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Environmental adaptation for Autistic children using Virtual reality

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ABSTRACT

This work in progress designs scenarios in a virtual environment for autism spectrum disorder (VE4ASD) in order to reduce the time and costs associated with taking autistic children to real environments as each needs to be accompanied by a mentor. It presents the user's interaction with the VR system and shows the relationship among the child, the other user (specialist or parent) and VR content. The VR prototype of VE4ASD is implemented as a proof of concept using MiddleVR for Unity3D. The VR database will be supported by SQL and Python. It will provide an effective educational tool for autistic individuals, helping them to adapt to new environments. Most of the previous studies have used the English language but this proposal will use the Arabic language, which will provide a beneficial contribution to the field of Arabic language research. We expect this study will reduce time, costs and human errors. Making the tool available to more people who want to assist children with autism and their families will lead to the development of early intervention strategies.

Keywords

Autism spectrum disorders; virtual reality; VR technology; social adaptation

1. INTRODUCTION

In Saudi Arabia, the integration of children with special needs with typically developing students is one of the Ministry of Education's objectives. It will help them to attend mainstream schools. Children with autism spectrum disorders (ASD) have difficulty adapting to new and unfamiliar environments, which may cause them anxiety and stress. Technology provides solutions for many problems in our daily lives and makes life easier, but there is a limitation on how technology can assist autistic children and help them in the problems they face every day in their lives. The purpose of this study is to design a school environment that helps children with ASD to prepare for attending an integrated school with students with autism and typically developing students.

To cope with daily life, autistic individuals and their educators need help in developing early intervention strategies. Therefore, some studies have investigated the use of virtual reality (VR) in autism. They found that a simulation of the real world based on computer graphics, can be useful as an educational tool during learning[1]. A key reason for using VR is that some scenarios are difficult to create with physical objects. It is costly in time to get the autistic children to real environments because each needs a mentor. "VR makes it possible at a low cost" [2]. For this reason, VR technology will undoubtedly be an effective educational tool for individuals with ASD in helping them to adapt to new environments.

Using VR in providing several selected scenarios will help them to adapt to new environments and feel less anxiety. Although there is no known treatment, the role of early intervention programmes is to modify autistic traits, teaching appropriate behaviour and integration within the community[3]. It also can help them gain self-care, social and communication skills[4].

This study aims to help children with ASD to adapt to new and unfamiliar environments by providing realistic scenarios to prepare the children for the real environment, providing a safe space to help them to explore the surroundings without feeling afraid. Having early training for children with ASD will improve their skills and get them used to real environments. Consequently, VE4ASD is an educational tool especially for autistic children. It will provide new environments by using VR to help the children to cope, as many autistic children have difficulty adapting to new situations.

2. LITERATURE REVIEW

Researchers agree that VR technology is an effective tool for education. After conducting many types of research that proved that VR is a technology that improves education and gives better results than other methods, it has been found to be better in education than traditional teaching tools especially for children [5, 6].

One study was applied to children with autism in the framework of Virtual Dolphin-Assisted Intervention (VDAI) including four core educational directions such as development of cognitive skills, personal relevance and societal adaptation/reconstruction. The authors discussed the need to reach an effective balance that is to be derived from practical use with the spectrum of diverse needs evident in autistic individuals. They concluded the use of VR technology is still in its infancy phase [3].

A study of VR-SCT was focused on improving social aspects, such as social skills and social cognition. The scenarios were designed as meeting new people, handling a roommate conflict, negotiating financial or social decisions and interviewing for a job. Inside the system – VR – the coach guided the participant to interact in each social situation. At the end of each scenario, the coach asked the participant questions about the scene and gave instructions. Then the next scene started, and the participant could benefit from the feedback. All ten of the VR-SCT training sessions were completed by all participants. Improvements were noted in social cognitive measurements of theory of emotion and mind recognition[7].

Another study focused on cognitive behavioural therapy (CBT) to reduce anxiety. The immersive technology, 'Blue Room' was used, which means participants did not need to wear a headset because they can see 360° around spanning walls and ceiling and can move about in the room. The psychology assistant helped in scenario steps with 4 session treatments of 20–30 minutes for each participant. Beginning with a relaxing scene, the scenario then commenced (e.g. taking the bus, shopping) ranging from low level to high level, depending on the participant's comfort level. Using this immersive virtual environment (VE), the study concluded that 8 out of 9 participants showed improvement and positive outcomes and 7 out of 9 reported increased confidence[8].

In a further case study, participants were concerned with getting a job. The case comprised two phases: the first phase invited the participant to try three scenarios using VR and then the second phase presented two longer and more intense scenarios. It included: Apollo 11 mission and Tuscan house. All participants in phase one agreed to wear the VR head-mounted display (HMD); 86% of them finished the three scenarios. After phase one, 79% agreed to return for phase two and 11 participants were selected. All the selected participants completed the two scenarios in phase two. They used impressive VR and equipment (PC, HMD, input device and headphones)[9].

Based on the previous research using VR with autistic people, VR technology has been shown to be an effective educational tool for individuals with ASD when helping them to adapt to new environments. Most of the previous studies used the English language. Our project will use the Arabic language which will provide a beneficial contribution to the field of Arabic language research. The purpose of our study is to design a school environment that helps children with ASD to prepare for an integrated school setting with both typically developing students with those with autism. It is one of the Ministry of Education's objectives to help children with special needs to attend integrated schools.

3. MATERIAL AND METHODS

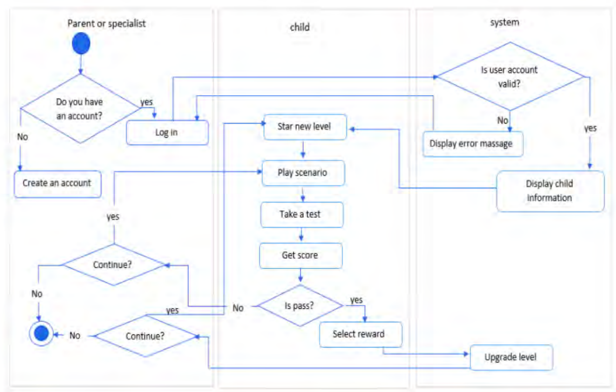

Figure 1. The illustration of the proposed VR system (activity diagram)

3.1 Hardware and Software Tools

To facilitate the software implemented process, MiddleVR for Unity3D[10], visual studio for coding by C#[10] and Blender for designing the models[11] are used. A major reason for this is to create a powerful and interactive fast VR application using a head-mounted display (HMD) system.

In addition, mobile HMDs can provide a portable and inexpensive experience, compared to the HMDs connected to a powerful computer. The Oculus Go device is portable, light-weight and easy-to-use. It is applicable for reliable assessment for our proposed study[12]. For this, all modules will be implemented using Unity 3D, Blender and PHP MyAdmin. Then they will be developed and tested in Unity3D 5.1 with C# as the programming language. The virtual reality database will be supported by the programming languages SQL and Python, the environment setting required to support our system by VR glasses.

3.2 Example Scenario

A VR environment with high accuracy is required. The VR scenarios should comprise real school situations faced by school children in their life. While giving the child appropriate freedom to interact in the scenario, the specialist or parent should still be able to lead and facilitate the education proceeding and intervene when necessary. Considering these basics principles, a HMD VR system will be chosen to facilitate the designated programme.

3.3 Virtual Environment for Autism Spectrum Disorder (VE4ASD)

The current VR system offerings will be described in this section. The details regarding hardware environment, software environment and VR content design and development will be presented. Figure 1 illustrates our elementary concepts on the current VR system. It presents the user's interaction with the system and shows the relationship among the child, the other user (specialist or parent) and the VR system.

- The specialist or parent should create an account for the child successfully.
- A parent or specialist logs in to the VR system by username and password to access their child's account.

- To start a new scenario, the child wears the HMD glasses as appropriate and presses the start button to view the scenario.
- To watch the scenario with 360°, the scenario will be displayed at 360° so that the child can move their head to see the virtual environment around them.
- Take a test. When the scenario display is finished, a simple test is displayed.
- Get the score. After completing the test, the child is given a score based on the correct answers.
- Choose a reward. The child chooses a reward from a list of rewards.
- The child, parents or specialist can press the exit button at any time.

The proposed VR system can analyse the results of the score and provide some recommendations to add a new environment and to the upgrade the child's level (see Figure 2).

Figure 1. The illustration of the proposed VR system (use case diagram)

3.4 Entity Relationship Diagram

The entity relationship diagram is a technique for data models that graphically describes the entities of the information system and the relationships between those entities.

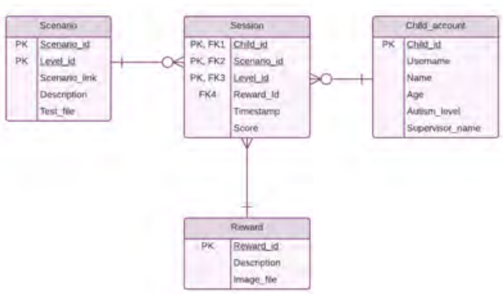

Figure 2. Entity relationship diagram

3.5 Prototype Unity3D

The VR prototype of VE4ASD is implemented as a proof of concept using Unity3D, C# and Blender. Of course, this is a simple design, which is obviously expected to improve as the research develops.

Some examples of school environment are in the following figures:

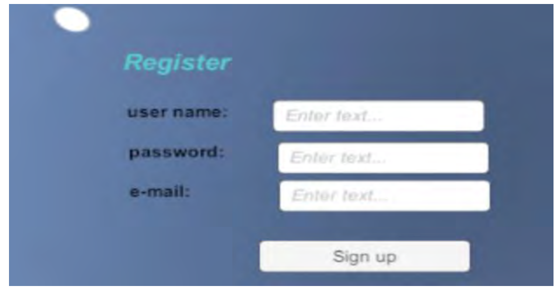

Figure 4. Register interface (Unity3D)

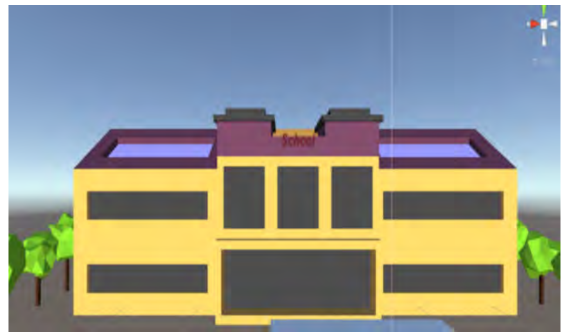

Figure 3. School from outside (Unity3D)

Figure 6. Classroom (Unity3D)

4. DISCUSSION

The proposed VR system will provide a new educational tool especially for autistic children that will facilitate improved social skills in individuals using VR capabilities. A prototype is illustrative of an original product which shows simple representation of the system and essential functions and how it will become after completing the implementation. The prototype is designed to gather feedback from users while the developers can modify the planning and design. In addition, the prototype helps to increase accuracy and remove ambiguity to make the product clear and easily comprehensible for users.

Most of the previous studies have used the English language but this proposal will use the Arabic language, which will be a beneficial contribution to the field of Arabic language research. Importantly, the current study will reduce time, costs and the number of human errors and it will develop early intervention strategies by making it available to more people who support the autistic children and their families.

4.1 Features

This paper addresses the use of VR for autistic children, which is an interesting and potentially effective application. It makes a pertinent contribution in the area of educational tools for people with ASD. The description of the VE4ASD system is too technical to include here. When describing the ongoing work, the following is expected:

- To study the performance of typically developing children in a VE that was designed to support the adaptation of autistic individuals in real school environments.
- A comparison can be made to distinguish actual contributions from work for identifying the difference between the proposed VE and the VEs for typically developing children.
- It would be relevant to distinguish the results of the use of VR as an educational tool for autistic children. In addition, it would be of interest to explore in what way multidisciplinary teams were used for development.
- Analysing the results and providing recommendations.

Consequently, VE4ASD is an educational tool especially for autistic children. It will provide new environments by using VR to help the children to adapt, because many autistic children find new environments stressful. Analysing the results and providing recommendations will improve educational progress, particularly the development of cognitive skills and societal adaptation.

5. CONCLUSION AND FUTURE WORK

In this paper, a virtual environment for autism spectrum disorder (VE4ASD) is proposed. A notable point of this study is the use of the Arabic language, which makes a beneficial contribution to the field of Arabic language research. The prototype illustrates an original product that shows a simple representation of the system and the essential functions and how it will develop upon completion. It aims to accomplish the following: to reduce the time of the traditional educational process where the speed of reaching a goal is very important; to reduce the number of human errors; and to make this educational tool available to all people.

At present, only the integrated school scenario is implemented in the study. The prototype is designed to modify the planning and design. In future, VE4ASD will add new scenarios. Thus, it will be an effective educational tool for autistic individuals in helping them to adapt to new environments. In addition, it will help to increase accuracy and remove ambiguity to make the product clear and comprehensible for users.

6. REFERENCES

[1] Bellani, M., et al., Virtual reality in autism: state of the art. Epidemiology and psychiatric sciences, 2011. 20(3): p. 235-238.

[2] Wenting, Z. VR provides training for autistic kids. 2018; Available from: https://www.thedailystar.net/health/virtual-reality-technology-vr-provides-training-autistic-children-china-shanghai-interactive-games-1563691.

[3] Stahmer, A.C., N.M. Collings, and L.A. Palinkas, Early intervention practices for children with autism: Descriptions from community providers. Focus on Autism and Other Developmental Disabilities, 2005. 20(2): p. 66-79.

[4] Scott, M.M. and P. Chris, Management of children with autism spectrum disorders. Pediatrics, 2007. 120(5): p. 1162-1182.

[5] Greenwald, S., et al., Technology and applications for collaborative learning in virtual reality. 2017.

[6] Fernández-Herrero, J., G. Lorenzo-Lledó, and A.L. Carreres, A Bibliometric Study on the Use of Virtual Reality (VR) as an Educational Tool for High-Functioning Autism Spectrum Disorder (ASD) Children, in Contemporary Perspective on Child Psychology and Education. 2018, InTech.

[7] Kandalaft, M.R., et al., Virtual reality social cognition training for young adults with high-functioning autism. Journal of autism and developmental disorders, 2013. 43(1): p. 34-44.

[8] Maskey, M., et al., Reducing specific phobia/fear in young people with autism spectrum disorders (ASDs) through a virtual reality environment intervention. PloS one, 2014. 9(7): p. e100374.

[9] Newbutt, N., et al., The acceptance, challenges, and future applications of wearable technology and virtual reality to support people with autism spectrum disorders, in Recent Advances in Technologies for Inclusive Well-Being. 2017, Springer. p. 221-241.

[10] Bond, J.G., Introduction to Game Design, Prototyping, and Development: From Concept to Playable Game with Unity and C. 2014: Addison-Wesley Professional.

[11] Dovramadjiev, T., Modern accessible application of the system blender in 3d design practice. International scientific on-line journal" SCIENCE & TECHNOLOGIES". Publishing House" Union of Scientists-Stara Zagora", ISSN, 2015: p. 1314-4111.

[12] Pope, H., Virtual and Augmented Reality Applications. Library Technology Reports, 2018. 54(6): p. 12-17.

Maximizing lenticular lens performance for Multi User VR displays

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Abstract - **One of the ongoing issues of Virtual Reality systems regardless if they are head-mounted or projection based is that they can only provide a correct perspective to one user. This limitation reduces the usability of such systems for collaborative work which is nowadays the standard in any industry. One of the approaches for multiplexing images to different users from a single screen is through optical routing; this approach relies on bending the light from pixels to generate perspective correct images to different users. Lenticular lenses do exactly that; bend the light so different persons can see different images from different positions. On this paper we devise a lenticular lens simulator that compares and assesses different lenticular lens/screen combinations and finally present and discuss the performance of lenticular lenses for multiplexing images from a single screen to different users.**

Index Terms - **Lenticular lens; Multi user VR; Ghosting; pixel refraction.**

I. Introduction

Several methods for aiding in designing and interacting through VR have been proposed across the years, head mounted displays (HMDs), volumetric screens, projection-based virtual reality systems and several different devices help us interacting with computer generated worlds.

HMDs work really well when the person who is interacting with the simulation is working alone. But this is rarely the case in any industry. There have been attempts to work cooperatively with HMDs (Szalavári et al. 1998), these systems exhaust users because of weight and eyesight hindering among other issues. Although one may have different opinions on how much a see through HMD might occlude one's face, it makes facial expressions less visible to other participants removing an important nonverbal communication channel.

When a group of domain experts get together, they surround and gesture toward a common dataset hoping they achieve a consensus. This engagement is persistent across disciplines and insists for a need of a VR system that accommodates small groups of people working close to each other with correct perspective viewpoints. What looks like a sphere for a user cannot look like an egg to another. Studies like the ones proposed by Pollock et al (Pollock et al. 2012) back up this idea by demonstrating that even when perspective correct 3D is not needed for each user, collaboration times get significantly longer when participants stay at different locations compared to the same location relative to the center of perception (CoP).

Different approaches have been attempted to multiplex images from a single display to different users providing a correct perspective for each one; In (Bolas, McDowall, and Corr 2004), Mark Bolas presents a great classification on the different approaches for doing multiuser immersive display systems. He proposes in his research that all these attempts convey into a "Solution Framework" which fall into four general categories: Spatial Barriers, Optical Filtering, Optical Routing and Time Multiplexing.

Lenticular lenses fall in the optical routing approach and are widely used for lenticular printing, corrective lenses for improving vision, 3D TV and lenticular screens among other uses (Wikipedia 2018).

On this paper we are going to present and discuss an assessment of the performance of lenticular lenses for multiplexing images from a single screen to different users.

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II. Background

A. Anatomy of a Lenticular Lens

A lenticular lens is basically a set of cylinders (lenticules) placed next to each other overlapping with one side flat and the other side with the protubing lenses (fig 1), these lenses are designed so that when viewed from different angles different slices of an image are displayed (fig 2).

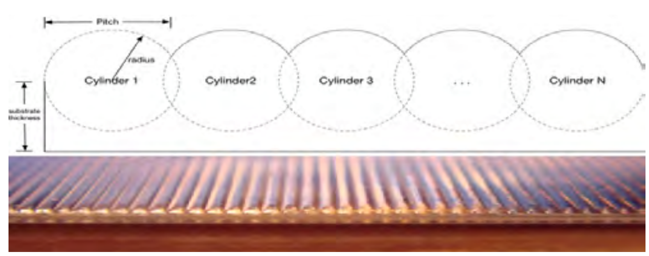

Figure 1: Top: Diagram of a lenticular lens, Bottom: Real lenticular lens

The most common example of lenticular lenses are the ones used in lenticular printing, where the technology is used to give an illusion of depth, or to make images that appear to change or move as the image is viewed from different angles (Wikipedia 2018). Depending on the lens used the effect achieved changes.

B. Types of lenticular lenses

Lenticular lenses are normally classified by their Lenses Per Inch (LPI), the higher the LPI the smaller each lenticule is.

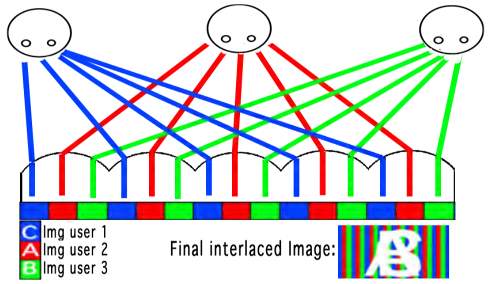

Figure 2: Image looked from different angles in a lenticular lens

Normally manufacturers offer lenses in 10, 15, 20, 30, 50, 60, 75, 100LPI lenses; However, with enough amount of funds one can get a lens with custom specifications manufactured.

Different types of lenticular lenses offer different effects (see fig 3); these effects can be just about anything you can do with video; some of the most popular effects include 3D, flip, animation and morph. (Microlens 2018) (LenstarLenticular 2018).

Figure 3: Flip to 3D lenticular lenses.

1. **3D effect:** This effect provides an illusion of depth and perspective by layering objects within an image (fig. 4 A).
2. **Flip effect:** In this effect, a dramatic swap of two images occurs vanishing and then reappearing from one to another (fig. 4 B).
3. **Animation effect:** This effect generates the illusion of motion coming from a set of video frames or sequential images (fig. 4 C).
4. **Morph effect:** This effect is commonly used to create the illusion of transformation (fig. 4 D).

With the same principle on how lenticular printing works; lenticular lenses have also been used for multiplexing images to different users in VR as an optical routing approach.

III. Previous Work

Optical routing uses the angle-sensitive optical characteristics of certain materials to direct or occlude images based on the user's position.(Bolas, McDowall, and Corr 2004).

In 1994, Little et al talk about a design for an autostereoscopic, multiperspective raster-filled display (Little, Gustafson, and Nikolaou 1994). Here, they propose a time multiplexed approach and an optical routing approach. The optical routing approach features video cameras and LCTV projectors. Here, they use an array of video cameras to capture multiple perspective views of the scene and then they

Figure 4: Lenticular lens effects. A: 3D, B: Flip, C: Animation, D: Morph

fed these to an array of LCTVs and simultaneously project the images to a special pupil-forming viewing screen. The viewing screen is fabricated by either a holographic optical element or a Fresnel lens and a pair of crossed lenticular arrays. Their resolution is limited by the LCTV projectors and they use a lot of projectors / cameras to provide multiple views. For the time-multiplexed approach they investigated the use of a DMD projector that provided 20 sequentially perspective views, each one separated by one degree in viewing angle by a spinning disk. The DMD approach is monochromatic.

Van Berkel et al in (Van Berkel and Clarke 1997) (Van Berkel 1999) built a prototype display using a LCD and a lenticular lens from Philips Optics to display 3D images; they slanted the lenticular lens with respect to the LCD panel in order to reduce the "picket fence" effect. Their display has a resolution of 342x200.

Later in the same year, Matsumoto et al in (Matsumoto and Honda 1997) proposes a system that consists of combination of cylindrical lenses with different focal lengths, a diffuser screen and several projectors to create a 3D image. They had issues with one of the lenses causing a dark stripe in the 3D image affecting the stereoscopic vision by reducing the sense of depth.

Omura presents a system that uses double lenticular lenses with moving projectors that move according to the tracked user's position to extend the viewable area (Omura, Shiwa, and Miyasato 1998), their system needs a pair of projectors per person and their projectors move to adjust each user's position. Their system suffers from latency due to the mechanical movement.

Lipton proposed the Synthagram (Lipton and Feldman 2002), a system that consists of an LCD Screen with a lenticular screen that overlays the LCD display. They angled the lenticular screen in order to reduce the moiré pattern and their system uses nine progressive perspective views from a single image. They sample these views into a program called the Interzig where they process the images and assign each pixel to a specific position in the screen. Synthagram files are stored as 24bit bmp files and it's not able to process images in real-time according to the authors.

Matusik proposes a system that consists of an array of cameras, clusters of network connected PCs and a multi-projector 3D display with the purpose to transmit autostereoscopic realistic 3D TV (Matusik and Pfister 2004). They record the imagery with a small cluster of cameras that are connected to PCs. The PCs broadcast the recorded video which later on is decoded by another cluster of consumer PCs and projectors. Their 3D Display consists of 16 NEC LT-170 projectors that are used for front or rear projection. The rear projection approach consists for two lenticular sheets mounted back to back with an optical diffuser material in the center and the front projection system uses one lenticular sheet with a retro reflective front projection screen material. They mention their system runs only at 12fps and the rear projection system exhibits moiré artifacts along some visible vertical lines due to the lenticular sheet used.

Another way of optical routing approach use is the display proposed by Nguyen et al (Nguyen and Canny 2005) (Nguyen and Canny 2007). Here, they propose a special display which consists of a screen with 3 layers that has directional reflections for projectors so each participant sees a customized image from their perspective; their system supports up to 5 viewing zones but doesn't support tracking and it needs a projector per participant.

