, specific postures, gestures, etc.). On the other hand, the main issues concerned the information load (i.e. too many things to look at in the scene), the disruption of the social dimension of watching TV (i.e. watching movies alone instead of together), and the risk of missing parts of the narrative sequence in programs having an elaborate narrative (i.e. looking elsewhere when something crucial happens).

Other authors also acknowledge this last issue and propose to solve this question with an interface able to separate spatial and temporal navigation. Using head movement, users can explore the environment and with hand gestures they can control the temporal navigation [14]. Yet, "freezing" time in order to explore the ambient while watching a movie is likely to disturb the continuity of the narration and therefore, the whole experience.

SOCIAL VR

We argued that people prefer to watch movies together because they want (whether consciously or not) to share the experience generated by the story told, as mentioned in other studies [10, 15].

At the most fundamental level, the social interaction is based on the actual perception of some sort of information "emitted" by other people. At the level of verbal communication, we could, for example, listen to their words; as for non-verbal communication we need on one hand to visually perceive some features of the other people's body, such as postures, quality of movements, facial expressions; on the other hand, the auditory channel allows us to detect the non-verbal communication features of the voice.

We think that the use of the VR headsets in the context of cinema is an inappropriate use of an existing technology because, by disconnecting the visual and auditory systems from the environment, they disrupt the perceptual processes at the base of the interpersonal communication. Therefore, natural social interactions during the watching of a movie will be at least difficult when all people wear a VR headset.

From this stand the Hyve-3D preserves the natural perceptual channels upon which communication is based, providing an "interaction framework" spontaneously enabling verbal and non-verbal communication among spectators. We named such VR systems as Social VR.

VR HEADSETS ISSUES

In this section we summarize the VR headsets issues according to the above mentioned related work. VR headsets introduce two main changes: first, the users are confronted to a new display closer to their eyes individualizing the experience of watching movies; second, the 360° movies paradigm changes the way people watch movies and how moviemakers conceive and shoot movies. We think these two changes are too many variations for spectators and cinema industry. In regard to the related works presented above, we formulated two main working hypothesis concerning the impact of VR headsets:

1. VR headsets are not the best media for the social experience of VR cinema, because of the following considerations:

People prefer to experience stories together, pointing facts into the movie and express their opinions verbally and through facial expressions. When users are disconnected from reality they cannot see and hear each other, they cannot see their gestures and interact with their near context (their seats, meals, drinks, etc.).

2. 360° is irrelevant for VR movies considering the following:

The focus of the action related to the main characters can be watched from one specific angle of view. If users are looking around in 360° the chances they miss details or even main events the director wants to communicate increases. In addition, since VR headsets prevent users from seeing each other and therefore their hands pointing something in the screen, this risk is further increased. This issue has also to be considered during the design of the storytelling because shooting in 360° requires an action in several parts of the scene, and this could confuse users.

Shooting the scene in 360° is also an issue for actors and technical staff. In fact, the direction and the technical staff, including sound, and all supporting personnel, has to be hidden from the 360° scene. In addition, actors are far from the direction and this eventually could affect their performance. Finally, the scene has to be designed considering a total surround view, requiring more resources, including more synchronized figurants, becoming consequently more expensive.

From an ergonomics stand, the 360° view has potential issues. In order to locate where the main action is going on, users have to explore the whole scene by turning around their heads and even their bodies. In the context of cinema or home video, the fact that people are seated on a chair or on a sofa, constraints these movements, and therefore the exploration of the scene.

Current dome theatres and planetariums provide a collective and immersive experience to the users. However, the spectators have to look to the ceiling (like looking to the stars) but this is not the natural position we look at the world (frontal viewing) like in movies. Yet, finding the main action in 360° remains an issue. For more casual visual and acoustic explorations (e.g. watching a panorama) these systems could be suitable but in the context of following the storytelling of a movie we think they could be inadequate.

VR SYSTEMS USED IN THE STUDY

Hyve-3D: is an innovative VR system that allows creating objects and environments collaboratively (local or remote) by 3D sketches and a natural interaction using tablets. Via a unique spherical-concave screen and an original projection (not 360°) based on *anamorphic images*, the system enables participants' immersion in life-sized representations without the need of VR headsets. The system was designed for collaboration between different co-localized users, or between several remotely interconnected systems. Hyve-3D is designed for creative fields like architecture, design, engineering, but also for visualisation in medicine, chemistry, sciences and cinema (Figure 1).

Hyve-3D is an immersive system where a complete immersive (real-time) 3D scene is displayed via a panoramic non-stereoscopic projection. Using a single projector, the spherically distorted image is reflected off a dome mirror and displayed on a 2.5m high, 5m-diameter

concave spherical screen made of an opaque fabric material. The screen allows the projection of the distorted image around an audience (see Figure 1). Thanks to the *trompe l'oeil* effect, users watching the movie surrounded by the spherical concave screen perceive the deformed image as a corrected perspective. This concave spherical screen is not 360° like dome planetariums in order to place the image principally in front of the spectators and avoid the above-mentioned VR headsets issues. We chose this system because at the same time it enables a non 360° immersive visualisation and a collective experience without wearing VR headsets.

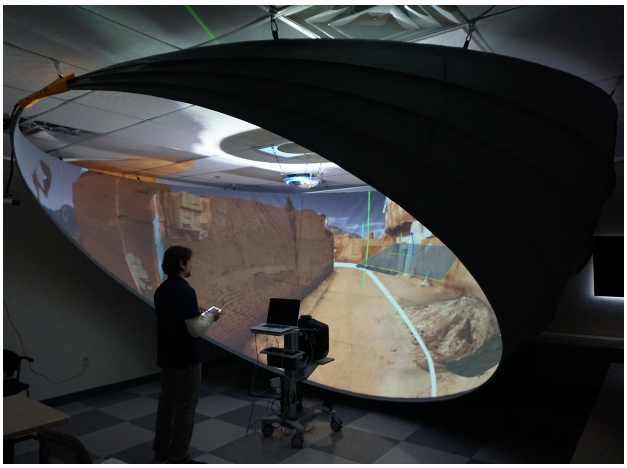


Figure 1: Hyve-3D.

VR headsets: we chose the cardboard VR headsets (HMrD) because they are less intrusive (i.e. not to be worn head-mounted using straps), allowing people to easily taking them off, in the context of evaluating social impact of the VR headset while watching movies. We agree that this kind of HMrD is the minimum expression of a VR headset (no tracked, etc.), but they offer us the possibility to control the impact of the sound which was external in both study's conditions. This also offers to the participants the affordance of listening and talking to each other. Even though more sophisticated VR headsets can offer parallax and head tracking, they would heavily affect the social interaction considering the total isolation (visual and auditory) from reality, in addition of the difficulty to take them off. In our study, we used two iPhones 5s with retina display inside the cardboards, displaying 4K resolution 360°, non-stereo movies.

Concerning digital representations of spectators, at this time exist some implementations of having point cloud 3D scan of users inside virtual environments (Dassault Systèmes, Dream Sketcher, etc.). However, in the context of 360° movies these techniques could be an issue, because of resolution issues concerning face expressions since these representations are in 3D while the movie is spherical and the fact of including several spectators in the scene. Concerning 3D avatars, we think that using 3D trackers in the context of cinema to allow social interaction is irrelevant and disturbing.

VR MOVIES

Many software solutions like Kolor Eyes™ (by Kolor) can deform stitched cylindrical panoramas (Figure 2) into spherical panoramas videos (Figure 3). This kind of 360° videos use a 6 or more camera-rig like those developed by Jaunt (http://www.jauntvr.com), placed within the scene, pointing the cameras at orthogonal axis directions. Other spherical lens like Gopano Pro™ (by EyeSee360) can be used to film directly in spherical panoramas videos although with less resolution because only one camera is used. The cylindrical spherical panoramas coming from stitched cameras can be produced at the ratio of 2:1 from resolution attending for example 3840x1920 and 4096x2048 pixels (4k), that can be handled by the graphic cards of current laptops and smart phones (Figure 2). Both Hyve-3D and VR headsets using iPhones can display effectively these spherical panoramic movies.

Figure 2: Cylindrical panoramic movie, ratio 2:1. Hollywood Rip Ride Rockit video (by Universal 360°, from Youtube.com).

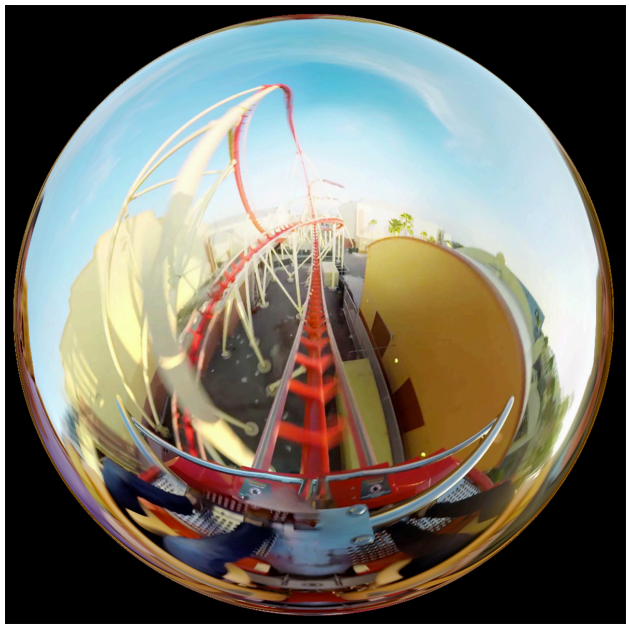


Figure 3: Spherical panoramic movie, deformed by Kolor Eyes™ (by Kolor). Hollywood Rip Ride Rockit video (by Universal 360°, from Youtube.com).