Takaki et al proposes a system that can produce 72 views(Takaki 2005). Their system consists of a light source array, a micro lens and a vertical diffuser (a lenticular sheet). They mention that as the horizontal positions of all light sources are different, rays from different light sources proceed to different horizontal directions after passing through the micro lenses thus generating different views. They also mention that it's difficult to fabricate a large micro lens array and also say that unused pixels remain at the corners of the LCD panel.

Later on. In (Nakanuma, Kamei, and Takaki 2005) (Kikuta and Takaki 2007) followed by (Takaki 2009), Takaki discusses a multiple projection system that is modified to work as a super multiview display. Here, they attach a lens to the display screen of a HDD projector and by combining the screen lens and the common lens, they project an aperture array. This aperture array is placed on the focal plane of the common lens, and the display screen (a vertical diffuser) is placed on the other focal plane. Hence, the image of the aperture array is produced on the focal plane of the screen lens. With this, the image of an aperture array gets enlarged generating enlarged images that become viewpoints. The authors comment that there is some discontinuity between the different generated views when the observation distance is different from the distance to the viewpoints.

In 2009. Takaki and his team introduce a prototype panel that can produce 16 views (Takaki, Yokoyama, and Hamagishi 2009). They do this by building a LCD with slanted subpixels and a lenticular screen. They place a diffusion material between the lenticular sheet and the LCD screen in order to defocus the moiré pattern but increase the crosstalk among viewpoints. They mention that by slanting the subpixel arrangement instead of the lenticular sheet, they can increase the number of views but the optical transmittance of the display decreases. They conclude that by slanting the subpixels in the screen instead in the lenticular sheet, they can reduce significantly the crosstalk and moire compared to the normal approaches. Their approach requires to build a LCD display which is a quite a complex task.

Finally, in 2010 Takaki and his team combine several 16-view flat-panels that have slanted subpixels(Takaki, Yokoyama, and Hamagishi 2009) and creates a system with 256 views(Takaki and Nago 2010). They superimpose the different projected output of the panels to a single vertical diffuser. The multiple viewing zones for each flat panel are generated on an incident pupil plane of its corresponding projection lens. Each projection lens projects to the display surface of its corresponding flat panel system on the common screen and finally a screen lens is located on the common screen so the lens generates viewing zones for observers. They mention that their prototype display has the possibility of producing 3D images on which the human eye can focus but also they report that there is considerable crosstalk between the viewing zones and the resolution of the prototype is not very high.

Another system that takes advantage of the optical routing approach is the Free2C display, a project proposed by Surman in (Surman et al. 2006). Here, they created a single viewer autostereoscopic display using a head tracker. The display accommodates the head movement of the viewer by continually re-adjusting the position of the lenticular lens in relation to the LCD to steer the stereoscopic views onto the eyes of the viewer. Their display resolution is 1200x1600, the viewing distance goes from 40cm to 110cm and side to side movements range of approximately +-25 degrees from the center of the screen. They also attempted a multi-user display that steers the LCD instead of the lenses to produce image regions for the users but they mention the display performance was really poor.

Similarly to Free2C, Brar et al use image recognition to track users' heads to produce multiple steerable exit pupils for left and right eyes (Brar et al. 2010a) (Brar et al. 2010b). Here, they describe the design and construction of a stereoscopic display that doesnt require wearing special eye wear. A stereo par is produced on a single LCD by simultaneously displaying left and right images on alternate rows of pixels. They propose steering optics controlled by the output the aforementioned head tracker to direct regions, referred as exit pupils to the appropriate viewers' eyes. Their prototype is not optimal due to insufficient brightness and instability in the holographic projector and their current research doesn't support multiple users.

Kooima et al (Kooima et al. 2010) uses 24" and 42" 3DHD Alioscopy displays which come with integrated lenticular lenses. They propose a system that consists of scalable tiled displays for large field of views and use a generalization of a GPU based autostereoscopic algorithm for rendering in lenticular barriers.They tried different methods for rendering but they had issues where they perceived repeated discontinuities, exaggerated perspectives and as the displays pixels cannot be moved smoothly but in discrete steps. The tracked viewer moves into transition between channels, the user begins to see the adjacent view before the channel perspective is updated to follow the user's head.

Zang et al propose a frontal multi-projection autostereoscopic display (Zang et al. 2014). Their approach consists of 8 staggered projectors and a 3D image guided screen. The 3D image screen is mainly composed of a single lenticular sheet, a retro-reflective diffusion screen and a transparent layer that is filled between them to control the pitch of the rearranged pixel stripe in interlaced images. Their system is space efficient compared to previous approaches that produce light from the back of the screen, but the loss of intensity and crosstalk are seriously increased out of the system boundaries and besides being complex it doesn't provide perspective perfect views for each user.

We have mentioned here some research that has been done throughout the years that use an optical routing approach; specifically, lenticular lenses to separate users. Still, none of these projects mention an objective approach for the correct lens values for each of the setups used.

IV. SIMULATING LENTICULAR LENSES

Different lenses work better with different screens due to the different variables each lens / screen marriage have. Ideally, factors like ghosting (being able to see images from other users), number of pixels perceived for each user and color banding are things that need to be taken into account when pursuing an optical routing approach for multiplexing images.

To assess the performance of any given lens/screen marriage, a lenticular lens simulator was developed to determine how good or bad a specific lens will work with a specific screen, see how much can the lens specifications be pushed with several users and theoretically come up with a lens that can work great with a given screen and a number of users.

Mathematical model for the simulator

A lenticular lens has several variables that can be modified to produce different effects; manufacturers sell lenses based on their LPI but at the end, each of these lenses comes with a set of specifications like the refraction index of the material the lens is made of, substrate thickness, viewing angle, lenticule radius, etc.(fig. 5) (Wikipedia 2018). To simulate how a lens

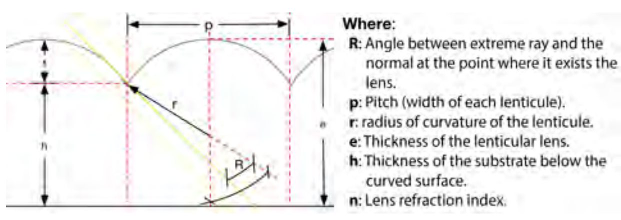

Figure 5: Detailed lenticular lens

works; a discretization of the light emitted from each pixel is represented with several rays that start from each subpixel along the lens substrate that get refracted to the air from the lenticular lens. To achieve this, the simulator generates a number of rays for each pixel and calculates ray trajectories from when they start in the pixel until they get refracted by the lens in three steps: Substrate contact, lens contact and lens refraction.

Step 1: Substrate contact.

In this phase n number of rays are calculated for each pixel with a spread S (in deg) in order to get n contact points $P_0, P_1 \dots P_n$ from a horizontal line (parallel to the screen) that defines the substrate thickness of the lens (fig. 6). To

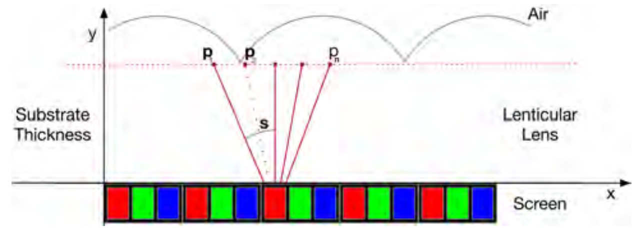

Figure 6: **Step 1:** Find where rays intersect substrate line.

find the points $P_0, P_1 \dots P_n$ where the rays intersect the end of the lens substrate we represent the rays from the pixel and the substrate with line equations and find their respective intersection points.

Given the points R_1 and R_2 from the line L_1 that represents the ray that gets generated from the pixel and points S_1 and S_2 from the line L_2 that defines the substrate of the lens, we can generate two standard line equations with the form $y = mx + b$, make them equal on the y axis (as it is the substrate thickness that the manufacturer gives) and find the intersection point P_i on x (fig. 6).

$L_1 \rightarrow y = m_1 x + b_1 \qquad L_2 \rightarrow y = m_2 x + b_2$

$$\boxed{x = \frac{b_2 - b_1}{m_1 - m_2}} \quad \text{intersection X axis } (P_x).$$

Again, finding the P_y becomes trivial as is given by the lens manufacturer and is the lens substrate thickness.

Step 2: Lens contact.

After finding where the rays of light intersect in the substrate thickness line, we proceed to find which lens the ray "belongs" to in order to apply the corresponding refraction in step three.

To do so, we find the center C_i of the lenticule l_i that is closest to the intersection P_j in order to know which lens refracts each ray from the pixel (fig. 7). To find these centers

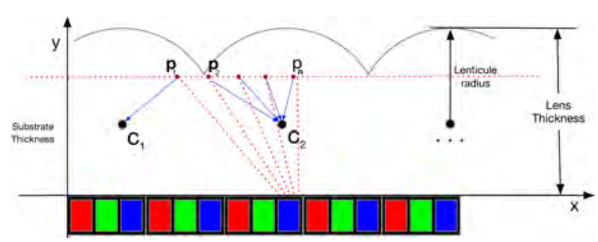

Figure 7: **Step 2:** Find points P_j closest to lens center C_i.

we just need to find C_x for each lens because C_y in all the lenticule centers remain the same and can be easily deduced from figure 7 as $C_y = lensThickness - lenticuleRadius$.

Getting C_x is also pretty straight forward as the pixel number ($PixNum$) the ray comes from is known, the physical pixel size (Pps) has already been pre-calculated from the screen density *PPI* and we can know each lenticule size (Ls) by just dividing the LPI of the lens by 1 inch ($Ls = \frac{1}{LPI}$).

First, we calculate the lenticule center that stays on top of the current pixel (Lct) with:

$$Lct = \left(\left\lfloor \frac{PixNum * Pps}{Ls} \right\rfloor * Ls \right) + \left(\frac{Ls}{2} \right) \tag{1}$$

After calculating Lct (eq. 1), we proceed to check if the distance with P_x i is lesser than half of an individual lenticule size ($|Lct - P_x| < \frac{Ls}{2}$), if it is we have found the lenticule center C_x the ray belongs to, else we carry checking for neighboor lenticule centers with $C_x \pm \frac{Ls}{2}$ until the condition gets satisfied.

In conclusion, the algorithm for finding the lenticule center C_j that belongs to the ray intersection P_i we are calculating in this phase can be seen in Alg. 1.

Algorithm 1 Get closest lens center from ray intersection P_i

```
procedure CLOSESTCENTER(PixNum, Pps, Ls, P)    ▷ Return closest C to P
    C_y ← lensThickness − lenticuleRadius
    Lct ← (⌊(PixNum * Pps) / Ls⌋ * Ls) + (Ls / 2)
    if |Lct − P_x| < Ls/2 then
        return C(Lct, C_y)
    end if
    counter ← 1
    while true do                ▷ Search neighbor lens centers
        centerL ← Lct − (counter * Ls)
        if |centerL − P_x| < Ls/2 then
            return C(centerL, C_y)
        end if
        centerR ← Lct + (counter * Ls)
        if |centerR − P_x| < Ls/2 then
            return C(centerR, C_y)
        end if
        counter ← counter + 1
    end while
end procedure
```

Step 3: Lens Refraction.

After finding the closest lenticule center C_j from a given ray intersection P_i we can continue with the ray direction $\vec{r}$ and finally find the intersection point Q_i with the lenticule L_j where we can calculate the ray refraction (fig. 8). $\vec{rf}$.

Finding lens intersection point: To find Q_i (fig 8) we can treat each lenticule as a circle and the rays that come from each pixel as lines and then the lens-ray intersection point can be treated as a line-circle intersection as follows (AmBrSoft 2018) (Projects 2011):

Given a circle with center (c_x, c_y) with radius r representing the lenticule with center C_j and a line representing the ray of light that comes from a given pixel:

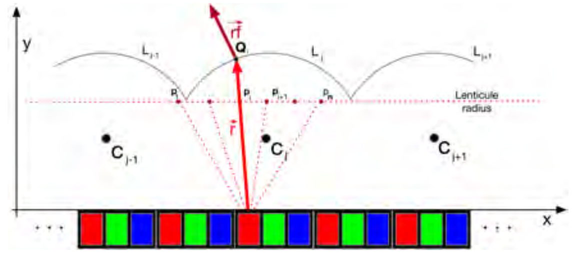

Figure 8: **Step 3:** Ray intersection with lens and refraction.

$$\textit{Ray} \rightarrow y = mx + b \quad \textit{Lens} \rightarrow (x - c_x)^2 + (y - c_y)^2 = r^2$$

$$0 = (x - c_x)^2 + (mx + (b - c_y))^2 - r^2 \quad \textit{Replace ray in lens equation}$$

$$0 = x^2(1 + m^2) + x(2mb - 2c_x - 2mc_y) + (c_x^2 + b^2 - 2bc_y + c_y^2 - r^2)$$

Solving the quadratic form of the resulting equation we end up with:

$$x_{1,2} = \frac{-mb + c_x + mc_y \pm}{1 + m^2} = \frac{\sqrt{-2mbc_x + 2mc_xc_y - b^2 + 2bc_y - c_y^2 + r^2 + r^2m^2 - m^2c_x^2}}{1 + m^2} \tag{2}$$

After finding the x component in eq. (2), we can see we have three possible values that the quadratic equation gives us under the square root. Lets call this D.

$$D = -2mbc_x + 2mc_xc_y - b^2 + 2bc_y - c_y^2 + r^2 + r^2m^2 - m^2c_x^2$$

$$D \begin{cases} < 0 \text{ No intersection point (ray doesnt touch the lens).} \\ = 0 \text{ The line touches the lens tangentially.} \\ > 0 \text{ Two intersection points(as this is at the end a circle).} \end{cases}$$

We are only interested in the positive value as the lenses point torward the positive Y axis so on this case, the x component of the intersection point Q_i where the ray touches the lens ends up being:

$$x = \frac{-mb + c_x + mc_y +}{1 + m^2} = \frac{\sqrt{-2mbc_x + 2mc_xc_y - b^2 + 2bc_y - c_y^2 + r^2 + r^2m^2 - m^2c_x^2}}{1 + m^2} \tag{3}$$

Finally, just by replacing this value (eq. 3) on the line equation from the ray one can get the y component of Q_i.

Generating refracted ray from the lens: After finding the point of intersection where the ray (coming from the pixel) touches the lens (Q_i). One can finally calculate the refracted pixel ray ($\vec{rf}$)(fig. 8) using Snell's law (De Greve 2006).

Snell's Law states that the products of the index of refraction and sines of the angles must be equal (eq. 4).

$$n_1 \sin(\theta_1) = n_2 \sin(\theta_2) \tag{4}$$

Snell's equation (eq. 4) can be re-written as:

$$\sin(\theta_2) = \frac{n_1}{n_2}\sin(\theta_1) \tag{5}$$

One can immediately see a problem here, and is that if $\sin(\theta_1) > \frac{n_2}{n_1}$ then $\sin(\theta_2)$ has to be bigger than 1 which is impossible. So when this happens, we have a TIR (*Total Internal Reflection*), TIR only happens if you go from a denser material (lens) to a less dense material (air). When TIR happens, we just ignore that ray and do nothing about it. So eq. 5 can be written like this:

$$\sin(\theta_2) = \frac{n_1}{n_2}\sin(\theta_1) \longleftrightarrow \sin(\theta_1) \leq \frac{n_2}{n_1} \tag{6}$$

To find $\vec{rf}$, lets begin by splitting it up in a tangent and a normal part:

$$\vec{rf} = \vec{rf_{\parallel}} + \vec{rf_{\perp}} \tag{7}$$

As all the vectors are normalized and any vector $\vec{v}$ can be decomposed in its tangent and parallel parts, and its parts are perpendicular to each other ($\vec{v_{\parallel}} \perp \vec{v_{\perp}}$), with basic trigonometry, the following rules apply:

$$\sin(\theta) = \frac{|\vec{v_{\parallel}}|}{|\vec{v}|} = |\vec{v_{\parallel}}| \qquad \cos(\theta) = \frac{|\vec{v_{\perp}}|}{|\vec{v}|} = |\vec{v_{\perp}}| \tag{8}$$

Since Snell's law talks about sines (eq. 6), we can use eq. 8 and rewrite eq. 6 as:

$$|\vec{rf_{\parallel}}| = \frac{n_1}{n_2}|\vec{r_{\parallel}}| \tag{9}$$

Since $\vec{rf_{\parallel}}$ and $\vec{r_{\parallel}}$ are parallel and point in the same direction, eq. 9 becomes:

$$\vec{rf_{\parallel}} = \frac{n_1}{n_2}\vec{r_{\parallel}} = \frac{n_1}{n_2}(1 - \cos(\theta_r)\vec{n}) \tag{10}$$

To find $\vec{rf_{\perp}}$ one can simply use pythagoras ($|\vec{v}|^2 = |\vec{v_{\parallel}}|^2 + |\vec{v_{\perp}}|^2$) and end up with:

$$\vec{rf_{\perp}} = -\sqrt{1 - |\vec{rf_{\parallel}}|^2}\,\vec{n} \tag{11}$$

Replacing eq. 9 and eq. 11 in eq. 7 we get:

$$\vec{rf} = \frac{n_1}{n_2}\vec{r} - \left(\frac{n_1}{n_2}\cos(\theta_r) + \sqrt{1 - |\vec{rf_{\parallel}}|^2}\right)\vec{n} \quad \text{Replacing 8}$$

$$\boxed{\vec{rf} = \frac{n_1}{n_2}\vec{r} - \left(\frac{n_1}{n_2}\cos(\theta_r) + \sqrt{1 - \sin^2(\theta_{rf})}\right)\vec{n}}$$

Finally, we need to find $\sin^2(\theta_{rf})$ in this last equation, but this can be easily deduced it using Snell's law in equation 9.

$$\boxed{\sin^2(\theta_{rf}) = \left(\frac{n_1}{n_2}\right)^2 \sin^2(\theta_r) = \left(\frac{n1}{n2}\right)^2 (1 - \cos^2(\theta_r))}$$

With these two equations one can finally obtain the refracted vector $\vec{rf}$.

Finally, another factor that needs to be considered in the analysis is the pixel spread. Pixel spread varies from screen to screen and in the simulator can be adjusted from 0 (pixel rays fully straight) to 89 degrees (fan like setting), it is worth noting that the more pixel spread, the more cross talk there is prone to happen in the end image for each user.

V. EXPERIMENT

To test the performance of the lenticular lenses for multiplexing user views, two experiments where made. The first one with commercially available lenses with 10, 15, 20, 30 and 3D-40LPI mated with three types of screen: a 3D TV LG55E6 (∼81ppi), an Asus PG278Q monitor(∼109ppi) and the iPhone X (∼458ppi).

The second experiment was performed with a theoretical lens specifically designed to fit the physical pixel sizes of the Asus PG278Q monitor and a theoretical screen of 55" with iPhone X pixel sizes.

Each of the tests were performed with three users evenly separated by 50 centimeters between users and 1 meter away from the screen.

Pixel spread was measured by drawing a vertical line on the screens and with a protractor attached to a camera we noticed that at ∼30 degrees from the center the screens contrast and brightness started to change. Two types of pixel spread where assessed with the screens, pixels with 0 deg spread and 30 deg spread.

If the reader noticed, the iPhone X doesn't support stereo nor is big enough for multiple users. This is on purpose and is to compare increasing pixel density across the screens and as of now in 2018 is one of the densest screens.

VI. DATA ANALYSIS

A. Commercially available lenses

Different lenses have different parameters. Depending on the lens/screen combination used, a given number of pixels can be fit under each lenticule as seen in table 1. Each of these values come from the lens manufacturer and affect how the refracted pixels get displayed in the monitor. The more pixels per lenticule the more pixels one can see from different angles but at the same time the less pixels available throughout the screen.

LPI	Material Type	Refrac Idx	Substrate thick (in)	Pitch (in)	Radius (in)	px/lent LG55E6	px/lent PG278Q	px/lent iPhoneX
10	Acrylic	1.47	0.1083	0.100	0.0601	8.062	10.896	45.876
15	Acrylic	1.47	0.0894	$0.06\overline{6}$	0.042	5.374	7.264	30.583
20	PETG	1.56	0.0575	0.050	0.0300	4.031	5.448	22.938
30	PETG	1.56	0.0401	$0.03\overline{3}$	0.020	2.687	3.632	15.291
3D40	PETG	1.56	0.0669	0.025	0.0309	2.0163	2.724	11.469

Table 1: Pixels availabe to fit per lenticule

All these values (screen and lens parameters) vary a lot depending on the combination used. In table 2, the LG55E6 TV has the largest and less dense screen (55", ∼81ppi). A relation between pixel density and ghosting can be seen on both spread and straight pixels; this screen being the less dense has the most ghosting (∼43% for the center user with a 10LPI lens and spread rays). This means that the center user for any given image it will perceive ∼50% of said image from other users.

The LG55E6 screen starts to show ghosting on the center user with straight pixels with just 20LPI, something that doesn't happen with the other monitors; with regards the

Asus PG278Q monitor, one can see in table 3 that ghosting is further reduced for the center user and even more in table 4.

Tables show that ghosting rapidly increases when the LPI increases for spread pixels, this is due to factors like uncomplete number of pixels that can be fit under each lenticule as the LPI raises among others, the 3D 40LPI lens suffers an abrupt change on shared pixels per user and ghosting values due to the fact that in this lens, the angle of view is narrower than a normal lens. It is also worth mentioning that the more "straight" the pixel rays are the better.

LPI	Ray type	pixels User 1	Shared User 1	pixels User 2	Shared User 2	pixels User 3	Shared User 3
10	Straight	613px (15.96%)	0px (0%)	1015px (26.43%)	0px (0%)	630px (16.41%)	0px (0%)
15	Straight	715px (18.62%)	0px (0%)	1172px (30.52%)	0px (0%)	733px (19.09%)	0px (0%)
20	Straight	821px (21.38%)	2px (0.24%)	1337px (34.82%)	5px (0.37%)	836px (21.77%)	3px (0.36%)
30	Straight	962px (25.05%)	228px (23.70%)	1725px (44.92%)	459px (26.61%)	1164px (30.31%)	231px (19.85%)
3D 40	Straight	1094px (28.49%)	324px (29.62%)	1873px (48.78%)	653px (34.86%)	1436px (37.40%)	329px (22.91%)
10	Spread	1177px (30.65%)	412px (35.00%)	1941px (50.55%)	828px (42.66%)	1198px (31.20%)	416px (34.72%)
15	Spread	1342px (34.95%)	650px (48.44%)	2192px (57.08%)	1292px (58.94%)	1363px (35.49%)	642px (47.10%)
20	Spread	1384px (36.04%)	725px (52.38%)	2280px (59.38%)	1451px (63.64%)	1420px (36.98%)	726px (51.13%)
30	Spread	1504px (39.17%)	1120px (74.47%)	2684px (69.90%)	2214px (82.49%)	1807px (47.06%)	1096px (60.65%)
3D 40	Spread	1330px (34.64%)	745px (56.02%)	2340px (60.94%)	1496px (63.93%)	1666px (43.39%)	751px (45.08%)

Table 2: User separation LG55E6 (3840x2160, ppi: ∼81).