METHOD

We compared Hyve-3D to cardboard VR headsets. In order to better explore the social experience and the effectiveness of the two VR systems for movies we collected different kind of data. Specifically, we collected data about subjective experience through a questionnaire; in addition, we obtained data from a behavioural analysis of the video recordings; finally, the study was enriched with qualitative data of an exit interview aimed at

obtaining a deeper understanding of the quantitative results [6].

Participants

Twenty participants (4 women and 16 men) were recruited from design courses and people from the building of our laboratory. The educational level of the group ranged from under to graduated students and the age from 21 to 44 years (mean=26.8; standard deviation=5.1). All participants were new to Hyve-3D and just one of them had a previous experience with VR headsets. We ask each participant to bring a student friend in order to watch a VR movie together. Participants knowing each other were coupled in 10 dyads and this request intended to prevent a bias in the social interaction caused by a poor relationship between the two participants.

Procedure

We conducted a within-subjects study. We asked participants to watch two sequences (1 & 2) each one composed by two different comparable short videos (around 5-minute length in total). Short videos were selected instead of long films since the latter are hard to find, and because their implementation and analysis are time-consuming considering the exploratory character of this study. The first video of each sequence was a video without a storyline (i.e. panoramic rollercoasters), while the second one was a thrilling act presenting a short story. In both conditions participants were in standing position, in order to avoid constraints due to seats. The videos were 360°, and in Hyve-3D, we oriented the portion of the video containing the main action in front of the spectators, since the main story action happens in a particular portion of the scene. With Hyve-3D only around 60° of the scene were hidden.

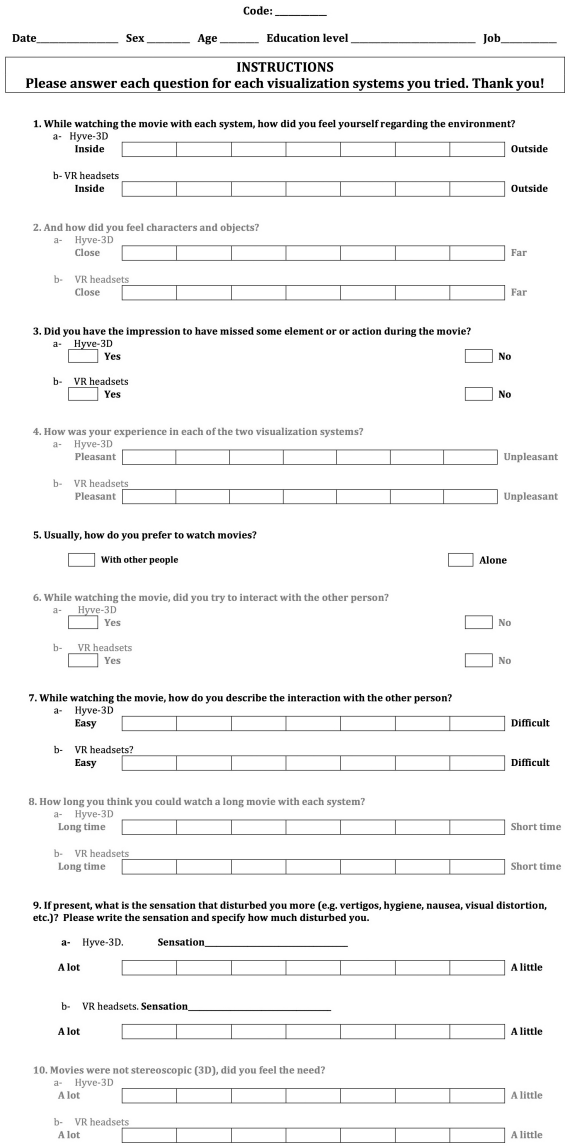
6 dyads watched first the sequence 1 (3 Hyve-3D, 3 VR headsets) and 4 dyads started watching sequence 2 (2 Hyve-3D, 2 VR headsets). The two videos were started at the same time by two researchers and the audio coming from one of the VR headset was shared using a high quality Bluetooth speaker. The same speaker was used for Hyve-3D. After watching each sequence, they filled a questionnaire and then they participated in an exit interview in groups of four. Movie watching and exit interviews were video recorded for the subsequent behavioural analysis.

Measures

Questionnaire.

We administered a questionnaire (Figure 4) asking questions about: sense of presence, user experience, social interaction, and personal preferences. We used a 7-point Osgood-type scale presenting opposite-meaning adjectives at each end (i.e. close/far, inside/outside, easy-difficult) for questions measuring the degree of a sensation, an attitude, or a personal preference. The rest of the items (2) required a yes/no answer. Here is a description of each variable measured:

Presence. According to Lombard et al. [11] we measured the sense of presence by using two items: the first item intended to measure *presence as sense of transportation* into the VR (how much participants felt themselves "there in the scene" – inside-outside); the second item intended to measure *presence as psychological immersion* (how much objects and characters have been perceived close to the user – close-far). We also asked about the need of a stereoscopic vision in order to have a better experience.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Date_____ Sex _____ Age _____ Education level _____ Job_____

INSTRUCTIONS
Please answer each question for each visualization systems you tried. Thank you!

1. While watching the movie with each system, how did you feel yourself regarding the environment?
a- Hyve-3D
Inside ☐☐☐☐☐☐☐ Outside
b- VR headsets
Inside ☐☐☐☐☐☐☐ Outside

2. And how did you feel characters and objects?
a- Hyve-3D
Close ☐☐☐☐☐☐☐ Far
b- VR headsets
Close ☐☐☐☐☐☐☐ Far

3. Did you have the impression to have missed some element or or action during the movie?
a- Hyve-3D
☐ Yes ☐ No
b- VR headsets
☐ Yes ☐ No

4. How was your experience in each of the two visualization systems?
a- Hyve-3D
Pleasant ☐☐☐☐☐☐☐ Unpleasant
b- VR headsets
Pleasant ☐☐☐☐☐☐☐ Unpleasant

5. Usually, how do you prefer to watch movies?
☐ With other people ☐ Alone

6. While watching the movie, did you try to interact with the other person?
a- Hyve-3D
☐ Yes ☐ No
b- VR headsets
☐ Yes ☐ No

7. While watching the movie, how do you describe the interaction with the other person?
a- Hyve-3D
Easy ☐☐☐☐☐☐☐ Difficult
b- VR headsets?
Easy ☐☐☐☐☐☐☐ Difficult

8. How long you think you could watch a long movie with each system?
a- Hyve-3D
Long time ☐☐☐☐☐☐☐ Short time
b- VR headsets
Long time ☐☐☐☐☐☐☐ Short time

9. If present, what is the sensation that disturbed you more (e.g. vertigos, hygiene, nausea, visual distortion, etc.)? Please write the sensation and specify how much disturbed you.
a- Hyve-3D. Sensation_____
A lot ☐☐☐☐☐☐☐ A little
b- VR headsets. Sensation_____
A lot ☐☐☐☐☐☐☐ A little

10. Movies were not stereoscopic (3D), did you feel the need?
a- Hyve-3D
A lot ☐☐☐☐☐☐☐ A little
b- VR headsets
A lot ☐☐☐☐☐☐☐ A little

Figure 4. Questionnaire including all the research aspects

User experience. We measured the valence of the experience by 1-item question asking how much they enjoyed the experience (positive-negative).

Storytelling. In order to evaluate the ability to follow the narrative of the videos presented, we asked participants if they noticed to have missed something in the scene (yes/no).

Social interaction. One question asked participants if they tried to interact with their mate during the movie viewing (easy-difficult).

Disturbing sensations. We asked participants to write the most disturbing sensation they experienced (if any) and to rate it (intense-mild).

Moreover, we asked a question whether they like to watch a movie with someone or alone and which VR systems seems more suitable for watching long movies.

User behaviour

In order to obtain also additional objective information, we analysed user's behaviour within the Hyve-3D and while using the VR headsets. We focused on two types of behaviours in video recordings: visual exploration of the immersive space (head turning, body re-orientation) and social interactions (talking and pointing at the scene).

Data analysis

For each condition, we analysed the mean values obtained from each Osgood-type scale of the questionnaire using the Wilcoxon signed-rank test. This statistical test is applied for median comparison in repeated measures design (such the present study). In addition, it is recommended with ordinal variables, with small samples, and when data are not normally distributed [1]. The significance level was set a priori for a p-value<.05.

As for behavioural analysis, we used the computer-assisted qualitative data analysis software Atlas.ti. By looking at the video recording, each visible movement of the head was coded as a "head movement", while when the movement involved a movement of the hips it was coded as "body re-orientation". Concerning the social interactions, we counted the number of times the participants talked or pointed something with their hands. We then considered the number of behaviour for each condition. In addition, we compared the behaviour during the vision of the videos with and without storyline. Finally, in the analysis of the exit interview we inductively identified the main themes. These different types of data were then triangulated in order to draw our conclusions.

Results

Most of the variables showed a skewed distribution justifying the use of the Wilcoxon signed-rank test [1]. Outliers were discarded from the analysis.