LPI	Ray type	Pixels User 1	Shared User 1	Pixels User 2	Shared User 2	Pixels User 3	Shared User 3
10	Straight	323px (12.62%)	0px (0%)	812px (31.72%)	0px (0%)	342px (13.36%)	0px (0%)
15	Straight	401px (15.67%)	0px (0%)	961px (37.54%)	0px (0%)	417px (16.29%)	0px (0%)
20	Straight	397px (15.51%)	0px (0%)	1060px (41.41%)	0px (0%)	422px (16.48%)	0px (0%)
30	Straight	510px (19.92%)	31px (6.08%)	1291px (50.43%)	66px (5.11%)	538px (21.02%)	35px (6.51%)
3D 40	Straight	342px (13.36%)	199px (58.19%)	1866px (72.89%)	419px (22.45%)	382px (14.92%)	220px (57.59%)
10	Spread	685px (26.76%)	254px (37.08%)	1544px (60.31%)	519px (33.61%)	728px (28.44%)	265px (36.40%)
15	Spread	817px (31.91%)	454px (55.57%)	1793px (70.04%)	930px (51.87%)	869px (33.95%)	476px (54.78%)
20	Spread	748px (29.22%)	417px (55.75%)	1779px (69.49%)	838px (47.11%)	784px (30.62%)	421px (53.70%)
30	Spread	883px (34.49%)	650px (73.61%)	2036px (79.53%)	1312px (64.44%)	920px (35.94%)	662px (71.96%)
3D 40	Spread	668px (26.09%)	667px (99.85%)	2559px (99.96%)	1398px (54.63%)	731px (28.55%)	731px (100%)

Table 3: User separation PG278Q (2560x1440, ppi:∼109).

With ∼34% ghosting from the Asus PG278Q commercially available lenticular lenses are not feasible for multiplexing images.

LPI	Ray type	Pixels User 1	Shared User 1	Pixels User 2	Shared User 2	Pixels User 3	Shared User 3
10	Straight	123px (5.05%)	0px (0%)	478px (19.62%)	0px (0%)	59px (2.42%)	0px (0%)
15	Straight	143px (5.87%)	0px (0%)	553px (22.70%)	0px (0%)	69px (2.83%)	0px (0%)
20	Straight	157px (6.44%)	0px (0%)	585px (24.01%)	0px (0%)	76px (3.13%)	0px (0%)
30	Straight	189px (7.76%)	0px (0%)	689px (28.28%)	0px (0%)	98px (4.02%)	0px (0%)
3D 40	Straight	0px (0%)	0px (0%)	1191px (48.89%)	0px (0%)	0px (0%)	0px (0%)
10	Spread	500px (20.53%)	178px (35.60%)	1328px (54.52%)	356px (26.81%)	386px (15.85%)	178px (46.11%)
15	Spread	580px (23.81%)	282px (48.62%)	1494px (61.33%)	548px (36.68%)	446px (18.31%)	266px (59.64%)
20	Spread	582px (23.89%)	276px (47.42%)	1411px (57.92%)	544px (38.55%)	463px (19.01%)	268px (57.88%)
30	Spread	611px (25.08%)	335px (54.83%)	1487px (61.04%)	648px (43.58%)	480px (19.70%)	313px (65.21%)
3D 40	Spread	3px (0.12%)	2px (66.67%)	2435px (99.96%)	2px (0.082%)	0px (0%)	0px (0%)

Table 4: User separation iPhone X 5.85", ppi: ∼458.

B. Designing a theoretical lens

Commercially available lenses are still difficult to accomodate to screens without ghosting regardless the pixel density. Which values should be tweaked then to generate a lens that maximizes the the number of pixels per user for multiplexing images while minimizing ghosting the most?

Some values are easier to modify than others in the physical world we live in. The index of refraction is a variable that is innate from the material the lens is made of; if one decided to modify the index of refraction one would need to change the material the lens is made of and find another material that has a solid structure, can be molded to the other lens variable requirements and has the index of refraction one is looking for. Due to this, is easier to modify other values from the lens like the substrate thickness, lens pitch and lenticule radius and leave the index of refraction unchanged.

An ideal lens for any specific screen lies on the mix of the optimum values for the correct substrate thickness, lens pitch and lens radius. All these values should minimize the ghosting among the interacting users while maximizing the number of unique pixels seen by any given user regardless of their position.

To find the correct lens values a geometric approximation to this problem was thought. A three axis space of combinations between pixels per lenticule (x), substrate thickness(y) and maximum ghosting perceived from all the interacting users(z) or the minimum number of pixels either of the users perceive(z') is generated. All of these values separated by an increase of the minimum radius allowed for each of the lenses with increases of 10% up until double the minimum radius permitted by each lens.

On the pixels per lenticule axis, values go from 1 to 50 pixels with 1 pixel increment. With regards to the substrate thickness axis, values vary from 0 to 3mm with increments of 0.25mm. Finally, the third axis lets one assess the maximum percentage of ghosting between the interacting users, the minimum unique pixels a user perceives or the minimum percentage either of the user sees from the screen.

B.1 Theoretical lens for the Asus PG278Q monitor. With a resolution of 2560 pixels with a pixel size of 0.2331mm, pixel spread of ∼30 degrees and 55 rays per pixels calculated from the screen, the reader can look on figure 9 how the different lens values for a substrate thickness of 0.5mm looks like.

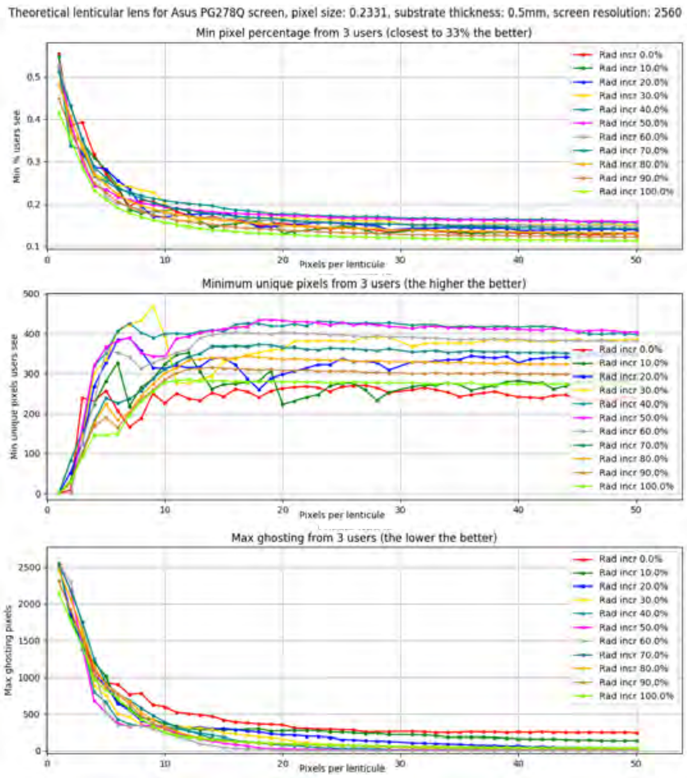

Figure 9: Lens combinations Asus PG278Q monitor. 30deg spread, 55 rays per pixel

If the reader notices, the ideal lens radius for this monitor lays between 40% and 60% increase from the base model. As one can see in figure 9, with a radius increase of 50% and 18-21 pixels per lenticule there is minimum ghosting for the three users with a maximum number of unique pixels for either the three with around a minimum of 18% screen share from the users.

To keep the 3D graphs readable, only lens radius increments from 30% to 70% where included in the graphs. If the reader would like to see a specific lens value and how it affects each of the three users, one can refer to the data in (Simulator a)

In figure 9 the reader can see that the lens that maximizes the minimum number of unique pixels perceived by either of the three users and at the same time minimizes ghosting the most is a lenticular lens that has 21 pixels per lenticule with a radius increase of 50% from the minimum supported lens radius for a screen that has physical pixel sizes of 0.2331mm.

Unfortunately, if the reader notices, a minimum of around 400 pixels for a user is just not enough to assemble an image with enough detail for today's standards.

B.2 Theoretical lens 55" screen with iPhone X px size. How would the multi user experience be with a 55" screen with iPhoneX physical pixel sizes?. Said screen will consist of 21580 pixels and as shown in figure 10 it will provide at a minimum, 5K images for either of the users.

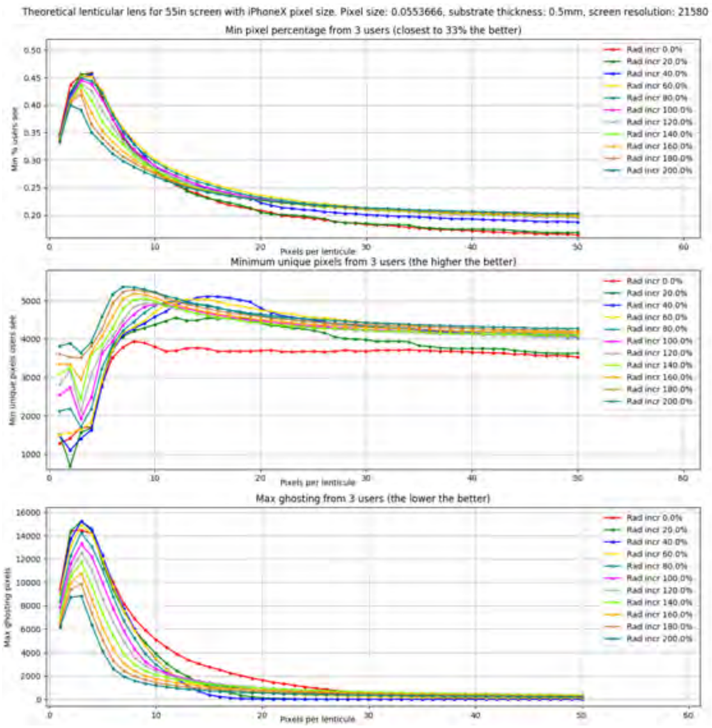

Figure 10: Lens combinations theoretical 55" screen. 21580px, 30deg spread, 55 rays per pixel.

If the reader looks closer at figure 10, one will notice that the value that maximizes the minimum amount of unique pixels and minimizes ghosting is a lenticular lens with 18 to 19 pixels per lenticule with a radius increase of 40-50% from the minimum lenticule radius.

In figures 11, and 12 the reader can also see how the substrate thickness affects the values. These values where generated with 20 to 80% radius increase in order to make it easier to understand the graph.

All of these values where calculated with the simulator; If the reader is interested to see how the other lens radiuses affect the graph, one can look in (Simulator b) to check the data.

VII. Conclusions

A simulator for lenticular lenses was presented and the mathematics of the lenticular lens where introduced and explained. It was shown that pixel density is a big factor that contributes to ghosting when multiplexing images.

Ghosting is one of the factors that deter the most the experience when multiplexing different images through one

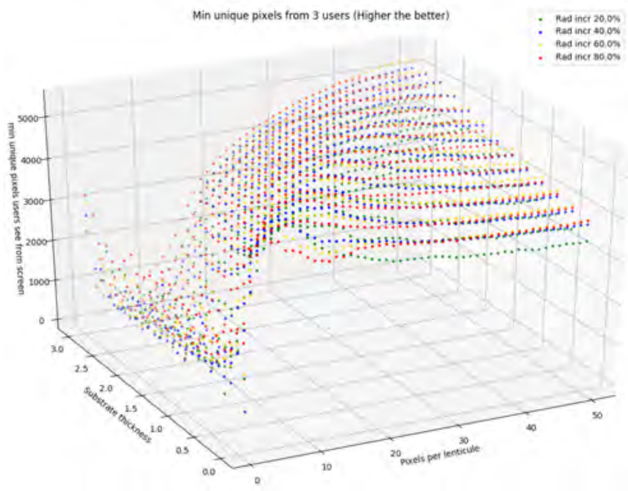

Figure 11: Lens combinations theoretical screen minimum unique pixels per user.

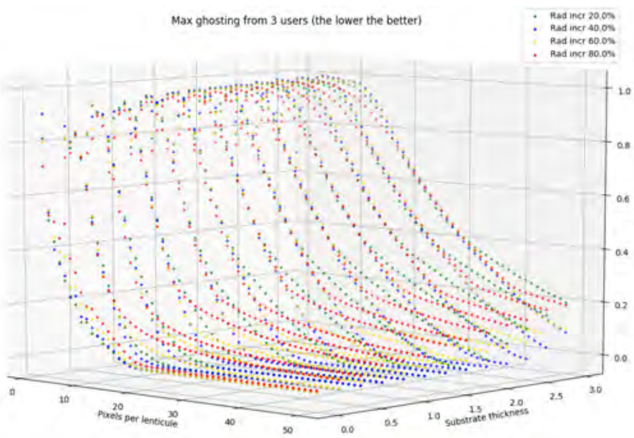

Figure 12: Lens combinations theoretical screen for maximum ghosting users get.

screen. Pixel spread is a contributing factor when using lenticular lenses, as shown in this paper, the more straight the rays from pixels are the less ghosting the system will produce.

Commercially available lens values where tested and assessed with commercially available screens and it was shown that they are not good enough for multiplexing users; still. With straight pixel rays these lenses could be usable.

A theoretical lens was designed for the Asus PG278Q monitor and it was shown that the lens that maximizes the pixels perceived per user and minimizes ghosting the most is a lens with 50% radius increase from the minimum possible radius with 21 pixels per lenticule and a substrate thickness of 0.5mm.

A theoretical screen of 55inch with pixel sizes of the iPhone was also presented and analyzed. The minimum number of pixels a user perceives is a 5k image with zero ghosting with a lens that has between 18-19 pixels per lenticule, a radius increase of 40-50% from the minimum lenticule radius and a substrate thickness of 0.5mm.

In the case it's not possible to physically make a lenticular lens of said requirements due to the substrate thickness; it's feasible to increase the thickness to some extent without inducing ghosting.

VIII Future work

Pixel spread is a contributing phenomenon to ghosting. Privacy screens reduce the spread to a degree but they don't completely make pixel rays straight. It would be worth checking for materials from privacy screens to see if its possible to completely make the rays from pixels straight.

The lenticular lens simulator helped assessing and finding the best lens values for any given screen setup. Unfortunately it doesn't show the amount of color banding from subpixel augmentation the lenses produce. A ray tracer could show how much banding is generated with the optimal lens values covered in this paper and perhaps find a method to know to what extent banding is produced for any given pixel size and lens without needing to have the physical lens/screen.

Subpixel layout is a critical factor that either can make colors look different from pixel to pixel on some screens or can produce subpixel augmentation when using low LPI lenses; it would be worth doing a further analysis to asses which subpixel layout would be best for reducing subpixel augmentation from low LPI lenses and at the same time not lose pixel brightness similarity across the screen.

User movement should be considered for the data in order to see if the best lens values are consistent regardless user's positions within limits.

References

[1] AmBrSoft. 2018. Intersection of a circle and a line. http://www.ambrsoft.com/TrigoCalc/Circles2/circlrLine_.htm. Accessed: 2018-Nov-14.

[2] Bolas, M.; McDowall, I.; and Corr, D. 2004. New research and explorations into multiuser immersive display systems. *IEEE computer graphics and applications* 24(1):18–21.

[3] Brar, R. S.; Surman, P.; Sexton, I.; Bates, R.; Lee, W. K.; Hopf, K.; Neumann, F.; Day, S. E.; and Willman, E. 2010a. Laser-based head-tracked 3d display research. *Journal of Display Technology* 6(10):531–543.

[4] Brar, R. S.; Surman, P.; Sexton, I.; and Hopf, K. 2010b. Multi-user glasses free 3d display using an optical array. In *3DTV-Conference: The True Vision-Capture, Transmission and Display of 3D Video (3DTV-CON), 2010*, 1–4. IEEE.

[5] De Greve, B. 2006. Reflections and refractions in ray tracing. *Retrived Oct* 16:2014.

[6] Kikuta, K., and Takaki, Y. 2007. Development of svga resolution 128-directional display. In *Stereoscopic Displays and Virtual Reality Systems XIV*, volume 6490, 64900U. International Society for Optics and Photonics.

[7] Kooima, R.; Prudhomme, A.; Schulze, J.; Sandin, D.; and DeFanti, T. 2010. A multi-viewer tiled autostereoscopic virtual reality display. In *proceedings of the 17th ACM Symposium on Virtual Reality Software and Technology*, 171–174. ACM.

[8] LenstarLenticular. 2018. Possible lenticular effects. https://www.lenstarlenticular.com/lenticular-effects/ Accessed: 2018-Nov-12.

[9] Lipton, L., and Feldman, M. H. 2002. New autostereoscopic display technology: the synthagram. In *Stereoscopic Displays and Virtual Reality Systems IX*, volume 4660, 229–236. International Society for Optics and Photonics.

[10] Little, G. R.; Gustafson, S. C.; and Nikolaou, V. E. 1994. Multiperspective autostereoscopic display. In *Cockpit Displays*, volume 2219, 388–395. International Society for Optics and Photonics.

[11] Matsumoto, K., and Honda, T. 1997. Research of 3d display using anamorphic optics. In *Stereoscopic Displays and Virtual Reality Systems IV*, volume 3012, 199–208. International Society for Optics and Photonics.

[12] Matusik, W., and Pfister, H. 2004. 3d tv: a scalable system for real-time acquisition, transmission, and autostereoscopic display of dynamic scenes. In *ACM Transactions on Graphics (TOG)*, volume 23, 814–824. ACM.

[13] Microlens. 2018. Choosing the correct lenticular lens sheet. `http://www.microlens.com/pages/choosing_right_lens.htm`. Accessed: 2018-Nov-12.

[14] Nakanuma, H.; Kamei, H.; and Takaki, Y. 2005. Natural 3d display with 128 directional images used for human-engineering evaluation. In *Stereoscopic Displays and Virtual Reality Systems XII*, volume 5664, 28–36. International Society for Optics and Photonics.

[15] Nguyen, D., and Canny, J. 2005. Multiview: spatially faithful group video conferencing. In *Proceedings of the SIGCHI conference on human factors in computing systems*, 799–808. ACM.

[16] Nguyen, D. T., and Canny, J. 2007. Multiview: improving trust in group video conferencing through spatial faithfulness. In *Proceedings of the SIGCHI conference on Human factors in computing systems*, 1465–1474. ACM.

[17] Omura, K.; Shiwa, S.; and Miyasato, T. 1998. Lenticular autostereoscopic display system: multiple images for multiple viewers. *Journal of the Society for Information Display* 6(4):313–324.

[18] Pollock, B.; Burton, M.; Kelly, J. W.; Gilbert, S.; and Winer, E. 2012. The right view from the wrong location: Depth perception in stereoscopic multi-user virtual environments. *IEEE Transactions on Visualization & Computer Graphics* (4):581–588.

[19] Projects, A. 2011. Circle and line intersection. `http://apetrilla.blogspot.com/2011/12/circle-and-line-intersection.html`. Accessed: 2018-Nov-14.

[20] Simulator. Lens combinations pg278q. `https://goo.gl/vD5Bbd`. Accessed: 2018-Nov-20.

[21] Simulator. Lens combinations theoretical 55in. `https://goo.gl/VaKf2h`. Accessed: 2018-Nov-20.

[22] Surman, P.; Sexton, I.; Hopf, K.; Lee, W. K.; Bates, R.; IJsselsteijn, W.; and Buckley, E. 2006. Head tracked single and multi-user autostereoscopic displays.

[23] Szalavári, Z.; Schmalstieg, D.; Fuhrmann, A.; and Gervautz, M. 1998. "studierstube": An environment for collaboration in augmented reality. *Virtual Reality* 3(1):37–48.

[24] Takaki, Y., and Nago, N. 2010. Multi-projection of lenticular displays to construct a 256-view super multiview display. *Optics express* 18(9):8824–8835.

[25] Takaki, Y.; Yokoyama, O.; and Hamagishi, G. 2009. Flat panel display with slanted pixel arrangement for 16-view display. In *Stereoscopic Displays and Applications XX*, volume 7237, 723708. International Society for Optics and Photonics.

[26] Takaki, Y. 2005. Thin-type natural three-dimensional display with 72 directional images. In *Stereoscopic Displays and Virtual Reality Systems XII*, volume 5664, 56. International Society for Optics and Photonics.

[27] Takaki, Y. 2009. Super multi-view display with 128 viewpoints and viewpoint formation. In *Stereoscopic Displays and Applications XX*, volume 7237, 72371T. International Society for Optics and Photonics.

[28] Van Berkel, C., and Clarke, J. A. 1997. Characterization and optimization of 3d-lcd module design. In *Stereoscopic Displays and Virtual Reality Systems IV*, volume 3012, 179–187. International Society for Optics and Photonics.

[29] Van Berkel, C. 1999. Image preparation for 3d lcd. In *Stereoscopic Displays and Virtual Reality Systems VI*, volume 3639, 84–92. International Society for Optics and Photonics.

[30] Wikipedia. 2018. Lenticular lens. `https://goo.gl/t2yQ4L`. Accessed: 2018-Nov-12.

[31] Zang, S.-F.; Wang, Q.-H.; Zhao, W.-X.; Zhang, J.; and Liang, J.-L. 2014. A frontal multi-projection autostereoscopic 3d display based on a 3d-image-guided screen. *Journal of display technology* 10(10):882–886.

Using VR technology to improve BIM: maintenance and construction

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ABSTRACT
Research on the application of virtual reality (VR) in the construction activity, adopted normally low-immersive desktop VR or highly immersive VR, which involves using a mobile headset. Immersive VR spaces can promote a better communication between clients and specialist, around a building, in a maintenance or inspection activity, or in the real construction place, following the planned construction steps. The two primary features of VR are immersion and presence. And when linked with the building Information modeling (BIM) concept, consulting and handling information, are complementary features that can improve both technologies. Most VR environments constitute a visual experience displayed on a computer screen, but using the most advances VR technologies over the 3D BIM model a more immerse space can be handle. Simulating the real world can be improve with VR+BIM, as the interactive capacities allowed by VR software, and the access to information archive in a BIM model, supports in a more intuitive way maintenance and construction control tasks.

Keywords
BIM, VR, VR software, VR+BIM applications, construction.

1. INTRODUCTION
Building Information Modelling (BIM) is a methodology supported in a virtual three–dimensional (3D) model-based process, allowing modelling and the management of all activities inherent to Construction. It provides architects and engineers the visualization and the tools to plan, design, build and manage more efficiently engineering works. BIM, as a concept, has been coming essential; supporting the development of multitasks within the Construction industry, including concept/design, construction work planning/scheduling or maintenance/management of buildings. BIM implementation is widely disseminated in the international community and across several sectors within the Construction field [1]. The technological progress achieved over the past years, leads to the development of new and better products.

VR technology has undergone continual development, produced many applications, and is used by the construction industry to facilitate communication and the understanding of building components. Furthermore, VR reduces the risk of exclusion of certain professional groups from the maintenance process or construction work. In addition, the intuitive interaction with the VR system allowed for a much faster entry into the inspection activity. Considering the cost and ease of use of related equipment, most applications have mainly used desktop VR. Nevertheless, practical application of this technology requires that problems concerning hardware and space be solved.

VR will not replace the traditional maintenance process on screen, but it provides a useful addition to engineering companies helping specialist to communicate better with other members of the team including the client [2]. Boundary-pushing concepts can be tested and refined at a human scale in the virtual world, long before committing to real-world construction, and professional can use VR to build better buildings and improve the client experience.

VR technology still needs to evolve, but as the pace of innovations accelerates, systems allow for more novel modes of visualization and interaction to support engineering design reviews. Currently, the classic design review process is often performed on a PC with the support of CAD software packages. However, CAD on a screen cannot always meet all the requirements and a BIM model containing, in a centralized way, all the information, can easily support the access to all type of information, concerning construction or maintenance [3]. The text analyses the degree of achievement allowed by the actual software to perform each aspect combining BIM and VR.

2. VR INTERACTION
Virtual Reality and BIM can improve building construction and asset management. The sense of presence in a virtual space, building in inspection or local place of a construction in progress, is much truly as advanced technological VR devices is used. The sensation of actually being inside a building makes VR an important powerful tool for communicating design intent. Clients, in particular, often don't have the ability to understand spatial relationships and scale simply by looking at a 2D plan or 3D model. And VR can evoke an almost real response that physical architecture can.

Most CAD and BIM models feature extremely detailed geometry, which is not needed for VR. Fully interactive VR software also has extremely high performance demands, so some form of model optimization is required when bringing BIM data into a VR environment. This is one area where specialist VR consultancies earn their keep with finely tuned processes for tasks like simplifying geometry, adding lighting, fixing gaps in the model and culling objects that will not be visible in the scene [4].