Using both Hyve-3D and the VR headsets participants experienced a good sense of presence: they felt themselves "transported" into the scene and they perceived objects and characters as if they were close to them. However, VR headsets induced a higher sense of transportation and immersion than Hyve-3D (Figure 5). The Wilcoxon signed-rank test showed both differences (transportation and immersion) to be statistically significant (z=1.965; p=0.0494; z=2.577 p=0.0100). Participants also reported a general positive experience with both systems, the more positive while using Hyve-3D (Figure 5). Again, the Wilcoxon signed-rank test showed this difference to be statistically significant (z=-2.442; p=0.0146).

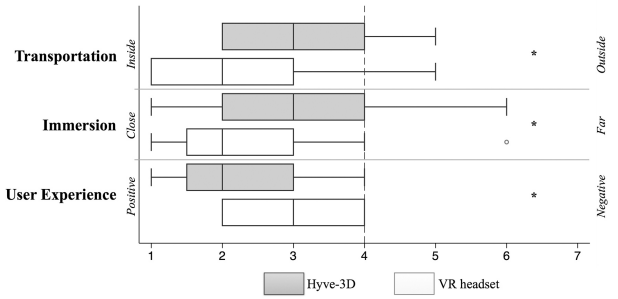

Figure 5. Perception of presence (sense of transportation and psychological immersion) and user experience. *Difference statistically significant.

Regarding the ability to follow the storytelling, 80% of participants using VR headsets reported having missed some content while only 15% using Hyve-3D (Figure 6).

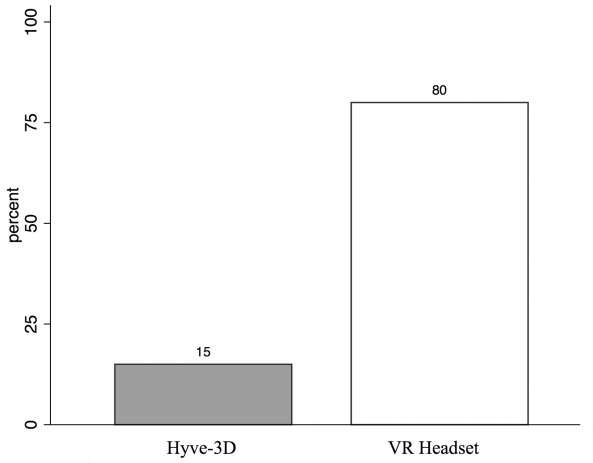

Figure 6. Percentage of people that missed at least one content using each VR system.

Concerning the length of the movies, Hyve-3D was perceived as more suitable for watching long movies (Figure 7). About the preference to share the experience of watching movies, 83% of participants declared that they usually watch movies with friends. Using Hyve-3D, 50% of participants tried to interact with the partner, while 55% using VR headsets. Social interaction using Hyve-3D has been perceived far easier than with the VR headsets (Figure 8). The Wilcoxon signed-rank test showed this difference to be statistically significant (z=1.965; p=0.0494).

Around 55% of the group reported some kind of disturbing sensation using both displays. We didn't find a significant difference between intensity of these sensations between the two VR systems.

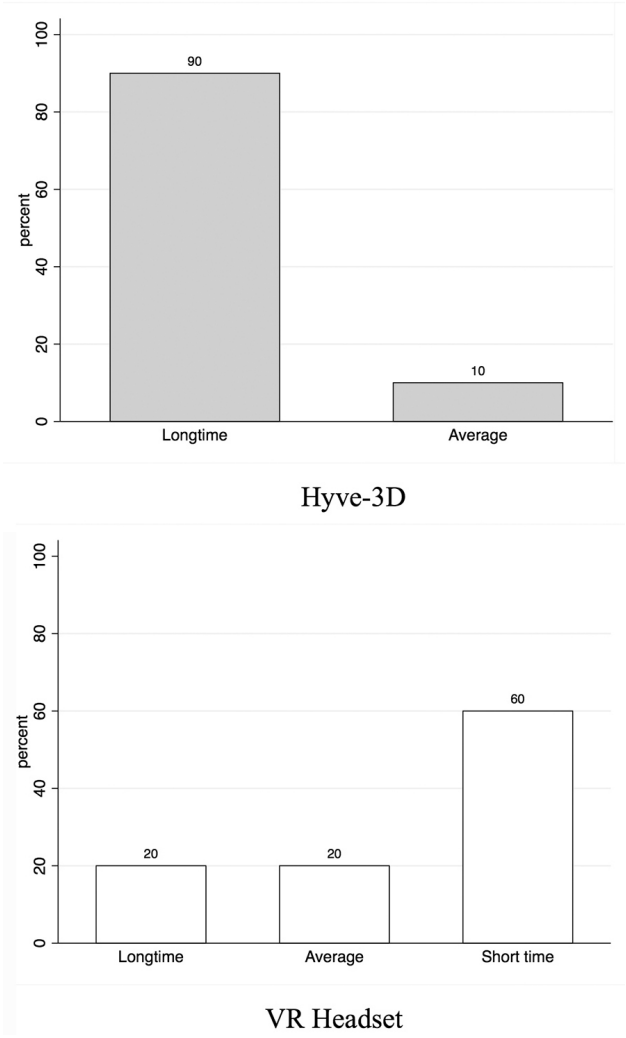

Figure 7. How long participants thought they could watch a movie using each VR system.