BIM can reduce risk levels and improve design management around key activities in construction and Virtual Reality can help to identify potential problems in the design before construction commences and reduce coordination errors. Contractors are able to manage and reduce risk through using BIM for 4D simulation, on site spatial coordination, and clash detection.

In an engine VR experiences the onus tends to be on presenting a polished vision of a proposed building, rather than delivering practical tools for solving real world design and construction problems. Currently there are various applications of virtual reality tour applied in the field of construction (Figure 1):

- Software like **Navisworks** or **Tekla BIMsight**, are equivalent tools inside a VR environment, as they are not VR software but BIM models can be seen and handling inside. Navisworks project review software lets architecture, engineering, and construction professionals holistically review integrated models and data with stakeholders during preconstruction to control project outcomes. Tekla BIMsight is a professional tool for construction project collaboration, allowing the entire construction workflow combining models, check for conflicts and share information using in a BIM environment;

- While most game engines strip out metadata, which is important for true BIM processes, when moving from Revit to **Autodesk Stingray**, data is not only retained, but users can click on objects and view the underlying attribute information;

- **Revizto**, is a dedicated tool for turning BIM models into navigable 3D environments, has a similar capability. In VR mode, users can click on an object to view information, including metadata. Revizto is a visual collaboration software for the AEC (Architecture, Engineering and Construction) industry. Connects BIM and VDC specialists with stakeholders and streamlines BIM coordination workflow;

- **IrisVR Prospect** retains BIM data when importing models from Revit, although the developers have not yet delivered tools to work with this data. Prospect can streamlined VR delivery process, both internally for office design reviews;

- **WorldViz** is investing in collaborative VR and is already used for co-presence experiences where users can interact with each other in the virtual world. Participants of a construction planning review session can highlight different aspects of the construction design simply by moving their virtual hands or pointing lasers at objects and VR scene can also stop real-life collisions.

- Looking to the future and taking this idea a step further, Microsoft's 'mixed reality' **HoloLens** could even be used to visualise a holographic 3D BIM model in context on site. Using augmented reality, users could solve issues by literally seeing the design model overlaid on a partially constructed building;

- **Virtalis** is specialize in virtual reality CAVEs and walls that use powerful projectors and 3D glasses to deliver a 1:1 scale experience. Deploying a CAVE on a construction site, could help problem-solve issues between the real and virtual worlds, combining as- built data with BIM models.

Figure 1: VR use in Navisworks, Tekla BIMsight, Revizto, IrisVR Prospect, WorldViz, HoloLens and Virtalis.

Combining BIM and VR clients can easily walking through the actual life sized model of an on-going construction place or a building in inspection. The specialist can be sitting virtually inside the model and evaluate every nook and cranny of it. This is an fruitful improvement than sitting at a table and zooming into a 15' screen. The acceptance and expansion of VR has been growing exponentially. Ever since embracing the idea of VR, the AEC sector has benefited a great deal. As per the reports, companies began seeing faster project approvals, increased positive client interactions and higher client satisfaction. The checklist can be prepared smoothly so as to save valuable time and money for the company as well as the client. With all the rapid progress happening, it is not surprising that architects, engineers and construction techies are already exploring the length and breadth of this technology.

3. CONSULTING BIM DATA

An accessible high end visualization and virtual reality of a BIM model is obtain using the VR plugin of Revit, the Enscape [5]. Enscape is a virtual reality (VR) and real-time rendering plugin for Revit. Inside Revit is possible to access the plugin Enscape and start to walk through the fully rendered project, without uploading to cloud or exporting to other programs. A virtual tour together with Enscape allows the facility manager to look around the facility and check the conditions of equipment and obtain relevant information from the BIM model. For instances, visualizing the BIM model of a MEP system, in a virtual tour and using on a tablet PC, helps the facility manager to understand what is installed behind the ceiling tile. The user can observe both models in Revit and in Enscape (Figure 2). So, all changes in Revit are immediately available to evaluate in Enscape.

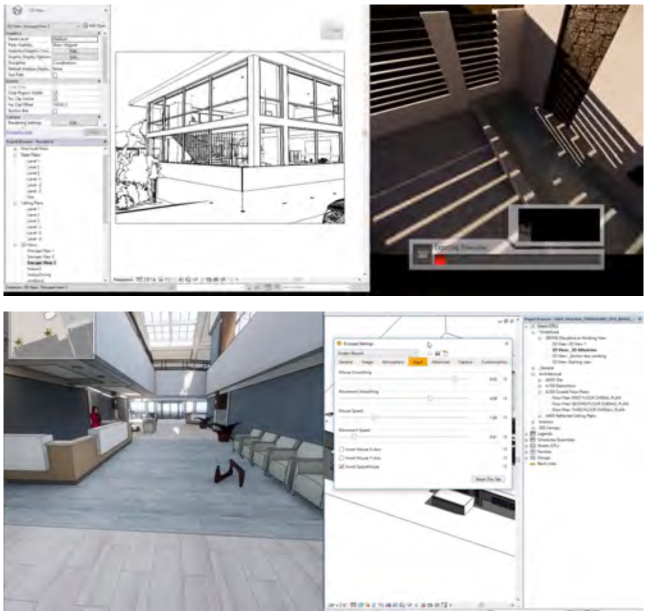

Figure 2: Enscape plugin of Revit

With the plugin, the user is able to quickly explore different design options and present projects to clients. If the client wants to see alternative solutions or changes in the design, Enscape will immediately show the changes the designer makes in the project. With the option to create standalone files, is possible to send an Enscape file to the clients or colleagues which allow the engineer to quickly demonstrate the project. Enscape has become a standard application in projects worldwide. As the Revit allows the user can work over the model applying all the capacities of modelling, consulting the information linked to the parametric objects used in the model process, and obtain cuts over perspectives allowing the analyses of the composition of all elements of the BIM model. So the aspect of linking the consulting capacity and the VR ability of walking around is a very important improvement in the use of BIM methodology. To improve VR experience Enscape can also be used together with Oculus Rift.

In construction activity the use of Virtual Reality brings great potentials. Presenting BIM models of projects in VR environment redefines communication and collaboration in the field and in the office. BIM technology and VR have the ability to innovate the building industry. Collaboration in VR can be the future of VR BIM. At a first glance, many feel the benefits of using a BIM model with VR are purely for marketing leveraging the 3D model for visual aids, but taking a deeper look at a BIM model it will reveal many practical reasons to adopt BIM with VR.

CAVE-like platforms have been developed for immersive VR experience as they track user's head and control wand usually with 6 degrees of freedom, to navigate inside the virtual environment and interact with the contents. Due to its immersive experience and intuitive manipulation capability, it quickly gained popularity in both research and industry community. But also VR head-mounted displays (HMDs) such as the Oculus Rift have the capacity to improve the way architects design and communicate buildings before they are built. The wearer is instantly immersed in a true three dimensional environment that gives an incredible sense of scale, depth and spatial awareness that simply cannot be matched by traditional renders, animations or physical-scale models. The sense of presence was overwhelming.

This sensation of actually being inside a building also makes VR an incredibly powerful tool for communicating design intent. Clients, in particular, often don't have the ability to understand spatial relationships and scale simply by looking at a 2D plan or 3D model [9]. VR can evoke a visceral response in exactly the same way that physical architecture can play an important role at all stages of the design-to-construction process, from evaluating design options and showcasing proposals, to designing out errors and ironing out construction and serviceability issues before breaking ground on site.

Fully interactive VR software also has extremely high performance demands, so some form of model optimization is required when bringing BIM data into a VR environment. This is one area where specialist VR consultancies earn their keep with finely tuned processes for tasks like simplifying geometry, adding lighting, fixing gaps in the model and culling objects that will not be visible in the scene. Once the model is inside the VR environment, things like materials, lighting, furniture and other small details that make the VR experience feel real are added.

Compared to dedicated AEC design review software like Navisworks or Tekla BIMsight, equivalent tools inside a VR environment are still very much in their beginning. This is particularly true of game engine VR experiences, where the onus tends to be on presenting a polished vision of a proposed building, rather than delivering practical tools for solving real world design and construction problems. When moving from Revit to Autodesk Stingray, data is not only retained, but users can click on objects and view the underlying attribute information. In VR mode, users can click on an object to view information, including metadata.

In view of growth of Building Information Modelling in various EU Member States, ACE has established in 2015 a work group to look at the legal, technical and financial issues surrounding the advent of BIM, develop its policy and engage with work to develop an European (CEN) standard. The Conference "BIM IN EUROPE" will present the results of two years of work of the ACE BIM Work Group, together with interventions by the EU BIM Task Group, CEN Committee and BIM users. The event is organized with the support of the Creative Europe Program of the European Union. The next summit will be held in December in Brussels, Belgium.

4. CONCLUSIONS

For architects and designers, VR+BIM enable them to better communicate design. A challenge for architects is that of communicating concepts and visions for buildings. The advantage to using VR is in the communication of ideas, concepts and the vision for their building. This enables all the parties to more quickly reach a full appreciation of the building plan. When everyone shares a common understanding of the design, the project is executed more efficiently from the outset. This current BIM with VR topic require dissemination; application in real cases and pointed out, in reports, achievements and limitation; following the technologic advances that supports the BIM use and the visualization of data, in real time while the interacting with the model made possible by VR technology. BIM + VR provide an opportunity to analyze and explore BIM models within virtual environments.

5. REFERENCES

[1] Eastman, C., Teicholz, P., Sacks, R. and Liston, 2011, K, *BIM Handbook: A Guide to Building Information Modeling For Owners, Managers, Architects, Engineers and Contractors*. Publisher John Wiley & Sons Inc, Publication date 18 May 2015, Edition Statement 2nd Edition, ISBN10 1118942760, ISBN13 9781118942765.

[2] J. Wolfartsberger, J. Zenisek, C. Sievi, M. Silmbroth, 2017, *A Virtual Reality supported 3d environment for engineering design review*, in: 2017 23rd International Conference on Virtual System Multimedia (VSMM).

[3] Kieferle, J., and Woessner, U. 2015. *BIM Interactive - About Combining BIM and Virtual Reality, A Bidirectional Interaction Method for BIM Models in Different Environments*, Proceedings of the eCAADe 33, 14 – 15 September, 2015, Vienna, Austria, 69-75.

[4] Breen, J., 2017, *Design and Build Better with VR and BIM*, Proceedings of the Auckland Build 2017

[5] Enscape plugin of Revit https://enscape3d.com/

New collaborative game experiences, the example of “Game Jockey”

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ABSTRACT
We present a research on the possible interactions between the disk jockey and video game creation. After a description of the practice of disk jockey, we propose a theoretical model applied to the video game we call: game jockey. Based on this model, we present and analyze three creations. The last one offers an interactive interface allowing to mix elements characteristic of other games with activated clips.

Keywords
Video game, remix, jockey, game master, research-creation, technologies, visual interface, digital, interaction

1. INTRODUCTION
Our approach is part of an artistic desire to hybridize the practice of disk jockey (DJ) with video game creation. We observe that the disk jockey practice proposes a creative method based on the mix, using technologies, allowing an exchange with the public that could renew our way of creating video games. We call this new form of DJ-inspired video game creation: the Game Jockey.

It is in this context that we ask ourselves how to proceed to carry out this hybridization: what characteristics could be important in the creation of video games for mixing? How to distinguish players from a jockey in a video game device? What kind of video game could be produced with the game jockey?

We will answer these questions on the basis of a research-creation with 3 experiments trying to reproduce the DJ model for videogame creation. First, we propose a description of the practice of disk jockey and the examination of our video game creation needs, so we will be able to formulate a model for the Game Jockey, on which our three creative experiences will be based. In the end, we will be able to offer a software solution to produce a DJ-like experience applied to video games creation.

2. MIX THE DISK JOCKEY WITH THE CREATION OF VIDEO GAME
The disk jockey is a musical performance activity on stage where a person (the jockey) produces a mix (selection of musical parts) using more or less complex technological instruments, in interaction with an audience. To use Frank Broughton's expression: "DJs track down greatness in music and squeeze it together." [1]. The practice is of interest to researchers who do not hesitate to develop new technologies and uses[2]. We join this enthusiasm for the practice of disk jockey: to have more or less complex instruments to produce an aesthetic experience for an audience, while exploiting a library of sounds selected in advance.

To define the practice of the game jockey, we need to define the basis of the video game mix. For this we rely on two conceptions of video game from a fragmentary point of view[3] : the game design pattern[4], allow us to consider models common to games that can be exchanged, and the game feel[5], allow us to consider the specific interactions of video game through variables that can evolve over time.

From these references we propose the following game jockey model: it is a practice where a jockey with technological tools mixes patterns and the game feel in live performance for an audience of players. This performance evolves with the interactions between the three components: the product mix, the jockey and the players (see Fig. 1).

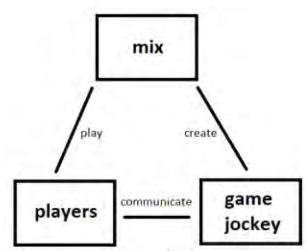

Figure 1. Diagram of Game Jockey model.

3. CREATION EXPERIMENTS BASED ON THE THEORETICAL MODEL OF THE GAME JOCKEY

3.1 First experiment of variations of the game in live performance
To experiment with our theoretical jockey game model, we started with two creations: Avoid and Starship.

Avoid is a video game with 1 to 6 players in competition where the goal is to avoid obstacles and survive the longest (Fig. 2). Players have two ground buttons that allow them to move the character to the left or right. We have integrated a limited practice of the jockey through an operator next to the screen with a mixer allowing to modify several parameters of the game: visual elements, speed of movement of the obstacles, frequency of their appearance, size of the obstacles.

Starship is the second video game with 1 to 6 players in cooperation where the goal is to get the most points by destroying opponents who can also destroy us (Fig. 3). To do this, players have 4 buttons to generate a different attack and two buttons to move the players' starship to the left or right. In this way, players contribute together to the control of the starship. It should be noted that the button can have a specific color programmed. The color of the button change with gameplay. So, each time the starship is touched by computer-controlled opponents, the function and the color of the buttons is reversed, requiring players to communicate with each other to define a new role (verbally or with gestures). If the sound is too lound during the performance, players use gestures with arms or jump to precise the new role of buttons. Like Avoid, we have integrated a Jockey figure that can intervene on visual and gameplay elements by modifying the size and speed or the characters' appearance. We have also enhanced this function by saving the game jockey mix, so that we can reuse them in live performance or modify them accordingly.

3.2 Mix variables in live performance with activatable clips

Although the first two experiments allowed us to experience a jockey practice through live performance, we noticed that it was mainly a modification of the values of a pre-existing game. It is through our third and final creation that we will move closer to this objective thanks to the complexity of its mechanism. It is always a cooperative game called Rez-jockey for 1 to 4 players where a series of opponents must be destroyed. Nevertheless, the environment, opponents or possibilities of action will be able to be changed in a more profound way by the jockey.

The jockey device consists of a mixer, a Launchpad and a computer with a gameplay mixing application. The application is inspired by FL Studio's Live Performance: we organize clips (finished sound recordings) that can be activated and deactivated at any time. We have reproduced this principle and adapted it to the real-time of video games in Unity 3D (Fig. 4). We found very interesting the idea that clip playback could be done in an intelligent way (playing clips in sequence, random playback, one-time playback, etc.). Thanks to this process we were able to record events that signal to the game our desire to make this or that element of the set appear, to make this or that amount of opponent appear, to change the function of the players, etc.

To make our mix, we considered that each clip was like a characteristic element of other games: the way to move around in one game, the appearance of sets in another game, the rule system specific to yet another game, etc. This live video clip choice brings us closer to the attitude of the disk jockey, applied to video game creation.

4. CONCLUSION

The game jockey is a live performance device involving three components: the mix (result produces performance, perceived as new game), the jockey (performer using technological tools producing the mix) and the players (performers playing the mix produced by the jockey).

From the last jockey game system, we were able to demonstrate that it was possible to practice a mix of game elements that could come from different origins. The choice to develop a solution separate from the original set allowed us to avoid being locked in the modification of a pre-existing set.

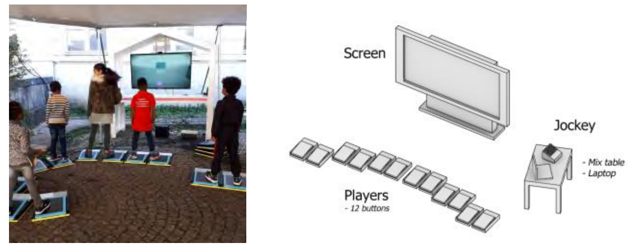

Figure 2. Avoid ingame (left) and its diagram (right)

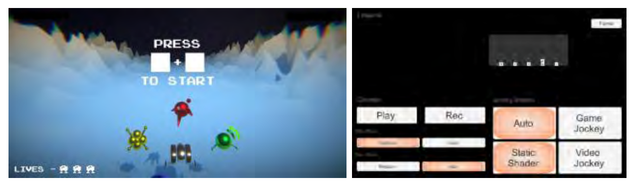

Figure 3. Starship ingame (left) and jockey interface (right).

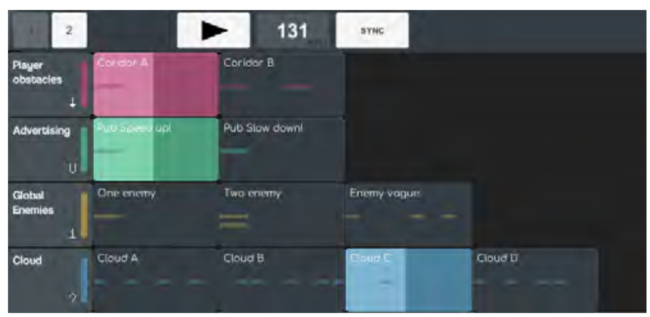

Figure 4. Game jockey with activated clips.

5. REFERENCES

[1] Broughton F. and Brewster. 2003. How to DJ right. The art and science of playing records. Grove Press, New York. P. 11

[2] Beamish T., Maclean K. and Fels S. 2004. *Manipulating Music : Multimodal Interaction for DJs*. Proceeding CHI '04 of the SIGCHI Conference on Human Factors in Computing Systems. ACM. https://doi.org/10.1145/985692.985734

[3] Lenhart, I. 2013. Defragmentation and Mashup : Ludic Mashup as a Design Approach. Proceeding of the 2013 DiGRA International Conference: DeFragging Game Studies.

[4] Björk S. and Holopainen J. 2004. Patterns In Game Design. Charles River Media, Boston.

[5] Swink S. 2008. Game Feel: A Game Designer's Guide to Virtual Sensation. Morgan Kaufmann, Burlington.

Effects of a Physical Prop on Torso Movement in a Virtual Reality Shooter

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ABSTRACT

Lower back pain is becoming an increasing problem due to low physical activity and prolonged sitting. For the purpose of rehabilitation, this project measures torso movement of different shooting methods in a Virtual Reality game and tests whether a physical rifle prop increases movement and immersion. Four different shooting methods were implemented and compared to each other. Tests were conducted on healthy participants with motion trackers placed between their shoulders and on their lower back to measure the difference in rotation between the two trackers. Furthermore, the participants evaluated the shooting methods through a questionnaire where they ranked them in terms of fun and comfort as well as picking the most immersive and overall preferred way of interaction. Test results show that the rifle prop was the most immersive, fun and overall preferred. Analysis of the rotation data showed that the prop increased rotation around the horizontal axis compared to using the rifle without a prop. The single handed pistol increased rotation around the vertical axis and increased a sidewise tilting motion compared to the three other shooting methods. In conclusion the prop did increase immersion, but only increased rotation around one axis. Further evaluation under different conditions are needed in order to single out the best method for rehabilitation.

CCS CONCEPTS

• **Human-centered computing → Interactive systems and tools**; *Virtual reality*; • **Software and its engineering →** *Interactive games*; Software creation and management;

KEYWORDS

Props, Virtual Reality, Games, Exergaming, Low Back Pain, Rehabilitation

1 INTRODUCTION

Lower back pain (LBP) is one of the world's most common and costly medical problems today [4, 16], and is mostly due to low physical activity and prolonged sitting [4]. Advice for treating LBP is to avoid bed rest, stay active and continue with daily activities. Furthermore, medication like paracetamol can help relieve LBP symptoms [12]. To help with treatment of LBP, physiotherapists may prescribe an exercise regime for the patient. It is, however, important to individualise the needs of the patient, as change of lifestyle can be challenging and the dropout rates lie around 50% [28]. If patients experience pain during therapy, they may develop a fear of movement due to pain known as kinesiophobia. This may lead patients to refrain from movement and hinder their rehabilitation progress [32].

Games have become a prevalent form of entertainment in recent years and are an interactive entertainment form popular with people of all ages [10]. This is also why the concept of "gamification" [1] has become popular, as it can be used to provide motivation to do monotonous and repetitive tasks [2]. By overcoming the challenges that games present to the player, who is immersed in the virtual world, their body can release chemicals that make them feel physical and mental pleasure. This was seen in the game Dance Dance Revolution which was discovered to have an impact on weight loss and attitudes towards health and exercise [17]. Utilising movement as interaction appears to be a good way to combine games and rehabilitation. One emerging tool that uses the human body for input is Virtual Reality (VR).

One popular genre of VR games are first person shooters (FPS). In real life, there are different stances and different ways to hold a gun. Especially two-handed guns are challenging to simulate in VR. One study [19] tried to make a controller that can swap between one and two-handed guns. The video "Guns in VR"[3] claimed that two-handed guns with scopes, e.g. a sniper rifle, are the most difficult guns to simulate realistically in VR. The reason being that people aiming with a scope rely on their shoulder to stabilise the gun and help them to aim. To overcome this challenge, we built a prop that can be used alongside VR, both to encourage torso movement and to increase immersion to combat kinesiophobia.

Using this as inspiration, this paper explores the idea of implementing a VR FPS game and evaluating different shooting methods and immersion, for the purpose of rehabilitation.

Our hypothesis is: ***A two handed physical prop will encourage torso movement and increase immersion in Virtual Reality***

The following section discusses VR as a rehabilitation tool and summarizes previous works with shooters and props.

[1]Using video game elements in non-game related contexts [8, 9]

2 BACKGROUND RESEARCH

2.1 Virtual Reality as a Rehabilitation Tool

VR has been utilised as a means to distract people from kinesiophobia during physical rehabilitation. A VR game called 'Cryoslide' was tested against patients' own techniques of distracting them from their chronic pain. The test was conducted on 20 participants, 10 using their own techniques such as reading or playing mobile games, while the other 10 played 'Cryoslide'. To gather data, a questionnaire of pain intensity was used. The results showed that participants reported a 36.7% lower pain intensity and thought about their pain 56% less [18] while playing 'Cryoslide'. Pain intensity in VR was also tested in another study on a patient that suffered severe trauma in an accident and had to go through physical therapy. The patient went through regular therapy sessions with a within-subject design study, where the patient tried therapy with and without VR. Once each session had been completed, the patient answered three pain rating scales, ranging from 0 to 10. Here the patient reported feeling less pain and unpleasantness in VR, while thinking about pain less and having more fun [14].

A recent study on VR's impact on pain perception and exercise benefits showed that people report feeling less pain and having to put in less effort while using VR, resulting in reaching exhaustion slower than the non-VR group it was tested against [23]. This study used verbal pain and perceived exertion ratings, while also using a self-report questionnaire to evaluate immersion. VR has created new possibilities for combining technology and exercise, and these are evaluated by the Virtual Reality Institute of Health and Exercise which has two professors in Kinesiology on their team [27].

This background research shows that the benefits of VR on physical fitness are still being evaluated, but showing a lot of potential for countering kinesiophobia while improving patients' overall experience of physical therapy.

2.2 Virtual Reality with Physical Props

Some examples of commercially available VR FPS are "Pavlov VR" [7], "Hover Junkers" [33] and the upcoming "Space Junkies" [30]. Two studies [20, 21] took a FPS game and compared it across VR and PC gaming. Another study on FPS games showed favourable results towards props in VR and tested a self-transforming controller that was meant to simulate a pistol and rifle in-game [19]. The prop had a formed grip, similar to that of a pistol, and the length of the barrel was adjustable, transforming between a rifle and a pistol. Furthermore, weight had been added to the prop, making it 3.5 times heavier than the HTC Vive controller. The prop was evaluated by 29 players, split into two groups. One group played a game using the standard HTC Vive controllers first, while the other group started with the self-transforming controller. To understand what the participants thought of the solution, they were asked to answer several questionnaires – the Game Experience Questionnaire, Player Experience of Need Satisfaction Questionnaire, Igroup Presence Questionnaire, Consumer Products Questionnaire and last Device Assessment Questionnaire [19]. Performance and in-game behaviour was also logged. The results showed an overall preference for the self-transformable controller. The study also reported on fatigue levels being very low. However, the participants only went through 4 minutes of play time before answering five questionnaires, and then proceeded to play 4 more minutes. This amount of play time may not be enough to evaluate fatigue levels as players rarely play games for 4 minutes at a time. The idea of using props in a VR environment has been explored numerous times. One study tested physical objects' impact on how realistic a virtual environment felt. The study was conducted on two groups of people. One group used physical objects, while the other did not. The results showed that the participants using physical objects considered the virtual environment to be more realistic and simulating laws of physics [13].

These studies show that props make the virtual environment seem more realistic. When it comes to kinesiophobia, distraction, from the real world is essential to lower attention on pain. Therefore, props could potentially immerse users such that they pay less attention to their fear of pain.

The next section describes our inspiration, design and implementation for a VR FPS game.

3 THE VIRTUAL REALITY SHOOTER

3.1 Stances, Hand Positions & Props

Based on preliminary research, we decided to implement a shooter game in VR to encourage movement of the torso. As previously mentioned, there are different stances and hand positions for different weapons.

For shooting pistols, there are several stances. Two of the most commonly mentioned are the Isosceles and Weaver stance. The Isosceles stance received its name because the arms and chest form an isosceles triangle, where two sides are the same. The shooter's body should face the target, holding the pistol in front of the middle of their chest and their feet at a shoulder-length distance from each other, with the toes facing the target [15, 29]. In the Weaver stance, the non-dominant foot is placed slightly ahead of the other foot for support. The arm accompanying the hand on the trigger is stretched out, elbow locked, while the other arm is bent at a 45 degree angle [15, 29]. Pistols can also be fired with one hand. The recommended stance for this is the Power Point stance, where the shooting arm is stretched out, and the gun-side foot is placed in front of the other [5].

When shooting rifles, hunters stand with their non-dominant foot in front of the other, their non-dominant hand holding the forestock of the rifle [24]. In a tactical situation for soldiers, the stance is similar but deeper, meaning their knees are bent and their upper body is slightly leaning forward [22].

As research encourages you to turn your body in the direction you are shooting, and not just twist the torso, we decided to test whether this translates to players in VR. In order to see if people would naturally do this, we conducted a small test on six participants to observe how much they moved their feet. We found that if the enemies spawned within 180 degrees, the players barely moved their feet and instead rotated their upper body. Furthermore, it was observed that some of the participants did not hold the guns out in front them to aim, which led to lack of rotation. This was due to a laser sight assisting their aim. Upon this observation, we removed the sight to encourage proper aim and torso movement.

Figure 1: Hand positions of gun with one (top) and two hands (bottom)

Figure 2: Hand positions of the rifle with no prop

The HTC Vive controllers, are ideal for gun shooter games as it has a grip and a trigger. The use of the HTC Vive controllers as guns can be seen in Figure 1.

When using a rifle, there is basically only one way to hold it, which requires two hands. We implemented the rifle such that one controller determined the position of the rifle in the virtual space while the other controller determined rotation. That way people had to use two hands to use the rifle in-game, as seen in Figure 2.

For the physical prop for HTC Vive controllers, we used a publicly available model for 3D printing [25]. Figure 3 shows the prop with the Vive controllers attached.

The 3D printed frame was very light, which suited the solution well as a physiotherapist recommended that weights should not be used for physical therapy without supervision. In other cases, to increase immersion, additional components may have been added to increase the weight to that of a real rifle.

Figure 3: The 3D printed prop

3.2 Creation of the Virtual Environment

When creating the VR game, we considered in particular ethical concerns surrounding games and the intended target group of the solution. While games can cater to many people, it is far from everyone that spends their free time engaging in games. Therefore, the game should not cater to hardcore players but should be made for casual players, and it should not include any gore despite being a shooter game. We decided to refrain from creating a realistic shooter game, and use a cartoonish design instead, which was based on a tutorial for a shooter with plush toys as targets [31]. Furthermore lighting was added using publicly available assets [11]. Figure 4 shows parts of the created virtual environment.

Figure 4: The virtual environment created with the Unity Assets

A physiotherapist informed us that without weights all types of torso movement are encouraged. The priority is that patients move. Therefore, we place the player virtually on a platform above ground level. Enemies first spawn on the floor within a 180 degree angle in front of the player to make them rotate from side to side. The enemies then move towards the platform where the player is standing. Next, new enemy types spawn; these fly and spawn in a vertical line in front of the player to make them aim up and down. Finally, the enemies spawn both vertically and horizontally to make the player rotate diagonally. The three different enemy types can be seen in Figure 5. While this is essentially supposed to be a game, there were some game aspects that we did not include. For example, the game does not have a lose condition. We decided that this should not be implemented as it would disrupt our data collection when comparing torso rotation between the different weapons. To create a goal for the players, we allowed the players to see their accuracy and score in the game.

Figure 5: The different enemy types

4 TESTING MOVEMENT IN VIRTUAL REALITY

4.1 Pre-Test Meeting With Physiotherapist

A preliminary test was conducted with a physiotherapist. She gave us feedback regarding the system as a tool for rehabilitation. She also talked with us about the different movements that she observed being encouraged and gave input on how to motivate other important movements. In her opinion, the amount of torso rotation was sufficient, but she was missing more tilting from side to side. She did see potential for more than LBP patients.

4.2 Procedure

As the purpose of this study was not to evaluate a VR rehabilitation system, but to evaluate how much people move in VR with different types of weapons and hand positions, the most important data is from the trackers. For this, no interviews were needed and the data is purely quantitative. However, while the movement is the main aspect of this, the trackers cannot measure which weapon the participants preferred to use. If the participants do not enjoy using the weapon, there is a chance that regular use will be discontinued. Therefore, a questionnaire about weapons was included in the evaluation. Additionally, we were interested in why the participants ranked the weapons the way they did, so this was asked after the participants had filled in the questionnaire and noted down.

The test was conducted using a repeated measures design [26] – each participant went through all the weapons. This can sometimes lead to confounding variables, undesirable results due to fatigue, practice effect etc. Therefore, counterbalancing was used and the participants used the weapons in different orders.

The participants were a mix of students, some were from different semesters of Medialogy and others were random participants picked out at the University from other studies. Their experience with VR also varied, as some had worked with VR as part of their study and others had never tried it.

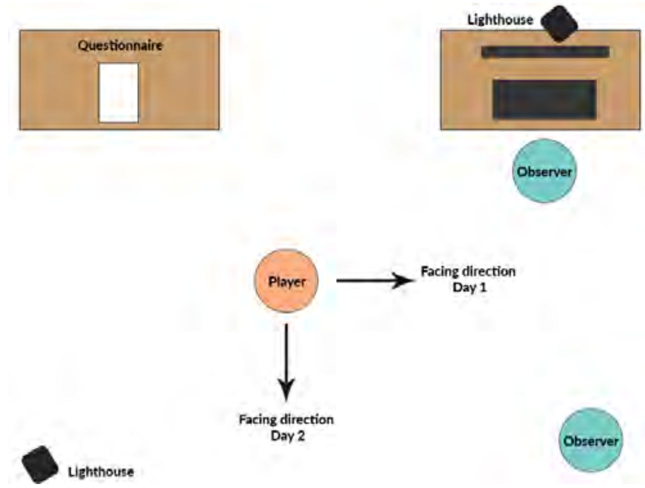

Figure 6: Evaluation Setup

The evaluation was conducted in a lab room at the university. The setup of the room can be seen in Figure 6. Between the two test days, the room was re-calibrated, thus the facing direction changed. The system used for testing had a 6GB 980Ti GPU, with a i7-4770 CPU running at 3.4GHz. The computer had 32GB of RAM running at 1333 MHz. An HTC VIVE was used as the head mounted display (HMD), running at 90Hz on two 1080x1200 pixels screens.

The participants were informed that they would go through two different weapons, and two different ways of using each weapon and they would not be evaluated on their performance, but if they wanted to, they could look at their accuracy in the game.

The observers helped the participants strap on the two trackers. As seen in Figure 7, one tracker was strapped between the shoulder blades, and another on the lower back.

Figure 7: Tracker placement

Once inside the game, the participants were asked to look straight ahead for calibration of the system and given instructions on how to aim with the rifle and with the pistol. Before starting the actual test, the participants had a chance to practice on targets. This starting scene can be seen in Figure 8. When ready, the participants would initiate the test themselves by shooting a "Play" button and the tracking of their torso movement would be logged. Between each wave of enemies, the observers would assist the participants in changing weapons.

Figure 8: Tutorial before the test

The participants were asked to fill out a questionnaire after the test about their experience with the different weapons and hand positions. They were asked to rank the weapons from most fun to least fun, most comfortable to least comfortable, and to pick which one felt most immersive, and which one was overall preferred to play with. Once a participant had filled out a questionnaire, they were asked why they ranked the weapons the way they did.

4.3 Results

The open-source tool RStudio [1] was used for a statistical analysis of the tracker data. We used boxplots to get an idea of how the data looks and the Wilcoxon Signed Rank tests for comparing the results [6].

4.3.1 Questionnaire data. The rankings by the participants varied depending on whether they were asked about comfort or fun. There was no significant difference between the rankings of fun. However, the rankings of comfort showed that there was a significant difference between the two handed pistol and the rifle without a prop. The pistol being most comfortable. When asked which of the four types they felt was most immersive and which they preferred overall, 14 (58%) participants found the rifle prop the most immersive which was significantly higher than the others. 12 (50%) participants preferred to use the prop, which also showed a significant difference.

During the testing and when asking the participants why they ranked the weapons the way they did, there was a wide variety of answers. One participant said that the no prop rifle felt like holding a bow and arrow. Here the participant was referring to how shooting with bow and arrow is often implemented in VR: one hand to hold the bow and aim, and one to pull the arrow back. This participant also preferred the pistol with one hand, and said they felt like Tomb Raider's Lara Croft when shooting. Another participant wanted to try it out with two pistols rather than just one. During game play, it was noted that a participant said the solution felt accurate and responsive. Two participants ranked a weapon last because they felt fatigued when using them. Two participants commented on the size of the rifle prop, being either too small or too big. For one participant, who was significantly taller, the prop lagged a lot due to the positioning of the HTC Vive Lighthouse stations in the room. This participant also said that this influenced ranking of the prop.

4.3.2 Tracker data. In the tests between the x-means, which is the average of the subscales for the horizontal rotation axis, for the overall rotation over time, it was evident that there was a significant difference between using the rifle with a prop and using the rifle with no prop with a respective p-value of 0.030. When compared to the boxplot seen in Figure 9, it is clear that the prop has an advantage over these two conditions. There was, however, no significant difference between using the prop and using the pistol with one hand.

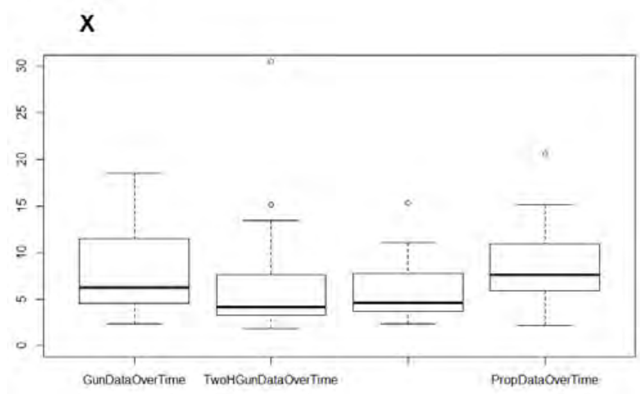

Figure 9: Boxplot over the overall rotation over time on the horizontal axis for all the conditions.

In the analysis for the y-means, which is the average of the subscales for the vertical rotation axis, there was only a significant difference between using the pistol with one hand or with two hands with a respective p-value of 0.021. When considering the boxplot in Figure 10, it is clear that compared to the two other conditions, rifle with no prop and rifle with prop, using the pistol with one hand slightly increases rotation.

In the analysis for the z-means, which is the average of the subscales for the side-to-side tilting, there was a significant difference between using the pistol with one hand and using the pistol with two hands with a respective p-value of 0.0037. There was also a significant difference between using the pistol with one hand and using the rifle with no prop with a p-value of 0.014. It can be seen in the boxplot in Figure 11 that the pistol is in advantage over these two other conditions. In comparison with using the prop, they seem to be equal in the boxplot with respect to the median, but the upper quartile is higher for the pistol.

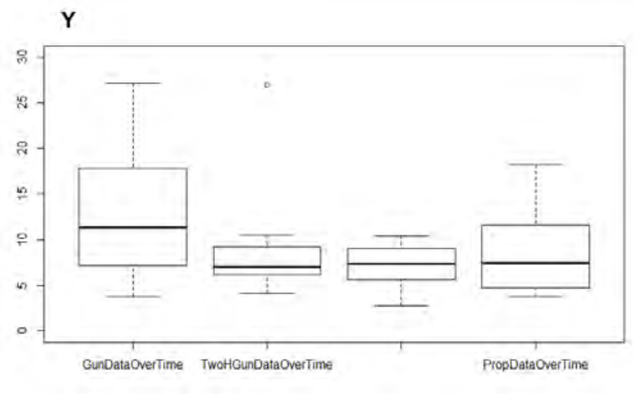

Figure 10: Boxplot over the overall rotation over time on the vertical axis for all the conditions.

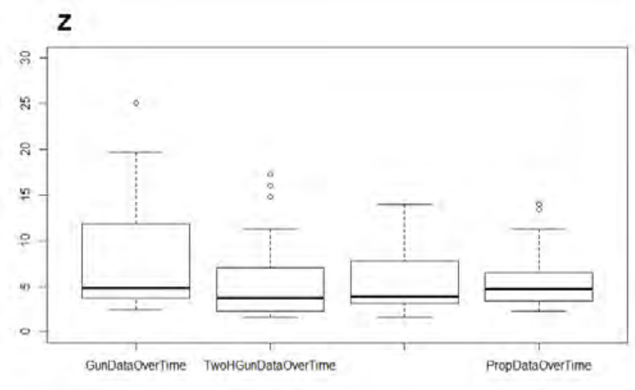

Figure 11: Boxplot over the overall rotation over time of side-to-side tilting for all the conditions.

5 DISCUSSION

5.1 User Questionnaire

On the 2nd day of the test, the tracking system had been re-calibrated such that participants were facing a different direction. Unfortunately, this caused a lot of issues with the prop, as the tracking was considerably worse. Despite that, the prop was still considered the most immersive and it was the overall preferred interaction. The prop was ranked third in comfort. This could be due to the frame not being adjustable. One tall participant said the prop felt small and unnatural to hold. The opposite was the case for a smaller participant, who felt that the prop was too large. This could potentially influence how comfortable the participants felt the prop was to use. When we asked the participants why they ranked the weapons the way they did, two participants said they felt fatigued using this type of interaction. It was noted that it was two different conditions but both were the last condition they went through. This shows why it was important to use counterbalancing of confounding variables, as this influenced how some participants ranked the weapons.

5.2 Tracker Data

The results showed a significant difference in up and down rotation between using the rifle prop and the rifle with no prop, as well as the two handed pistol, however there was no significant difference between the rifle prop and the single handed pistol. In regards to sidewise tilting and left and right rotation, the single handed pistol made people rotate significantly more than using the pistol with two hands. The results of the tracker data suggests that different weapons may encourage different types of movement, which could be useful for focused exercises.

As this was a game, we wanted the players to be immersed, and keep them on their toes. Therefore, we made the enemies move towards the player as a means of motivation. However, this created unreliable variables, as rotation, especially up and down rotation, depended on the distance between the player and the enemy. We are uncertain whether this influenced the results as people tended to attempt to shoot the enemies as fast as possible. However, sometimes enemies would make it all the way to the platform that the players were standing on before being taken out. This may have skewed our results. A more static environment for testing rotation may have been better as we would be in full control of the variables.

Overall, the subjective preference of weapons ranked by the users, does not match well with what the trackers say encourage the most rotation. The prop which won the overall preference and immersion only provided significant torso movement on one axis in comparison to not using the prop and the pistol with two hands.

5.3 Future Work

In order to fully determine which shooting method would be most suitable for rehabilitation, further testing is needed with static targets and also in collaboration with experts. Based on the interview we had with a physiotherapist, there is much room for improvement for the game mechanics to encourage more types of movement in the game, specifically sidewise tilting of the torso, as the therapist felt that it was missing from the current iteration of the game. This could be included by implementing enemy types that throw things at players' heads, forcing them to dodge the incoming attacks.

6 CONCLUSION

The purpose of this study was to test torso movement in VR using different gun shooting methods and evaluate whether a prop increases immersion for the users. Our hypothesis was that a two handed physical prop encourages torso movement and increases immersion in Virtual Reality. The results showed that the prop encourages increased rotation around the horizontal axis in comparison to the pistol with two hands and the rifle without a prop, while a pistol held with one hand encouraged significantly more side to side rotation and sidewise tilting compared to the two handed pistol. However, regarding immersion, the users felt significantly more immersed with the prop, and overall preferred to use this shooting method. In order to determine whether immersion and preference comes before movement efficiency, further tests under different conditions are required.

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REFERENCES

[1] Joseph J. Allaire. 14/12/2018. RStudio: Open Source and Enterprise-Ready Professional Software for R. https://www.rstudio.com/. Accessed:14.12.2018.
[2] D. Basten. 2017. Gamification. *IEEE Software* 34, 5 (September 2017), 76–81. https://doi.org/10.1109/MS.2017.3571581
[3] BrandonJLa. 2017. Guns in VR. Found at https://www.youtube.com/watch?v=iYrkXK3V2ik, last accessed 13/12/2018.
[4] Eric R. Castillo and Daniel E. Lieberman. 2015. Lower Back Pain. *Evolution, Medicine, and Public Health* 1 (2015), 2–3. https://doi.org/10.1093/emph/eou034
[5] Chris Christian. 14/12/18. Found at https://www.shootingillustrated.com/articles/2016/4/5/top-five-shooting-stances/.
[6] Michael J. Crawley. 2015. *Statistics : An Introduction Using R* (2nd ed.). Wiley, New York, USA.
[7] davevillz. 2017. Pavlov VR. Found at https://store.steampowered.com/app/555160/Pavlov_VR/.
[8] Sebastian Deterding, Dan Dixon, Rilla Khaled, and Lennart Nacke. 2011. From Game Design Elements to Gamefulness: Defining "Gamification". In *Proceedings of the 15th International Academic MindTrek Conference: Envisioning Future Media Environments (MindTrek '11)*. ACM, New York, NY, USA, 9–15. https://doi.org/10.1145/2181037.2181040
[9] Sebastian Deterding, Miguel Sicart, Lennart Nacke, Kenton O'Hara, and Dan Dixon. 2011. Gamification. Using Game-design Elements in Non-gaming Contexts. In *CHI '11 Extended Abstracts on Human Factors in Computing Systems (CHI EA '11)*. ACM, New York, NY, USA, 2425–2428. https://doi.org/10.1145/1979742.1979575
[10] Michele D. Dickey. 2005. Engaging By Design: How Engagement Strategies in Popular Computer and Video Games Can Inform Instructional Design. *Educational Technology Research and Development* 53 (2005), 67âĂŞ83. Issue 2. https://doi.org/10.1007/BF02504866
[11] Flatriver. 2016. Retrieved from: https://assetstore.unity.com/packages/3d/props/simple-wall-lamp-69411.
[12] Nadine E. Foster, Johannes R. Anema, Dan Cherkin, Roger Chou, Steven P. Cohen, Douglas P. Gross, Paulo H. Ferreira, Julie M. Fritz, Bart W. Koes, Wilco Peul, Judith A. Turner, and Chris G. Maher. 2018. Prevention and treatment of low back pain: evidence, challenges, and promising directions. *The Lancet* 391 (2018), 2368–2383. Issue 10137. https://doi.org/10.1016/S0140-6736(18)30489-6
[13] Hunter G Hoffman. 1998. Physically touching virtual objects using tactile augmentation enhances the realism of virtual environments. In *Virtual Reality Annual International Symposium, 1998. Proceedings., IEEE 1998*. IEEE, Atlanta, GA, USA, 59–63.
[14] Hunter G. Hoffman, David R. Patterson, Maryam Soltani, Aubriana Teeley, William Miller, and Sam R. Sherar. 2009. Virtual Reality Pain Control during Physical Therapy Range of Motion Exercises for a Patient with Multiple Blunt Force Trauma Injuries. *Cyber Psychology & Behavior* 12 (2009), 47–49.
[15] Sam Hoober. 14/12/18. Found at http://gunbelts.com/blog/3-basic-shooting-stances/.
[16] D. Hoy, P. Brooks, F. Blythc, and R. Buchbinder. 2010. The Epidemiology of low back pain. *Best Practice & Research Clinical Rheumatology* 24 (2010), 769–781. https://doi.org/10.1016/j.berh.2010.10.002
[17] Katherine Isbister. 2016. *How games move us: Emotion by design.* MIT Press, Cambridge, Massachusetts, London, England.
[18] Weina Jin, Amber Choo, Diane Gromala, Chris Shaw, and Pamela Squire. 2016. A Virtual Reality Game for Chronic Pain Management: A Randomized, Controlled Clinical Study. *Medicine Meets Virtual Reality* 22 (2016), 154–160.
[19] Andrey Krekhov, Katharina Emmerich, Philipp Bergmann, Sebastian Cmentowski, and Jens Krüger. 2017. Self-Transforming Controllers for Virtual Reality First Person Shooters. In *Proceedings of the Annual Symposium on Computer-Human Interaction in Play*. ACM, Amsterdam, The Netherlands, 517–529.
[20] Jean-Luc Lugrin, Marc Cavazza, Fred Charles, Marc Le Renard, Jonathan Freeman, and Jane Lessiter. 2013. Immersive FPS games: user experience and performance. In *Proceedings of the 2013 ACM international workshop on Immersive media experiences*. ACM, Barcelona, Spain, 7–12.
[21] Jeann-Luc Lugrinn, Fred Charles, Marc Cavazza, Marc Le Renard, Jonathan Freeman, and Jane Lessiter. 2012. Are immerrsive FPS games enjoyable?. In *Proceedings of the 18th ACM symposium on Virtual reality software and technology*. ACM, Toronto, Ontario, Canada, 199–200.
[22] S.W.A.T. Magazine. 14/12/18. Found at http://www.swatvault.com/weapons-training-and-tactics/the-fighting-stance-maximize-your-shooting-ability/.
[23] Maria Matsangidou, Chee Siang Ang, Alexis R Mauger, Jittrapol Intarasirisawat, Boris Otkhmezuri, and Marios N Avraamides. 2018. Is your virtual self as sensational as your real? Virtual Reality: The effect of body consciousness on the experience of exercise sensations. *Psychology of Sport and Exercise* 7 (2018).
[24] Texas Parks and Wildlife. 14/12/18. Found at https://tpwd.texas.gov/education/hunter-education/online-course/shooting-skills/rifle-positions.
[25] SGU7. 2016. G36. Found at https://www.thingiverse.com/thing:1828084.
[26] Martyn Shuttleworth. 2009. Repeated measures design. Experiment Resources. Found at https://explorable.com/repeated-measures-design.
[27] Aaron Stanton and Sidian Jones. 2017. Found at https://vrhealth.institute/.
[28] Marek Szpalski, Robert Gunzburg, BjÃűrn L. Rydevik, Jean-Charles Le Huec, and Michael Mayer. 2010. *Surgery for Low Back Pain.* Springer, Berlin.
[29] Pew Pew Tactical. 14/12/18. Found at https://www.pewpewtactical.com/shooting-stance-grip/.
[30] Ubisoft. 2019. Space Junkies. Found at https://store.steampowered.com/app/647590/Space_Junkies/.
[31] UnityTechnologies. 2018. Retrieved from: https://assetstore.unity.com/packages/essentials/tutorial-projects/survival-shooter-tutorial-40756.
[32] Johan W.S. Vlaeyen, Jeroen de Jong, Mario Geilen, Peter H.T.G. Heuts, and Gerard van Breukelen. 2011. Graded exposure in vivo in the treatment of pain-related fear: a replicated single-case experimental design in four patients with chronic low back pain. *Behaviour Research and Therapy* 39 (2011), 151–166. Issue 2. https://doi.org/10.1016/S0005-7967(99)00174-6
[33] Stress Level Zero. 2016. Hover Junkers. Found at https://store.steampowered.com/app/380220/Hover_Junkers/.