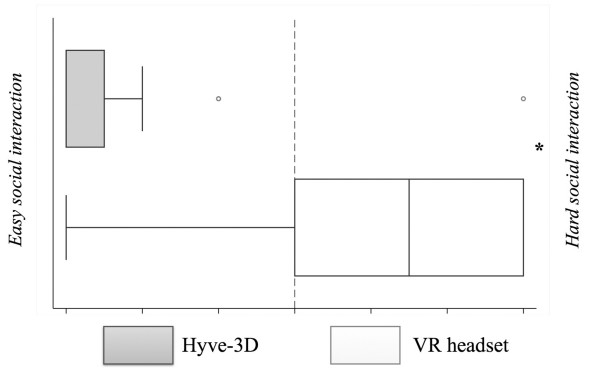

Figure 8. Perceived easiness of social interaction during movie watching using each VR system. *Difference statistically significant.

Behaviour analysis

Behaviour analysis of video recordings showed that people using VR headsets changed their body orientation far more than in Hyve-3D (253 body re-orientations vs. 5) (Figure 9 A).

They often looked around, up, and down turning their body of 180° and sometimes also of 360°. In addition, they often displayed multiple rapid movements of the head back and forth (e.g. right-left). Interestingly, the use of VR headsets produced more body re-orientations and head movements while watching the video with a storyline than the one without a storyline (Figure 9 B).

In Hyve-3D, small head movements seemed enough to watch the videos and to follow the story, while the body remained almost always oriented in the same direction. In addition, in Hyve-3D we observed the same pattern of exploration behaviour watching videos with as well as without storyline (Figure 9 B).

Concerning the social interaction, "talking" turned out to be the dominant behaviour during movie watching. People talked more while using VR headsets than Hyve-3D (Figure 10). Also, in both display systems they talked more during videos with a storyline. In both displays some people pointed contents in the scene, obviously their communication failed when using VR headsets (they took the VR headset off 3 times) (Figure 11).

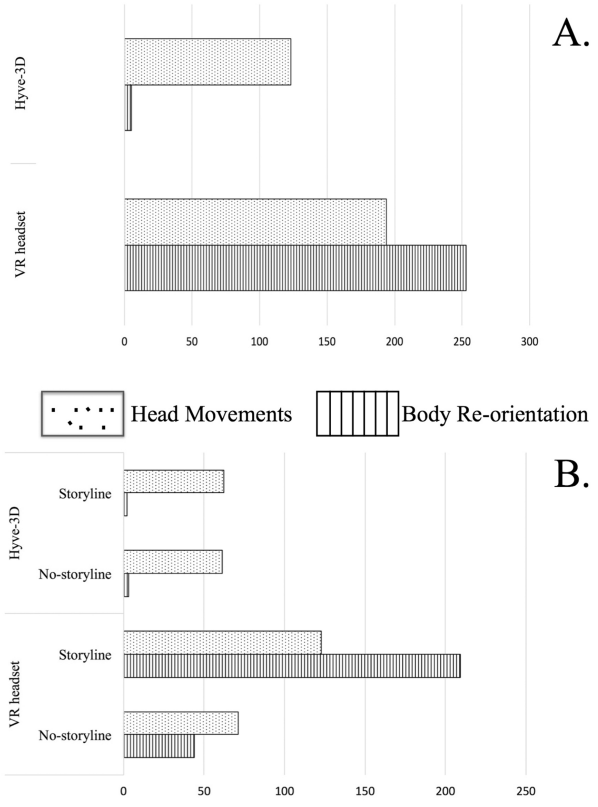

Figure 9. A – "Head movements" and "Body re-orientation" using Hyve-3D and the VR Headset. B – Comparison of "Head movements" and "Body re-orientation" each VR system during movies with and without storyline.

While watching a movie with a storyline using the VR headset, participants mainly asked questions about their own point of view "*where are you looking? Are you looking at ...?*" and checked if the mate did see some element in the scene "*Did you see it?*". In the Hyve-3D

they commented detail of the scene, made conjecture about the coming events or asked questions about details.