MITMI Man-In-The-Middle Interaction

The human back in the loop

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ABSTRACT

"The medium is the message" from McLuhan [13] showed and still shows how the medium influences how the message is perceived. This article proposes a new model for computer-human interaction named MITMI for (hu)man-in-the-middle Interaction in the context of digital art. This approach questions the concept of mediated interaction by placing the human as the driver and as the "translator" of the interaction process from a theoretical point of view. Indeed, mediated interaction is based on the fact that two humans are able to interact through a technological device [5]. We develop the idea of putting human back as an intermediary between the user/spectator and the technology. Our model thus introduces a way of conceptualizing interactive digital artworks, where the artist considered as an operator and creator can also take a central position and is no longer the only producer of the work taking thus entirely part of the artwork. We first explore the need to put the human back in the loop, then we will describe how the principles of mediated interaction help in defining the MITMI model. We will stress this model through several installations and interactive artworks based on the idea of shifting the artist position from the creator, to the mediator between the real world and the virtual world. Beyond the artistic approach, this model proposes to redefine and to explore new modes of co-creation or mediation, where digital media supports human-to-human interaction.

Keywords

computer-human-interaction, interactive digital art, performance, computer-mediated interaction, mixed reality

1 INTRODUCTION

McLuhan [13] showed and still shows how the medium influences the message's perception in his quote "The medium is the message." Crowley et al. [5] also consider media as a form of extensions of man. In the creative process, despite new technologies offers more degrees of freedom regarding immersion and interaction, we identify the need to question back this consideration about technology. Following these reflections, we propose to develop the idea of putting human back as an intermediary between the user/spectator and the technology theorizing a new model for computer-human-interaction in the context of digital art.

2 HUMAN IN THE LOOP IN DIGITAL CREATION

2.1 Computer-mediated interaction

The approach of placing human in the loop in digital creation questions the concept of mediated interaction by placing the spectator or user as the driver and, so, as the "translator" of the interaction process from a theoretical point of view. Computer-mediated interaction is based on the fact that two humans are able to interact together through a technological device [9] (Figure 1). In the context of digital theater and performances, several studies explore different models to assess the question of intersubjectivity between real and virtual actors. The open source project *The machine to be another* [3] is a typical use of computer-mediated interaction where through head-mounted displays, a user is able to see a first-person video with the eyes' perspective of a second person (the performer) who follows the user's movements. This experiment investigates the relation of identity or the empathy using embodiment and virtual body extension.

De Loor et al. [7] proposed a model which uses artificial models based on enactive considerations for the digital theater play *Il était Xn fois*. They design ontogenetic mechanisms for complex dynamic systems which were guided by people. The authors report their model addresses the fact that man can "learn from the machines which can learn in return" providing a clear parallel with the concepts of co-evolution and co-constitution of phenomenology.

Batras et al. designed a Virtual Reality model for improvisation in digital theater [2] that connects a real actor activity to a semi-autonomous agent switch from imitation to improvisation behaviors with the real actor. In this specific case, the actor is in a situation of computer-mediated interaction with himself as a deforming mirror for improvisation.

Figure 1: computer-mediated interaction between two humans

2.2 The MITMI model

We could see through these interactions an opposite model of the "mediated interaction" paradigm [9] where the computer tool serves as a communication channel between humans (Figure 1). In the cases described above, the exchanges are very different. Indeed, if in the first case the computer tool serves as an intermediary, whereas in our case a person is acting as an intermediary between the user and the machine. We call this interaction model MITMI (Figure 2), for Man-In-The-Middle Interaction, in reference as the Man-In-The-Middle attack (MITM) in computer security where the attacker secretly deforms the communication between two parties who believe they are directly communicating with each other [9]. This type of interaction leads, of course, to the notion of interpretation of the intermediate link also so-called "telephone game" [4] where misunderstandings accumulate in the retellings creating usually an interesting and significant difference between the statement announced by the first player and the one from the last player of the chain.

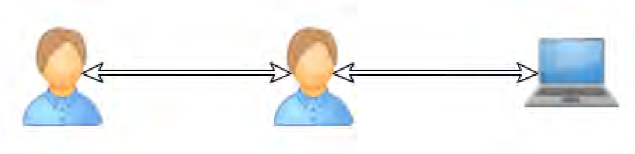

Figure 2: computer-mediated interaction between two humans

The Wizard of Oz technique [6] is part of this model and could be seen as a special case of MITMI. It consists of proposing an experience in which users interact with a computer system they believe it is autonomous, but which is in fact controlled by a human. This technique was used in the design experiments of an improvisation Virtual Reality application [3] dedicated to digital theater to understand how actors start an improvisation and feed it through computer-mediated interaction, the actors were invited to interact with a puppet (i.e. an entity manipulated from the outside) without being aware that the virtual entity is not autonomous. The user was therefore confronted with an entity controlled by a third party.

There is a strong link between mediated interaction and the MITMI model in the way that in both cases the device is at the center of the interaction, the great difference with this model is that the MITMI model takes into account the human interacting as a whole and in "his presence in the real world" and not through an interface that would restrict the perception of the user. Since the computer is no more filtering interaction, this leads to a finer perception and understanding of the "state of mind" of the human interacting. In the next section, we present several digital art artworks described using the MITMI model. The different types of interaction involved presented here allows to reconsider the link between the artist/performer, the public and the technology.

3 MITMI APPLIED TO INTERACTION IN DIGITAL ART

3.1 Theater Play

In the theater play *Cassandre-Materiaux* [12] the actress and director C. Chabalier is performing the role of Cassandra from Greek mythology. At the beginning of the play, she is immersed in the world of the predictions of the god Apollo presented as a giant virtual character (Figure 3).

Figure 3: Photography of the Stage in *Cassandre-Materiaux*

The actress is immersed and is interacting in the virtual world on stage using a virtual reality headset and a Kinect camera to detect gestures. The virtual god is also projected on an invisible tulle in order to be made visible to the spectators but not from the other actors on stage. She is therefore isolated in her own world without any vision of the real stage, the other actors and the spectators. In this case, the user-actor is observing a virtual entity which look completely isolated in its world but is still interacting with the actor and is the mediating interaction with the other real actors on stage (Figure 4).

3.2 Installation and Performance

In the installation-performance *Between The Lines* [17] presents the digital double of the performer M. Passedouet playing a fortune-teller. This character was projected on a tulle in a closed space which scenography represents the caravan of a fortune-teller. The actress dressed in the same way as her digital double walks silently through the gallery, leads the spectator to the caravan and play with the crystal ball. Her digital double comes to life and makes predictions. Here, the installation requires a mixed reality technology and a performance of the artist (Figure 4).

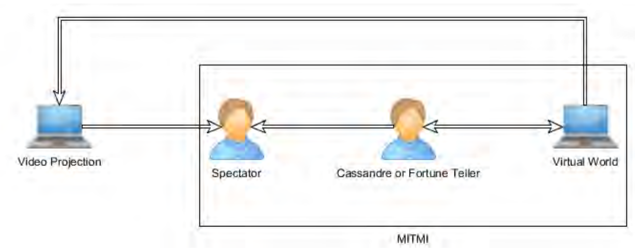

Figure 4: The MITMI model applied to the artworks Cassandre-Materiaux and Between the lines

3.3 Artistic Video Game

Our approach also creates perspectives in video games. The *Asile Escape* project (Figure 5) created by T. Fevrier and al. [8] proposes an asymmetrical gameplay using virtual reality technologies to create an escape game, i.e. a puzzle game where the player must escape, played by two people. The plot takes place in real old toilets of a university. One of the players is wearing a straitjacket and equipped with a virtual reality helmet and is only able to observe around him on the replica of the real room, the second player is free to move and can use the VR controllers.

Figure 5: *Asile Escape* [8], scenography and VR point of view

The two players' mission is to get out of the cell, despite the fact that they share same the real and the virtual space, they have to find different clues around them. The tied-up character immersed see a distorted and nightmarish vision of reality through his reality helmet and was able to see a certain number of clues, in return he could not interact with his environment and therefore had to give instructions to the unsubmerged player.

Each player was locked in his own plausibility bubble, holding information inaccessible to the other, and they have to dialogue to describe their respective bubble. Several immersed players report they really felt like they were locked in their bubble despite the presence of the second player with whom they were able to talk. This extreme isolation can refer to a modern Pythia whose visions are subjected to interpretation when confronted with reality.

3.4 Interactive Sculpture

Thus, we can see in the two previous examples of *Cassandre-Materiaux* and *Between The Lines* how this man-in-the-middle (in these cases a woman) serves as a connector between the "real world of humans" and the "virtual world" (Figure 4). In more anthropological approach, we propose to apply this model to the artistic installation *Ganesh Yourself* [11] from E. Grimaud, Z. Paré and A. Dubos.

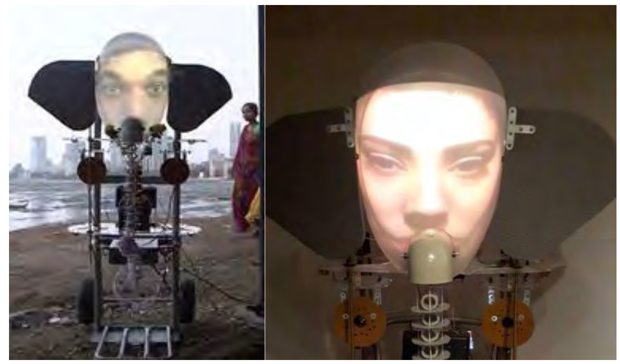

Figure 6: Robot of Ganesh Yourself [11]

This installation allows to control a robotic puppet where the face of the user or the spectator interacting is rear-projected on a Ganesh robot (Figure 6). Anyone can thus interpret the role of the Hindu god Ganesh which is a hybrid entity between a man and an elephant. It is interesting to note how different participants, both those who dialogue with the robot, and the robot operators or manipulators get caught up in playing the game of interaction as if the robot was really Ganesh.

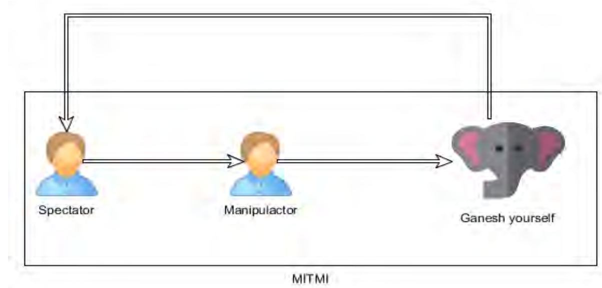

Figure 7: MITMI Model applied to *Ganesh Yourself*

This installation follows the previous works of the artist Z. Paré conducting performance with the robot replica of the researcher Hiroshi Ishiguro in his company Intelligent Robotics Laboratory. There, the robot was controlled by an external manipulator, which makes it "basically as a big puppet with sensors" [10]. According to the Ishiguro regarding a female robot he has created, "more importantly, we found that people forget that she is an Android while interacting with her. Consciously, it is easy to see that she is an android, but unconsciously, we react to the android as if she were a woman" [18]. In this case, the figure of the Man-In-The-Middle disappears in favor of putting the emphasis on the manipulated robot. We refer here to the term "manipulactor" (Figure 7) as the puppeteer who controls the device.

4 DISCUSSION & PERSPECTIVES

4.1 Toward a co-creative process

From these examples, we now explore how the MITMI model proposed for digital art application but it could be applied in CHI prototyping. It could be for instance used as a new cultural mediation system, by creating for example an exchange process where each interlocutor equipped with more or less immersive and interactive mixed reality technologies from AR to VR [14] can confront their point of view in a co-creative approach. In the field of movie production, new processes called previz-on-set allows to previsualize the filename result of a movie (post production) from the beginning of the production pipeline with the actors on set [15]. Usually, communication during the pre-production project does not take place in the virtual environment. The *OutilNum project* [16] proposes a collaborative approach (Multi-users and distributed VR/AR/MR) where each of the interlocutors becomes the man-in-the-middle of the others, thus offering a co-creation space based on interaction both on a real and virtual level. The MITMI model thus allows us to acquire from each participant point of view new elements of analysis.

4.2 Perspective for sharing

Beyond the artistic and collaborative axis, we could develop the MITMI model as a mediation tool for sharing the use of new technologies for specific audiences who could for instance not able to use computer tools for sensorimotor or cognitive, cultural or aging reasons. To do so, we could imagine enriching the model with qualitative study or interviews refining the transformations that take place between the user, the man-in-the-middle and the computer tool. Our model thus enables both the ability to understand the other as an empathy process sharing the point of view and the ability to disappear behind the technology. This could allow a progressive access to technology and understand its potential but also the limits of its communication channels. It can increase interaction as well as alter it, which in any case helps in feeding improvisation and sharing creativity.

REFERENCES

[1] Asokan, N., Niemi, V., and Nyberg, K. 2003. Man-in-the-middle in tunneled authentication protocols. *In International Workshop on Security Protocols*, pp. 28–41. Springer, Berlin, Heidelberg

[2] Batras, D., Guez, J., Jégo, J.-F. and Tramus, M.-H.. 2016. A virtual reality agent-based platform for improvisation between real and virtual actors using gestures. In *Proceedings of the 2016 Virtual Reality International Conference VRIC*, p. 34, Laval, France, ACM

[3] Bertrand, P., Gonzalez-Franco, D., Cherene, C., and Pointeau, A.,2014. The Machine to Be Another: embodiment performance to promote empathy among individuals. *Celebrating 50 years of the AISB.*

[4] Blackmore, Susan J., 2000. The Meme Machine. Oxford University Press

[5] Crowley, D. J., and Mitchell, D. 1994. Communication theory today. Stanford University Press

[6] Dahlbäck, N., Jönsson, A., and Ahrenberg, L., 1993. Wizard of Oz studies—why and how. in *Knowledge-based systems*, 6(4), pp. 258–266

[7] De Loor, P., Windelschmidt, C., Martinaud, K., and Cabioch, V., 2010. Connecting Theater and Virtual Reality with Cognitive Sciences: Positioning from computer science and artist meeting. in *Proceedings of Virtual Reality International Conference (VRIC 2010)*, 7–9 April 2010, Laval, France

[8] Fevrier, T., Carré, D., and Cocat, G., 2016. Asile Escape. Master création numérique parcours Arts et Technologies de l'Image, Université Paris VIII Vincennes Saint-Denis

[9] Grebennikova Krasautsava, I., 2008. L'interaction médiatisée à travers le chat comme dispositif sociotechnique. In *Les Enjeux de l'information et de La Communication*, 2008(1), pp. 20–30

[10]Grimaud, E., 2014. Pour quelques secondes de confusion ontologique Echecs et réussites du contact dans une expérience de Télé-robotique. In *La marionnette : Objet d'histoire, œuvre d'art, objet de civilisation*, pp. 143–168

[11]Grimaud, E., 2016. Ganesh Yourself. Retrieved from http://www.film-documentaire.fr/4DACTION/w_fiche_film/47610_1 on december, 20, 2018

[12]Guez, J. and Jégo, J.-F., 2017. Creating digital art installations with VR headsets in *Virtual Reality Headsets—A Theoretical and Pragmatic Approach*, Dir. Fuchs P. CRC Press

[13]McLuhan, M., and Lapham, L. H., 1994. Understanding media: The extensions of man. MIT press

[14]Milgram, P., and Kishino, F., 1994. A taxonomy of mixed reality visual displays. In *IEICE Transactions on Information and Systems*, 77(12), pp. 1321–1329

[15]Okun, J. A., & Zwerman, S., 2010. The VES handbook of visual effects: industry standard VFX practices and procedures. Taylor & Francis

[16]Plessiet, C., Chaabane, S., & Khemiri, G. (2015). Autonomous and interactive virtual actor, cooperative virtual environment for immersive Previsualisation tool oriented to movies. In *Proceedings of the 2015 Virtual Reality International Conference (VRIC 2015)* pp. 1–4

[17]Plessiet, C., and Passedouet, M., 2012. Between the lines. Galerie Crypt St Pancras – Londres - Royaume Uni ; City of Women Festival — Lubjiana - Slovénie ; Galerie 51 rue de Rivoli – Paris, France ; Zoom, espace de culture numérique - Bourg en Bresse- France ; Ars electronica Festival -Linz - Austria

[18]Whitehouse, D., 2005. Japanese develop "female" android. Retrieved from http://news.bbc.co.uk/2/hi/science/nature/4714135.stm on december, 20, 2018

Emerging Affect Detection Methodologies in VR and future directions

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ABSTRACT
The uses of Virtual reality are constantly evolving, from healthcare treatments to evaluating commercial products, all of which would benefit from a better understanding of the emotional state of the individual. There is ongoing research into developing specially adapted methods for the recognition of the user's affect while immersed within Virtual Reality. This paper outlines the approaches attempted and the available methodologies that embed sensors into wearable devices for real-time affect detection. These emerging technologies are introducing innovative ways of studying and interpreting emotion related data produced within immersive experiences.

Keywords
Virtual reality, Affect, Emotion, Emerging Technologies

1. INTRODUCTION
The applications for Virtual Reality (VR) are expanding rapidly, from research and training facilities to entertainment and healthcare. VR is no longer exclusive to laboratory settings as recent technological advancements have brought low-cost personal and portable VR headsets to the consumer market. This allowed for the sale of 13.5 million headsets units in 2017 [1]. From a research perspective, VR provides the platform for controlled experimental conditions while granting ecological validity and content resources [2]. Consequently, it is expected that more and more researchers will adapt VR for experimental design and execution. This is evidenced by the fact that there were over a million articles involving VR published in the last decade alone [3].

Regardless of the technological advances providing real time content interaction via input controllers, movement synchronisation and body capture, the emotional state recognition tools are only just emerging, due to the growing demand. The potential applications of affect detection in VR are abundant. With the visions of Affective computing in mind, emotionally intelligent algorithms for VR applications could unlock new paths for interactive realistic experiences, leading to a potentially better understanding of the process of immersion and presence in VR. Simultaneously, quantifying the state of the user can contribute to medical and psychology related applications, either to identify possible pathologies or to assist in the development of well-being tools and health-care related solutions [4]. Most of these applications require real-time data acquisition and vigorous analysis from multichannel sources, which in turn requires further technological and analytical advancement.

2. RELATED WORK
The nature of VR poses limitations to traditional affect detection techniques. The Head-Mounted Displays (HMD) cover almost two thirds of the user's face, which prevents expression detection via conventional camera tracking methods as well as the use of additional, external modalities around the area of the face and the head of the user. Additionally, due to the freedom of movement in room-scale VR experiences, the use of limb-embedded physiological sensors for affect recognition can be often erroneous while also insufficient for affect detection. Explicitly defined and adapted methodologies for affect recognition in VR are required, considering the parameters of the wearability, usability and comfort of the user while also the quality and value of the data handled.

2.1 Affect Detection Methods
Please Understanding the emotional state of the user in VR could assist in a range of use cases. It would aid real-time continuous affect recognition and the awareness of the user's state changes, affective design and adaptive control of the surrounding environment. Adaptive control is when specific signals can be utilised to alter the environmental parameters, which in turn can possibly alter the user's affect, as a feedback loop. In research on affective computing for real-time applications, most researchers prefer the use of traditional emotion models, such as the circumflex dimensional model [5]. This model is preferred over others as the various affective states are illustrated within a 2-dimensional space consisting of two primary axes; valence (positive or negative polarity of affect) and arousal (the excitement or intensity of the affective state).

Typically, the most common methods for systematic emotion analysis include biometric signal acquisition (e.g. speech, facial expressions, gestures, physiological signals) and analysis, in conjunction with subjective ratings from users (i.e. self-reports) and behavior-related observations [6]. However, an issue with the use of self-report techniques such as surveys, interviews and self-rating questionnaires is that they are reported to provide highly subjective responses and therefore those responses can be variant between participant results [7], meaning the data obtained often does not correspond to the actual emotional experience and concurrent physiological readings. This effect can be due to the subjective nature of interpersonal and cultural differences when rating emotion [8, 9]. Additionally, the incorporation of self-ratings in VR settings, either verbal or visual, could impede the user's overall experience of presence and immersion while also interrupting the narrative, or indeed any given task [10]. Ideally, researchers and experience designers would benefit from the combination of methods and the utilization of unobtrusive and continuous, objective measures throughout a VR experience.

Apart from conventional unimodal methods such as camera tracking or heart-rate sensors, recent software and hardware prototypes have emerged that combine multimodal approaches and affective read-outs specifically adapted for real-time applications. Commercial technologies including, Emotiv Epoc, LooxidLabs, Enobio, Neurable and EmteqVR [11, 12, 13, 14, 15] have emerged in recent years to provide real-time emotional feedback and affect recognition readings in VR. Although only a small amount of studies using these technologies in VR are published, we were able to gather some of the more relevant findings as well as the practical implications of each technology.

Arousal detection in VR, and especially the detection of stress, has been synonymised with analysing heartrate and electrodermal activity (EDA) changes [16]. The Q sensor by Affectiva [17] a wireless wearable biosensor has been used on a wide variety of studies, including one which investigated the levels of stuttering whilst in anxiety provoking VR environments. [18]. Although the Q sensor is no longer available on the market, Affectiva has designed and developed software solutions for affect detection, offering a software development kit (SDK) for developers using the Unity3D game engine [19].

For valence detection in VR, researchers and developers can utilise technologies that incorporate electroencephalography (EEG) sensors and/or electromyography (EMG) sensors. A recent study aiming to assess emotional responses induced in virtual reality found statistically significant correlations between the reported valence and arousal picture ratings and the EEG bands outputted from the Emotiv EPOC+ 14 channel EEG headset [20]. The system is light and easy to use, involving a short preparation of hydration of the sensors before usage. A limitation when using this headset alongside the HTC Vive VR system is the difficulty of ensuring precise localization of the electrodes which can increase variability of readings between participants but also between sessions of the same participant. Therefore, the Emotiv EPOC+ should be used in the correct context to ensure accurate affect detection.