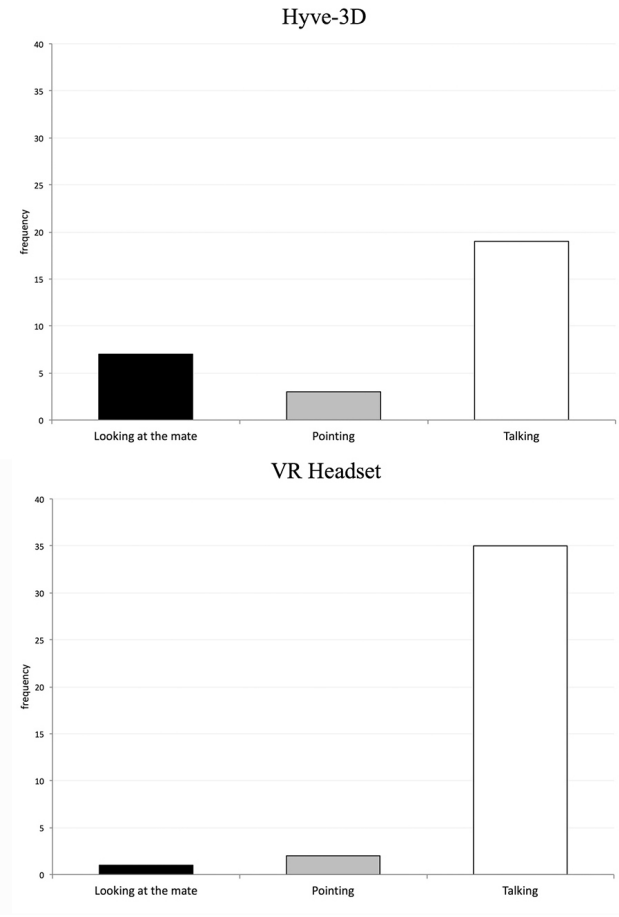

Figure 10. Verbal and non-verbal communication using Hyve-3D and the VR Headset.

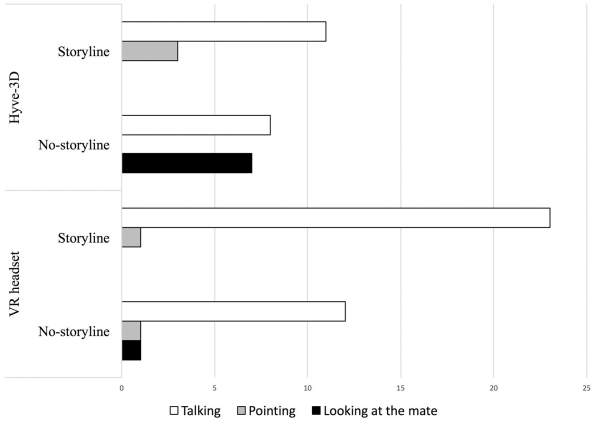

Figure 11. Verbal and non-verbal communication using each VR system during movies with and without storyline.

Exit interviews

At the end of the experience and after having filled the questionnaire we conducted a collective exit interview. In general, all of them appreciated both experiences with Hyve-3D and VR headsets. The main topics of the discussions were the sense of immersion, the quality and nature of the visualization and the social interaction during videos.

Immersion was indeed present in both cases, but in different ways. Hyve-3D, unlike VR headsets, kept an anchor with the external environment since it was still possible to see the limits of the screen and enabled to see the other person. Even if VR headsets gave freedom to explore in all directions and a sense of deeper immersion, the natural field of view was limited because peripheral vision was cut by the VR headsets' frame. In fact, users reported they had to move their head in every direction to be able to follow the action, which was perceived as tiring and disturbing for some. Only two participants reported that the seams of the fabric screen disturbed the immersion.

Besides the discomfort of the eyes, using VR headsets participants declared that they were not able to understand the story and they often missed some key elements of the storyline. In fact, when we asked them about some important details related to the story in the videos (i.e. a character that appeared) they confirmed they missed objects or actions. But, as the vision is wider in Hyve-3D, it gives more comfort and better observation capacity through peripheral vision. One participant says: "*In Hyve-3D, we have a capacity of vision which is very wide without the VR headsets. As humans, we naturally see wide [...] while with the glasses you can only see what you have in front [...] so you have to look everywhere all the time.*" This requires more physical and mental effort because of increased movements and the fact they need to search in the scene. Moreover, this seems to prevent passive relaxation experienced in the cinema. All participants expressed their concern about the use of VR headsets to watch a long film. This is due to the fact that there are visualization issues, difficulty in following the story, and also because VR headsets isolated them from the external environment, blocking communication with the other spectator. Since participants confirmed that cinema is considered a "social experience", the presence of the other was an important factor to enjoy the movie, and Hyve-3D was far favoured. Sharing the experience matters above of all. "*We feel more alone with glasses, so we feel more the need to talk. In Hyve-3D, I can see, I know what the other spectator sees, so I did not feel the need to talk to him. I think it is important for humans to see the experience of the other.*"

The issue of social presence repeatedly came in the discussion as one of the characteristics of the cinema experience. With VR headsets the presence of the other is missed, and even if participants make the effort to talk about something in the scene, it was often difficult to easily know in which direction to look.