Additionally, a new wave of portable EEG devices designed for gaming and VR purposes has emerged. The Neurable headset combines EEG sensors with the HTC Vive [21] HMD to ensure consistent localization, allowing user intent to be detected and used as interaction input in virtual environments [22, 23]. Further to this, Neurable have also developed an SDK for Unity 3D for developers [24]. Combining the SDK with the ability to measure gamma waves means there is potential for real-time affect detection in VR, as it has been found that gamma waves correlate with emotionality [25]. In 2016, a study examining the effect of body ownership in virtual reality using a different EEG sensor technology, Enobio (32 sensor set-up) noted that both augmented and virtual reality produce higher brain activity in beta and gamma waves than when present in the real world, which is something to consider when using EEG sensors in Virtual Reality research [26]. Another technology that came out in 2018 is the LooxidLabs headset, which combines 9 dry EEG electrodes and built-in eye tracking cameras into their own VR HMD. Unfortunately, we have little evidence of the system's accuracy of detecting affective states as it has not yet been used in an emotion related VR research study.

Currently, emotional valence is difficult to measure in room-scale VR (non-seated experience) and the current EEG approaches may add additional movement constrains to the user. The method of measuring electromyographic signals (EMG) from the face of the user in VR could give us a reliable indication of their affective state [27]. In this context, another recent example of multimodal affect detection technology is EmteqVR interface, whereby EMG and Photoplethysmograph (PPG) sensors are embedded on a foam VR insert, allowing it's use on commercial head-mounted displays (HMDs). Studies investigating the detection of valence and arousal using this device have shown promising results [28, 29]. EmteqVR and the aforementioned technologies could be improved further by the addition of eye motion tracking, to monitor the individual's gaze while in the virtual environment, thus, allowing a fully rounded analysis of the individual's affective state when experiencing an emotional stimulus.

The technologies presented in this paper, showcase the growing need for multimodal signal analysis to understand the user's emotional state in VR. As sensors become smaller and easier to integrate, we expect a rapid growth of affect-detecting technologies in the next years. The importance of heir unobtrusive wear-ability and usability in VR is paramount for VR research, as low levels of immersion and presence are correlated with hardware related distracting factors and reduced freedom of movement [30]. Ideally, researchers and developers in VR would benefit from the combination of metrics for simultaneous arousal and valence recognition, in user-centred hardware approaches that promote free movement and easy integration with HMDs.

3. CONCLUDING REMARKS

The continuously evolving affect recognition technologies for Virtual Reality are forming a strong new emerging technologies category. This could go on to enable new avenues for personalized experiences, user-centered interactions and well-being applications. The affect detection approaches, research findings and limitations per interface are briefly discussed to provide future directions towards further development of VR-embedded biometric sensors for activity and affect recognition for immersive technologies.

4. ACKNOWLEDGMENTS

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5. REFERENCES

[1] Statistica. Global VR Sales (2017). Retrieved 2018 from https://www.statista.com/statistics/752110/global-vr-headset-sales-by-brand/

[2] Thomas D. Parsons. 2015. Virtual Reality for enhanced ecological validity and experimental control in the clinical, affective and social neurosciences. *Frontiers in human neuroscience. 9*, 660. DOI= http://dx.doi.org/10.3389/fnhum.2015.00660

[3] Google Scholar. Google Scholar Virtual Reality Page (2018) Retrieved from: https://scholar.google.co.uk/scholar?hl=en&as_sdt=0%2C5&q=virtual+reality&btnG=&oq=virt

[4] Sarah Consentino, Sessa Salvatore, and Takanishi Atsuo. 2016. Quantitative laughter detection, measurement, and classification – A critical survey. *IEEE Reviews in biomedical engineering,* 9, 148-162. DOI= http://dx.doi.org/10.1109/RBME.2016.2527638

[5] James A. Russell. 1980. A circumplex model of affect. *Journal of personality and social psychology,* 30, 6, 1161. DOI= http://dx.doi.org/10.1037/h0077714

[6] Rafael A. Calvo and Sidney D'Mello. 2010. Affect detection: An interdisciplinary review of models, methods, and their applications. *IEEE Transactions on affective computing* 1, 1, 18-37. DOI= http://dx.doi.org/10.1109/T-AFFC.2010.1

[7] Tiffani Razavi. 2001. Self-report measures: An overview of concerns and limitations of questionnaire use in occupational stress research. *Discussion Papers in Accounting and Management Science,* 1-175

[8] William F. Wright and Gordon Bower. 1992. Mood effects on subjective probability assessment. *Organisational behaviour and human decision processes,* 52, 2, 276-291. DOI= http://dx.doi.org/10.1016/0749-5978(92)90039-A

[9] Daniel Kahneman. 2000. Evaluation by moments: Past and future. *Choices, values and frames,* 693-708. Cambridge University Press & Russell Sage Foundation, Cambridge.

[10] Bob G. Witmer and Michael J. Singer. 1998. Measuring presence in virtual environments: A presence questionnaire. *Presence*. 7, 3, 225-240.

[11] Emotiv EPOC, 2018. Emotiv HomePage. Retrieved in 2018 from https://www.emotiv.com/

[12] LooxidLabs, 2018. LooxidLabs HomePage. Retrieved in 2018 from https://looxidlabs.com/

[13] Enobio 32, 2018. Neuroelectrics Products Page. Retrieved in 2018 from https://www.neuroelectrics.com/products/enobio/enobio-32/

[14] Neurable 2018. Neurable HomePage. Retrieved in 2018 from http://neurable.com

[15] Emteq VR, 2018. Emteq HomePage. Retrieved in 2018 from https://emteq.net/

[16] Mel Slater, Pertaub, and Anthony Steed. 1999. Public speaking in virtual reality: Facing an audience of avatars. *IEEE Computer Graphics and Applications,* 19, 2, 6-9. DOI= http://dx.doi.org/10.1109/38.749116/

[17] Affectiva 2018. Affectiva HomePage. Retrieved in 2018 from https://www.affectiva.com/

[18] Gareth V. Walkom. 2016. Virtual Reality Exposure Therapy: To benefit those who stutter and treat social anxiety. In *Interactive Technologies and Games (iTAG) International Conference.* 36-41. DOI= http://dx.doi.org/10.1109/iTAG.2016.13

[19] Affectiva, 2018. Affectiva Product Page Emotion SDK. Retrieved in 2018 from https://www.affectiva.com/product/emotion-sdk/

[20] Marko Horvat, Marko Dobrinić, Matej Novosel, and Petar Jerčić. 2018. Assessing emotional responses induced in virtual reality using a consumer EEG headset: A preliminary report. In *41st International Convention on Information and Communication Technology, Electronics and Microelectronics MIPRO 2018.* DOI= http://dx.doi.org/10.23919/MIPRO.2018.8400184

[21] Vive. Vive Products (2016). Retrieved in 2018 from https://www.vive.com/uk/product/

[22] Arnaldo Pereira, Dereck Padden, Jay Jantz, Kate Lin, and Ramses Alcaide-Aguirre. 2018. Cross-Subject EEG Event-Related Potential Classification for Brain-Computer Interfaces Using Residual Networks. *HAL.* DOI= http://dx.doi.org/10.13140/RG.2.2.16257.10086

[23] Jay Jantz, Adam Molnar, and Ramses Alcaide. 2017. A brain-computer interface for extended reality interfaces. In *ACM SIGGRAPH 2017 VR Village.* DOI= http://dx.doi.org/10.1145/3089269.3089290

[24] Neurable, 2018. Neurable Developers Page. Retrieved in 2018 from http://www.neurable.com/developers

[25] Matthias M. Muller, Andreas Keil, Thomas Gruber, and Thomas Elbert. 1999. Processing of affective pictures modulates right-hemispheric gamma band EEG activity. *Clinical Neurophysiology*, 110, 11, 1913-1920. DOI= http://dx.doi.org/ 10.1016/S1388-2457(99)00151-0

[26] Filip Škola, Fotis Liarokapis. 2016. Examining the effect of body ownership in immersive virtual and augmented reality environments. *The Visual Computer,* 32, 6-8, 761-770. DOI= http://dx.doi.org/10.1007/s00371-016-1246-8

[27] John T. Cacioppo, Richard E. Petty, Mary E. Losch, and Hai Sook. Kim. 1986. Electromyographic activity over facial muscle regions can differentiate the valence and intensity of affective reactions. *Journal of personality and social psychology*, *50*, 2, 260. DOI= http://dx.doi.org/10.1037//0022-3514.50.2.260

[28] Ifigeneia Mavridou, Ellen Seiss, Mahyar Hamedi, Emili Balaguer-Balester, Charles Nduka. 2018. Towards valence detection from EMG for Virtual Reality applications, In Proc. 12th intern. Conf. ICDVRAT.

[29] Lorcan Reidi. 2018. A Gamified Approach to Cognitive Training using Virtual Reality and Affective Adaptation. Master's thesis. University of Cambridge, London, United Kingdom.

[30] Barfield Woodrow, Claudia Hendrix, and Karl-Erik Bystrom. 1999. Effects of stereopsis and head tracking on performance using desktop virtual environment displays. *Presence: Teleoperators & Virtual Environments* 8, 2 (April 1999) 237-240. DOI= http://dx.doi.org/10.1162/105474699566198

Windtherm: A Wearable VR Device That Provides Temperature-Controlled Wind

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ABSTRACT

We present a wearable VR device, called Windtherm, used with a Head Mounted Display (HMD) that provides tactile stimuli of temperature-controlled wind to a player's face in accordance with events in the virtual environment. Windtherm consists of a Wind Module that produces and blows wind whose temperature, force, and direction are controlled using elements such as Peltier elements, a fan, thermal sensors, and a servo motor; and a Control Module that controls physical conditions of wind incorporating with PC. We have made a prototype of Windtherm and confirmed that Windtherm is capable of producing wind of temperature in front of a user's face at maximum around 9℃ higher than the room temperature through PWM control and is also capable of blowing the wind synchronously to the visual and auditory information in the virtual environment.

CCS CONCEPTS

•Human-centered computing→ Mixed / augmented reality; Virtual reality

Keywords

Head mounted display, Temperature, Wind, Virtual reality, Multimodal interaction

Figure 1: Windtherm attached to HMD VIVE Pro.

1 INTRODUCTION

Research and development for realizing immersive virtual reality (VR) environments have recently made great progress incorporating with advance of related devices such as HMDs and various types of sensors and interfaces. For enhancing sense of immersion and presence in a virtual environment, multisensory stimuli including tactile (wind, thermal, etc.), olfactory, taste, and muscle stimuli as well as visual and auditory stimuli should be taken into account since such stimuli are what we have been experiencing in the real world. In [1], it is noted that lack of additional environmental feedback to the basic stimuli such as visual and auditory ones restricts potential immersive features and can have negative effects on user's sense of presence and the ability to interact with virtual environments. There are a number of study and systems that explore impact of multisensory stimuli to user's perception and to the sense of immersion and presence.

When we restrict the tactile sensations to wind and thermal ones, researches in psychology have suggested that wind and thermal stimuli have strong impact on how people perceive environmental surroundings [2, 3, 4]. There are also researches that utilize wind and/or thermal feedbacks in the context of virtual reality. Ogi and Hirose [5] utilizes airflow generated by small fans and blown on user's hands to represent vector information in a scientific visualization system. Head Mounted Wind [6] utilizes fan actuators regularly distributed around a user's head to provide wind of appropriate forces and directions. Kojima et al. [7] presents a wearable device with speakers and air tubes placed besides user's ears to provide local wind. AIRREAL [8] delivers tactile sensation in free air by generating air vortex and by providing it locally to a user's body. As for thermal sensation for VR, Hülsmann et al. [9] utilizes exterior fans and infrared lamps in a three-sided CAVE for enhancing immersive factors in VR experiences. Thermovr [10] utilizes Peltier elements placed at the contact part of the HMD around user's eyes and provides tactile sensation of heating and cooling. Ambiotherm [11] and Season Traveller [12] utilize wearable devices with Peltier elements, attached to a user's neck, and fans attached to the HMD to simulate the ambient temperature and wind conditions in the virtual environments. Haptic Around [13] utilizes a haptic device for providing hot air, heat, wind, rain drops and mist, set above a user, to recreate multiple tactile sensations in virtual reality for enhancing the immersive environment.

In this paper, we present Windtherm shown in Figure 1, a VR accessory for a HMD that generates and blows temperature-controlled wind to a user's face to enhance the sense of immersion and presence in the virtual world. The advantage and uniqueness of our device lie in providing local wind whose temperature is interactively controlled and in the portability of the device with a HMD while moving and walking. In our study, we first developed an exterior fan device that is fixed on a table and blows temperature-controlled wind to a user; and conducted preliminary experiments to examine user's sense of warmth for the wind blown with visual and auditory information in the virtual environment. Then, we developed a wearable device Windtherm attached to a HMD that consists of a Wind Module that generates and provides temperature-controlled wind using Peltier elements, heat sinks, thermal sensors, a fan, and a servo motor; and a Control Module that controls the temperature, force, and direction of wind. We have so far confirmed that the prototype system of Windtherm has basic capabilities of generating temperature-controlled wind and of interactively blowing it to a user's face synchronously to visual and auditory information of a VR application.

2 PRELIMINARY EXPERIMENTS USING EXTERIOR FAN DEVICE

Before developing the wearable device Windtherm for a HMD, we developed a VR system for examining how visual and auditory information in the virtual environment presented with the temperature-controlled wind affects user's subjective sense of temperature. The system consists of a HMD, an exterior fan capable of producing temperature-controlled wind, and a VR application. The overview of the system is illustrated in Figure 2.

2.1 Exterior Fan Device

The fan device consists of propellers with a motor, Peltier elements (TES1-12705, 15.4V, 5A, capable of -55℃ to 80℃), heat sinks, and a thermal sensor. It is connected to Arduino Uno that controls temperature inside the fan device through Peltier elements with the transistor (2SD2390, 160V, 10A). It also controls the force and timing of the blown wind, where the force is changeable in 256 levels through PWM control using the transistor (BC547B, 50V, 0.2A) and the timing of wind is decided by the commands sent from the VR application through port communication. The fan device with Arduino Uno is shown in Figure 3.

2.2 VR Application

We used the game engine Unreal Engine 4 (UE4) to construct a VR application and to interact with the fan device. The application was developed using Windows 10, the Blueprints Visual Scripting system of UE4, and HTC VIVE as a HMD.

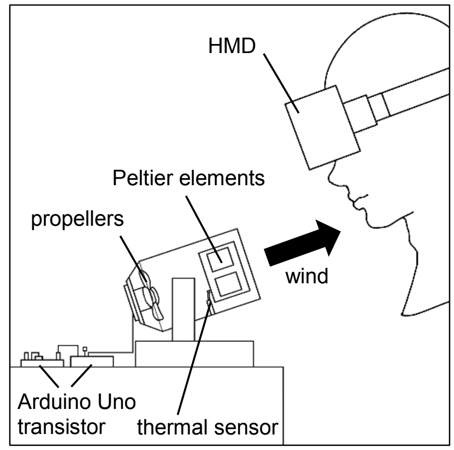

Figure 2: Overview of the system with HMD and exterior fan.

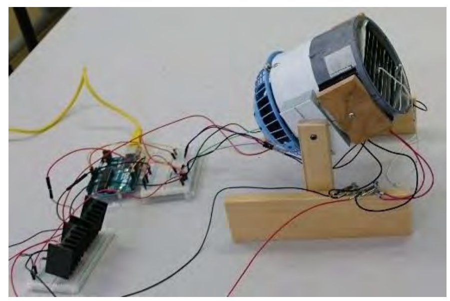

Figure 3: The implemented fan device and Arduino Uno.

The designed VR experience is to be in a dark cave and have multisensory stimuli of the images and sound of burning firewood and actual temperature-controlled wind. To examine how warm users feel the wind in the virtual environment, the following three types of statuses of firewood are prepared: (a) Extinguished; (b) Burning weakly; and (c) Burning strongly. Images of the statuses and the visual effect of the virtual wind are shown in Figure 4.

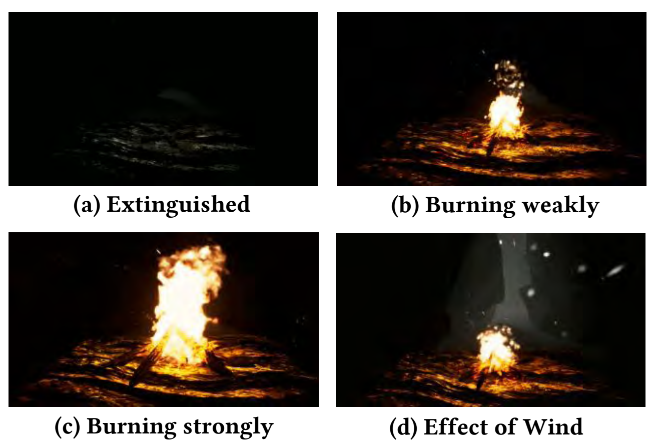

Figure 4. Images of firewood in the VR application.

2.3 Experiments and Evaluation

2.3.1 Experimental Conditions

To examine how stimuli of temperature-controlled wind incorporating with visual and auditory stimuli by the VR application affects the sense of warmth, we conducted preliminary experiments using the aforementioned exterior fan device and the VR application

Experiments: we conducted experiments using two kinds of actual wind: (i) wind with room temperature; and (ii) wind with temperature two centigrade higher at the thermal sensor than the room temperature, which we denote "room temperature+2℃."

In the experiments, we prepare all of the combinations of conditions for choosing two conditions (Conditions A and B) from the three statuses of firewood (a) "Extinguished"; (b) "Burning weakly"; and (c) "Burning strongly." There are 6 such combinations. Then we randomly choose a pair of conditions among them and make participants experience Conditions A and B in this order. In the experiments, participants are first relaxed for two minutes to get used to the environment and then wear the HMD. After having the VR experience of firewood under Conditions A and B with the actual wind with room temperature or that with room temperature+2℃, they answer how warm they feel for both of the conditions. The 5 candidates of the answer for the questionnaire are the following:

1. cool; 2. a little cool; 3. same with room; 4. a little hot; 5. hot

In one round of the experiment, VR image and sound of firewood are presented for 20 seconds, then actual wind is additionally blown for 3 seconds, and finally only VR images and sound are presented for 10 seconds. So, the total time in one round is 33 seconds. A participant experiences the above 6 pairs of conditions in random order with two kinds of wind temperature. A participant makes totally 12 rounds of VR experiences.

Environments and Participants: The room temperature for the experiments was set to 27℃ (±1℃). The humidity was 40~70%. The light in the room was put off during the experiments. As shown in Figure 5, the fan was fixed on a table with a distance about 50 cm from the face of the participants. Wind was aimed at being blown to the area between a nose and a neck of a participant. There were 15 participants of ages ranging from 19 to 25.

Figure 5. The fan on the table and a participant.

2.3.2 Results

Figures 6 and 7 show the results for the Questionnaire in Section 2.3.1, where Numbers 1 to 5 represent the answers of the degree of warmth/coolness participants feel. The letters "E", "W", and "S" represent the statuses of the firewood (a) Extinguished; (b) Burning weakly; and (c) Burning strongly, respectively. We mean by "E to W" for example the pair of experiments in which first the extinguished firewood is experienced and then the firewood burning weakly. The row axis represents the 6 pairs of change of statuses, from Condition A to B (A, B ∈{E, W, S}, A≠B). The column axis represents the number of participants for each of evaluation of the Questionnaire 1 to 5. Figure 6 is for the case of room temperature and Figure 7 is for the case of room temperature+2℃.

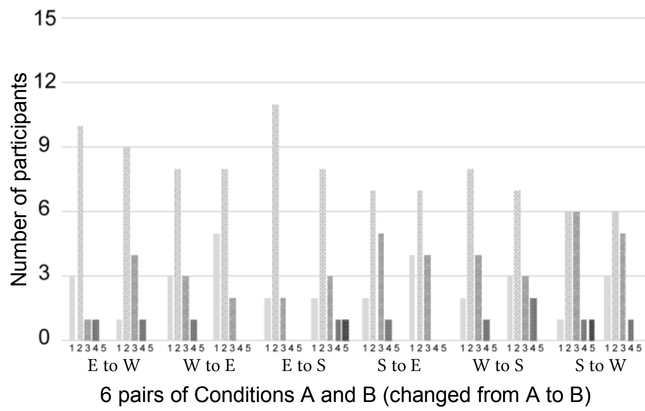

Figure 6. Results of the Questionnaire (room temperature).

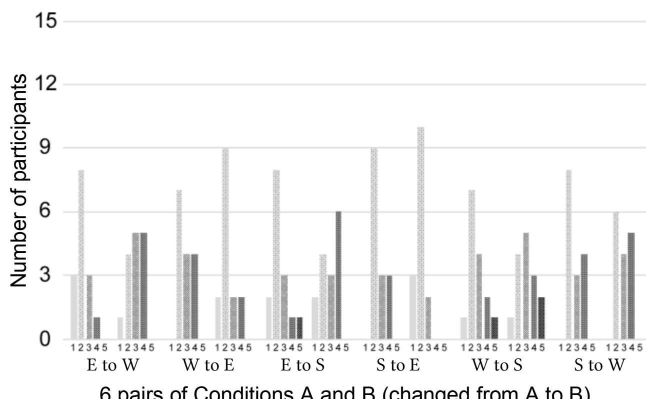

Figure 7. Results of the Questionnaire (room temp.+2℃).

Next, Figure 8 shows mean and SD (standard deviation) values of the Questionnaire for the wind with room temperature and room temperature+2℃. In the case of room temperature, mean and SD for the extinguished firewood were 1.95 and 0.67, those for the weakly burning firewood were 2.25 and 0.79, and those for the strongly burning firewood were 2.42 and 0.94, respectively. In the case of room temperature+2℃, mean and SD for the extinguished firewood were 2.18 and 0.85, those for the weakly burning firewood were 2.83 and 0.92, and those for the strongly burning firewood were 2.82 and 0.99, respectively.

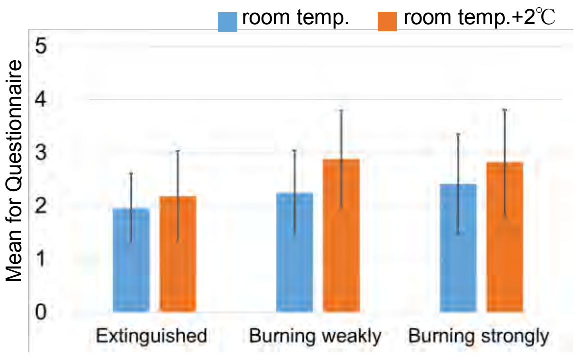

Figure 8. Mean and SD for the Questionnaire on warmth.

2.3.3 Discussion
In Figures 6 and 7, we observe that in most of the cases, score 2 (a little cool) was chosen by the largest proportion of the participants even in the cases of temperature+2℃. This could be because wind usually has the effect of making one feel cooler than the actual temperature. More specifically, in the extinguished case, the number of participants who chose score 2 was always the largest among all of the 5 scores, while in the cases of burning firewood (weakly/strongly), scores 3 (room temp.) and 4 (a little hot) were chosen more frequently. This implies that statuses of the firewood in the virtual space should affect the participants' sense of warmth in both cases of room temperature and room temperature+2℃.

From Figure 8, we can also deduce that participants tend to feel warmer when the firewood is burning weakly/strongly for both room temperature and room temperature+2℃. However, when the two cases of burning weakly and strongly are compared, especially in the temperature+2℃-case, the mean value in the case of burning weakly was even a little larger (2.83) than the case of burning strongly (2.82). Several reasons are considered for this. First, the distance of the exterior fan from the participants and the air of temperature+2℃ are so subtle and might not have clear impact on participants' sense of warmth. Second, such subtleness with the images of strongly burning firewood might cause inconsistency in terms of reality and the actual wind with temperature+2℃ cannot felt warm as expected from the images.