Also, the absence of the body in VR headsets was an issue for some participants, and when they noticed that, they often disconnected from immersion. Since, many people understand 360° vision as an opportunity to explore the virtual space, participants got disappointed because they were not able to touch the objects around them.

Videos were not stereoscopic. Participants declared that they did not expect it in Hyve-3D. However, they would

prefer to have it in VR headsets. The 3D illusion (anamorphic and *trompe l'oeil* effect) was much appreciated in Hyve-3D view, thanks to the extended field of vision, the scale of the objects and the curvy shape of the screen.

Discussion

The main goal of VR in cinema, is to immerge spectators in the scene and improve their experience. However, it is unfortunate that VR headsets are proposed as the only hardware for VR in cinema.

According to our study, user's experience while watching short movies using a VR headset seems an issue, because the cinema experience seems to be preferably social. Our results indicate that social interaction was perceived to be quite difficult using the VR headsets. Despite this, participants talked more using the VR headsets. Because from the interviews emerged that to be able to feel the mate's presence was an important aspect of the whole experience, we interpreted this result as the attempt to reach their friends verbally: since they lost all visual clues about their presence, their position, and their actions, verbal communication occurred to compensate the lack of other's presence.

Also, in both display systems participants talked more during videos with a storyline. As demonstrated in other studies [15], there is more enjoyment and appreciation of the experience when this one is shared and the persons are mutually conscious of other's reactions. This consciousness enhances emotions and contagion of emotional expressions between spectators even with a simple "out of the corner of one's eye" [15], which is a characteristic that Hyve-3D offers with ease to spectators.

Even if this exploratory study had several limitations (small and uneven sample, short movies, low quality VR headsets), this research pinpoint a bunch of possible issues in transferring the VR headsets in the context of cinema and it opens the door to further studies. The impact of the gender sharing the cinema experience, remains to be analysed in a more equilibrated sample. And even if participants suggested they prefer to watch long movies in Hyve-3D, the impact of VR in long films deserve further investigation.

The practical contribution of this study is to explore new VR displays for cinema that fulfil the needs of spectators about VR, in terms of immersion and the social experience and sharing. In this study Hyve-3D is presented as an alternative that really addresses these characteristics going beyond of headsets for VR cinema.

Conclusions

In order to succeed in the context of cinema, VR has to consider the perspective of spectators. In this article we present a comparative study regarding social interaction of spectators using Hyve-3D and VR headsets. Even though VR headsets seem to be suitable for some genre of videos (e.g. panoramic, touristic videos), we argue that this kind of display is intrusive in the context of cinema, affecting the shared experience and storytelling.

Defining VR in terms of technology only rather than an experience, it brings us to the particular situation we are describing in this work: the hardware is imposed to users instead of being adapted to them for an optimal experience which seems to require a social dimension.

Our results, consistently with those of Bleumers et al. [2], showed that people do prefer to interact with each other while watching movies. Increased talking while watching a video with a storyline using VR headsets seemed an attempt to keep the contact with the other person in order to ensure the sharing of the experience. Moreover, the increased exploratory behaviour during videos with a storyline using VR headsets, and the high percentage of people that missed contents using those glasses, suggest that the "freedom" given by the 360° scene is potentially confusing for the users.

Hyve-3D seems to be more suitable than VR headsets in the context of collective watching of movies. Because the peripheral vision and the particular spherical concave shape ensure an adequate immersive experience and at the same time, preserve the social interaction during visioning an immersive movie. Hyve-3D unobtrusively enables users to easily scan the scene and to perceive, also through the peripheral vision, the important components of a story.

VR headsets generate the perception of a frame of vision around the eyes giving the perception to the user that they are wearing blinders affecting the peripheral vision (moving objects coming from the side, etc.). This in our opinion is still maintained with solutions to improve the peripheral images [17] since the illusion of an extended image cannot replace the fact of be immersed collectively in a social VR display as in the anamorphic image of Hyve-3D. Moreover, VR headsets bring a hygienic issue. They have to be worn for a long period of time in the context of a feature film during which they are too close with people's skin, eyes and hair. Therefore, they are perceived as private items rather than public. Finally, there are some technical and economic implications concerning the use of VR headsets since each user needs his/her own system that have to be synchronized with others in order to provide a collective experience.

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