3 WEARABLE DEVICE "WINDTHERM"

3.1 System Description

Now, we introduce a wearable VR accessory for a HMD, Windtherm, that interactively provides temperature-controlled wind to a user's face. Windtherm consists of a Wind Module that generates and blows temperature-controlled wind and a Control Module that controls the temperature, force, and direction of the wind. The overview of the system of Windtherm and the Wind Module are illustrated in Figures 9 and 10, respectively. The Wind Module consists of Peltier elements used in Section 2, heat sinks for radiation, a DC fan (F5010ET-05PCV, 5V, 0.3A, 40mmx50mmx10mm, max air flow 0.27m^3/min), two thermal sensors for detecting temperatures inside the Wind Module and in front of a user's face, a servo motor (SG92R, 4.8V, Torque 2.5kgf·cm) set on the top of the Wind Module to change the direction of the wind, and a ping-pong ball that calms the wind not to be blown too directly to a user's face. The Control Module consists of Arduino Nano and control circuits for controlling the movement of the DC fan and the servo motor and for controlling the temperature of wind through PWM control. Windtherm works synchronously to the image and sound of the VR application presented by the HMD VIVE Pro and blows the temperature-controlled wind to a user's face. The overall flow of the processes is described in Figure 11.

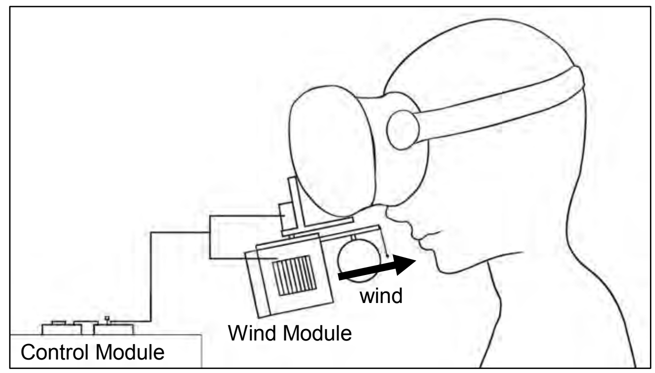

Figure 9. Windtherm with two modules in action.

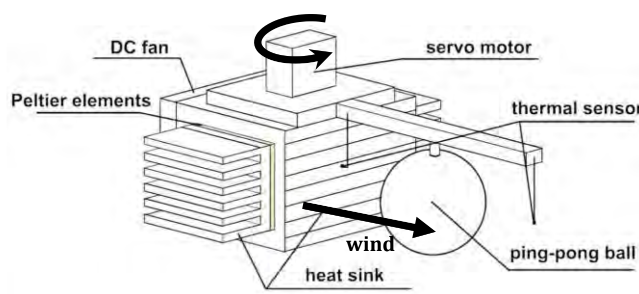

Figure 10. Design and elements of the Wind Module.

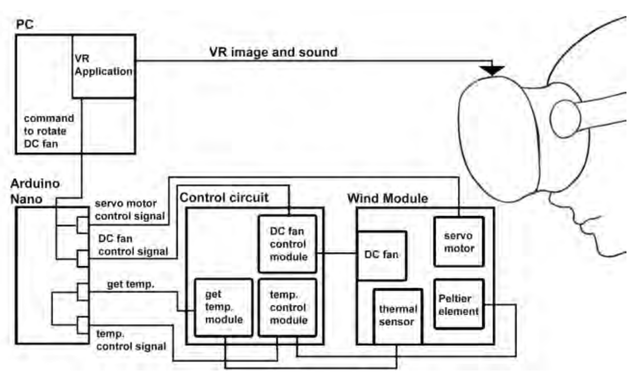

Figure 11. System flow of Windtherm.

3.2 Prototype of Windtherm

The fabricated Wind Module and the Control Module of Windtherm are shown in Figures 12 and 13. Weight of the Wind Module plus the parts for attaching it to VIVE Pro is about 276.8g.

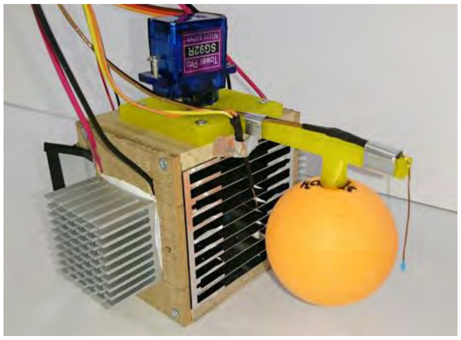

Figure 12. The fabricated Wind Module.

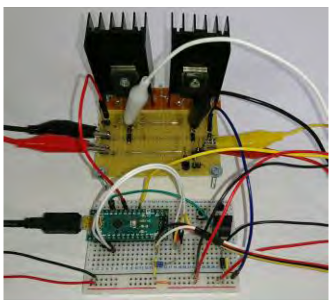

Figure 13. The Control Module with Arduino Nano and control circuits.

We have confirmed that Wind Module works synchronously with VR applications and achieves the inside temperature in the range of 30℃ to 40℃ through the PWM control. Namely, the goal temperatures of 30, 35, and 40℃ were achieved and stabilized, starting from the room temperature of around 26.0℃ within 30 to 60 seconds as shown in Figure 14.

We also conducted experiments on the relation between the temperature inside the Wind Module and that in front of a user's face. We first raised the inner temperature to room temperature+x℃ for x = 5, 10, 15, 20, waited for five seconds to stabilize the temperature, and then blew the wind for five seconds and measured the temperatures in front of a user's face throughout using the outer thermal sensor. We executed this process 5 times for all the cases x = 5, 10, 15, 20 and computed the mean of the increase value of temperature in front of a user's face from the initial room temperature after wind blow after five-seconds. The results are shown in Figure 15. The means of the increase of temperatures for x = 5, 10, 15, 20 were 3.0, 5.2, 7.0, 8.9, respectively. So, the increases of temperature in front of a user's face were almost proportional to the increases of temperature inside the Wind Module. Consequently, we confirm that Windtherm can send temperature-controlled wind in front of a user's face in this range of temperatures.

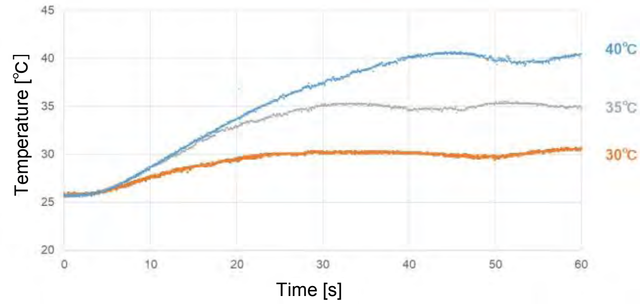

Figure 14. Convergence of temperature through PWM control.

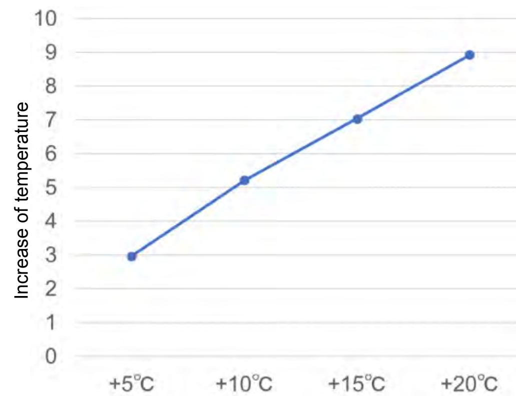

Figure 15. Relation of increase of temp. inside the Wind Module and increase of temp. in front of a user's face.

3.3 VR Application and Demonstration

We again used Unreal Engine 4 (UE4) and constructed a VR application for which wearable and mobile capabilities of Windtherm are effectively used. For this purpose, we constructed a virtual space of temperate desert where users experience some occurrences of wind, such as mass of dead branches, called tumbleweed, comes rolling with auxiliary breeze (Figure 16, Left); and sandstorm comes and pass by (Figure 16, Right). For these events, sound effects of blowing wind are also added.

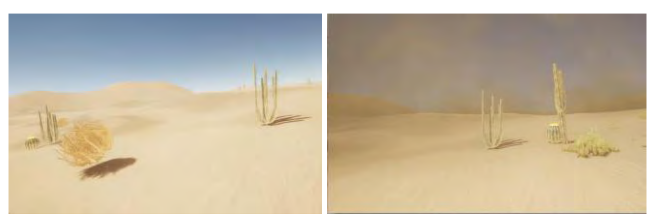

Figure 16. Scenes in desert with tumbleweed and sandstorm.

Finally, we show in Figure 17 an image of a user experiencing the virtual desert and receiving the actual temperature-controlled wind using Windtherm.

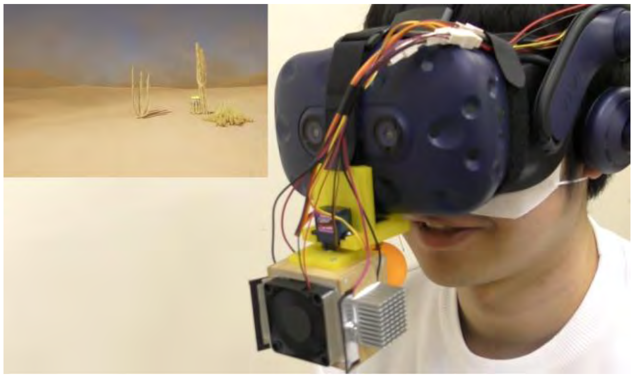

Figure 17. User experiencing virtual desert using Windtherm.

4 CONCLUDING REMARKS

We presented a wearable device for a HMD that provides temperature-controlled wind for enhancing the sense of presence in the virtual environments and confirmed its basic capabilities of generating and blowing wind with aimed temperature, force, and direction. Future work includes evaluating how Windtherm with the temperature-controlled wind affect the sense of warmth/coolness users feel and how it affects the user's sense of presence in the virtual environments. To develop novel digital contents using Windtherm is also our future work.

5 ACKNOWLEDGMENTS

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6 REFERENCES

[1] Witmer, B. J. and Singer, M. J. 1998. Measuring presence in virtual environments: A presence questionnaire. *Presence: Teleoperators and Virtual Environments*, 7(3), 225–240.

[2] Ahmed, K. S. 2003. Comfort in urban spaces: defining the boundaries of outdoor thermal comfort for the tropical urban environments. *Energy and Buildings*, 35 (1), 103–110.

[3] Andrade, H., Alcoforado, M.-J., and Oliveira, S. 2011. Perception of temperature and wind by users of public outdoor spaces: relationships with weather parameters and personal characteristics. *International Journal of Biometeorology*, 55(5), 665–680.

[4] Knez, I. and Thorsson, S. 2006. Influences of culture and environmental attitude on thermal, emotional and perceptual evaluations of a public square. *International Journal of Biometeorology*, 50(5), 258–268.

[5] Ogi, T. and Hirose, M. 1996. Multi-sensory data sensualizaton based on human perception. *Proceedings of the IEEE 1996 Virtual Reality Annual International Symposium*, 66–70.

[6] Cardin, S., Thalmann, D., and Vexo, F. 2007. Head Mounted Wind. *CASA*, No. VRLAB-CONF-2007-136, 101-108.

[7] Kojima, Y., Hashimoto, Y., and Kajimoto, H. 2009. A novel wearable device to present localized sensation of wind. *Proceedings of the International Conference on Advances in Computer Entertainment Technology*, 61-65.

[8] Sodhi, R., Poupyrev, I., Glisson, M., and Israr, A. 2013. AIREAL: Interactive tactile experiences in free air. *ACM Transactions on Graphics (TOG)*, 32(4), Article No. 134.

[9] Hülsmann, F., Fröhlich, J., Mattar, N., and Wachsmuth, I. 2014. Wind and warmth in virtual reality: implementation and evaluation. *Proceedings of the 2014 Virtual Reality International Conference*, ACM, 24, 8 pages.

[10] Peiris, R. L., Peng, W., Chen, Z., Chan, L., and Minamizawa, K. 2017. Thermovr: Exploring integrated thermal haptic feedback with head mounted displays. *Proceedings of the 2017 SIGCHI Conference on Human Factors in Computing Systems*, ACM, 5452-5456.

[11] Ranasinghe, N., Jain, P., Karwita, S., Tolley, D., and Do, E. Y.-L. 2017. Ambiotherm: Enhancing sense of presence in virtual reality by simulating real-world environmental conditions. *Proceedings of the 2017 SIGCHI Conference on Human Factors in Computing Systems*, ACM, 1731–1742.

[12] Ranasinghe, N., Jain, P., Tram, N. T. N., Koh, K. C. R., Tolley, D., Karwita, S., Lien-Ya, L., Liangkun, Y., Shamaiah, K., Tung, C. E. W., Yen, C. C., and Do, E. Y.-L. 2018. Season Traveller: Multisensory narration for enhancing the virtual reality experiences. *Proceedings of the 2018 SIGCHI Conference on Human Factors in Computing Systems*, ACM, 577, 13 pages.

[13] Han, P.-H., Chen, Y.-S., Lee, K.-C., Wang, H.-C., Hsieh, C.-E., Hsiao, J.-C., Chou, C.-H., and Hung, Y.-P. 2018. Haptic Around: Multiple tactile sensations for immersive environment and interaction in virtual reality. *Proceedings of the 24th ACM Symposium on Virtual Reality Software and Technology (VRST'18)*, Article No. 35.

VR Conferencing: communicating and collaborating in photo-realistic social immersive environments

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ABSTRACT
While Virtual Reality applications become more multi-user experiences, mostly artificial avatars are used for the representation of users in the virtual environment. This is fine for many multi-user scenarios but is less than ideal in more social settings like talking to your family, friends or business partners. In this paper, we like to outline the concept of Social VR based on real-time photorealistic capture and representation of users. Particularly, we introduce our web-based framework that allows for both the creation and consumption of photo-realistic social VR in 3D and 360-degree environments. Further, we evaluated our system both in a 360-degree remote collaborative meeting and in a full 3D experience. Our initial results indicate that our photo-realistic approach indeed offers a natural communication to the users with a high presence and immersion. With our system we do not only allow to explore, and experience VR together but also allow new forms of remote communication and collaboration.

Keywords
Virtual Reality, VR, Social VR, WebRTC, WebVR, interactive content, immersive virtual environments.

1. SOCIAL VR
Nowadays, social VR is mostly associated with graphical avatars in a graphical environment. Main examples are Facebook Spaces[1], AltSpaceVR[2], Mozilla Hubs[3] and many more. All these consist of a shared virtual environment, using graphical avatars to represent the users, and offering various possibilities, such as shared gaming and content consumption and multi-user communication and collaboration. The transfer of user motion to avatar motion is achieved by employing HMD and controller tracking. These environments offer a compelling experience of togetherness in which immersive video is combined with spatial and 3D audio [5], still, they are limited in the way you perceive other users. “The social cues that you would normally have about someone being creepy or safe weren’t there.” [3]

The alternative to a graphical avatar is a photo-realistic representation of users. When it comes to photo-realistic social VR we can distinguish between 3 types: i) capturing the user and environment at the same time (e.g. with omni-directional cameras), ii) capturing the user alone (e.g. with depth or stereo cameras) [1][2][4][6] and iii) capturing a full (volumetric) 3D representation of the user [7]. However. due to the complexity of processing and transmission of 360-degree and volumetric data the first and third approaches still needs more research to get closer to market ready. Our approach focuses on an individual user capture via RGB and depth sensors. This offers the benefit of being able to reuse traditional media processing and transmission and thus having a reliable end-to-end media chain.

[1] https://www.facebook.com/spaces

[2] https://altvr.com/

[3] https://hubs.mozilla.com/

Figure 1: multi user 360-degree experience

2. TOGETHER VR
Our social VR framework called Together VR extends current video conferencing with new VR functionalities, based on web standards and technologies. The framework is modular and allows for an easy creation of VR experiences that are social and the consumption of these experiences, using off-the-shelf hardware. With the framework, we aim to allow users to interact and collaborate while being immersed in interactive VR content.

To capture a photorealistic representation of a user, we first need to capture a color and depth image with the help of a depth camera (e.g. Microsoft Kinect v2 or Intel Realsense). In a second step the image is analyzed, and the user is separated from the background (the background is replaced with a chroma-key color). The resulting image is transmitted via a web client as video over WebRTC to another user’s web client. Finally, the complete virtual environment is rendered in the browser and the users are placed into the environment (making the chroma-key background transparent) so that he/she naturally blends into the surroundings.

Each end-point consists of a VR capable laptop, a single depth camera, audio headset and a VR HMD.

Figure 2: Social VR 3D-degree experience (incl. self-view)

3. MULTI-USER 360-DEGREE EXPERIENCE

In our multi-user 360-degree experience [2][4], 2-4 people sit around a table in VR. The view of each user is the same, each user sees the other users on the opposite side of the table and optionally a video or presentation on the top of the table (see Figure 1). To evaluate this experience, we held a 1-day experiment session in an informal and uncontrolled setting at our lab facilities, asking groups of 3 people to communicate while watching a video. We collected feedback through a short questionnaire from 54 participants (avg. age of 33 and 43% Female). People expressed a high level of interaction and immersion within the conversations. As part of the questionnaire the users rated the system with a "good" overall quality of 4.35 (SD 0.51) and video quality of 3.65 (SD 0.77) on a 5-point scale.

4. MULTI-USER FULL 3D EXPERIENCE

In our full 3D experience (see Figure 2), we include a full 3D environment and use both the color and depth information of the user capture to display users in 3D (as point cloud or mesh). This means, additionally to the replacement of the background with a chroma, a new image format combines the color image and the depth image. This is, we map the depth image into a grayscale and transmit the image as 2D video. To display this image as a point cloud or mesh we developed an optimized WebGL shader that maps each pixel into the 3D coordinates of the space [1]. This approach is also used to display a self-representation to each user. To evaluate this experience, we held a 2-day experiment session in an informal and uncontrolled setting at a conference venue. We collected feedback through a short questionnaire from 25 participants (avg. age of 35,26 and 12% Female) where 2 people were asked to communicate in our system while switching the environment between a 3D and a 360-degree virtual space. As part of the questionnaire, people expressed a preference for the 3D experience (60% 3D, 28% 2D, 12 % no clear preference) with a "good" overall quality of 6.92 (SD: 1.55) on a 9-point scale.

5. CONCLUSION AND FUTURE WORK

Overall, our current social VR web framework offers the possibility to easily create photo-realistic social VR experiences with a good user experience and natural interactions. It also allows to evaluate different types of VR technology and to quickly extend the software components with new functionalities.

Our next steps in development will focus on the following:

- Eye-gaze: to look each other in the eye. This year we will have a first version that replaces the HMD in a user representation with a photorealistic model of the face.
- Scalability: allowing large groups of people to join one session. This year we will scale our system to allow up to 10 users in one communication session, using a VR conferencing bridge.
- AR and mobility. As both augmented reality and mobile devices are becoming more important we are currently investigating how to extend and map our current framework to support AR and mobile display devices.
- Long term trials. We are currently setting up long term trials allowing people to use our system in their normal work environment for remote collaboration and meetings.

6. ACKNOWLEDGMENTS

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7. REFERENCES

[1] Gunkel, S.N., Stokking, H.M., Prins, M.J., van der Stap, N., Haar, F.B.T. and Niamut, O.A., 2018, June. Virtual Reality Conferencing: Multi-user immersive VR experiences on the web. In Proceedings of the 9th ACM Multimedia Systems Conference (pp. 498-501). ACM.

[2] Gunkel, S., Stokking, H., Prins, M., Niamut, O., Siahaan, E. and Cesar, P., 2018, June. Experiencing Virtual Reality Together: Social VR Use Case Study. In Proceedings of the 2018 ACM International Conference on Interactive Experiences for TV and Online Video (pp. 233-238). ACM.

[3] Leibrick, Suzanne, "Why women don't like social vr", https://extendedmind.io/social-vr

[4] Prins, Martin J., et al. "TogetherVR: A framework for photorealistic shared media experiences in 360-degree VR." SMPTE Motion Imaging Journal 127.7 (2018): 39-44.

[5] Waltemate, T., Gall, D., Roth, D., Botsch, M. and Latoschik, M.E., 2018. The Impact of Avatar Personalization and Immersion on Virtual Body Ownership, Presence, and Emotional Response. IEEE transactions on visualization and computer graphics, 24(4), pp.1643-1652.

[6] Woodworth, J.W., Ekong, S. and Borst, C.W., 2017, March. Virtual field trips with networked depth-camera-based teacher, heterogeneous displays, and example energy center application. In Virtual Reality (VR), 2017 IEEE (pp. 471-472).

[7] Zioulis, N., Alexiadis, D., Doumanoglou, A., Louizis, G., Apostolakis, K., Zarpalas, D. and Daras, P., 2016, September. 3D tele-immersion platform for interactive immersive experiences between remote users. In Image Processing (ICIP), 2016 IEEE International Conference (pp. 365-369).

Virtuality of Virtual Reality: Indiscernibility or Ontological Model?

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ABSTRACT

"Virtual" is now widely used in computer sciences. The classical conception states that virtual is typified by technological qualities, in which virtual and real are partially indiscernible. This paper finds a coherence between historical use of "virtual" in optical physics, which applies philosophical meanings of virtual, and technological ones in VR. It builds an ontological model of VR virtuality as being divided between a "virtual reality", an equivalent of "real object", "real world", a computer-generated actualization by "real images" on displays and a second virtualization by "virtual 3D images" in neural activity which forms a virtual reality in a "perceived object", "perceived world" sense. Virtual Reality does not exclusively pertain to the objective technological side but centers on the subjective psychological self.

Keywords

Virtuality; Virtual/Actual; Virtual Reality; Reality; Presence; Virtual Body; Virtual Image;

1 INTRODUCTION

The term "virtual" is commonly used in computer graphics technologies. Virtual reality, virtual embodiment, virtual incarnation, virtual cognition, virtual humans and, virtual collaborative world, etc. We aim to get a precise definition of what is virtual in Virtual Reality. The conception of defining the virtual by its technological characteristics is a starting point. The virtual is reduced to an empirical concept as being partially indiscernible from reality. Could not ontology, used as a scientific tool, help understand this highly connoted concept? Or is the carnapian gesture really useful to VR sciences?

2. VIRTUAL REALITY: A COMPUTATIONAL REALITY WITH A PARTIAL REAL/ VIRTUAL INDISCERNIBILITY

2.1 Opposition of conceptions of virtual

Two conceptions of virtuality in a scientific and technological area of VR seem to get into an opposition. One way is conceiving along with Berthier, Nannipieri and J. Guez that the virtual does not oppose to the actual but to the real. At the opposite, Pierre Levy and Couchot understand the virtual as really being opposed to the actual and part of the real. Which difference is there between these two ways of conceiving virtuality of VR?

2.2 Implicit definition: the virtual connotes computers' sides

The main technical definition of virtual reality in the international scientific community is given in *Virtual Reality: Concepts and Technologies*: *"Virtual reality is a scientific and technical domain that uses computer science (1) and behavioral interfaces (2) to simulate in a virtual world (3) the behavior of 3D entities, which interact in real time (4) with each other and with one or more users in pseudo-natural immersion (5) via sensorimotor channels."*[1]. What does 'virtual' actually denotes? Virtual is the qualifier of the world in which interactions in real-time, interfaces and 3D entities find their reality: computer-generated objects.

Therefore, how is the world which is virtual? A virtual world stands for a kind of world which differs from a "real world". Hence, *"The definition proves to be different from a simplistic vision of virtual reality being a "mere copy" of the "real" world."* [2] A "virtual world" is more than in a relation of representing the real world. It makes specific worlds *"a digitally created artificial world, [...] can be imaginary, symbolic or a simulation of certain aspects of the real world"* [3] Simulations can have a realistic side, but it still keeps a difference to bring an interest to VR compared to its real counterpart. Symbolic and imaginary worlds open a gate to incomparable, creative worlds.

Virtual qualifies a kind of world which can be in a semi-realistic relation to a real world but also to worlds which are independent from reality. The specificity of virtuality would be its technological properties.

2.3 The main definition of "virtual" is being partly indiscernible to the real

Even though VR opens gaps with the real world, one main part of it is its capacity to act as a substitute for it. Berthier explains that "virtual" is congruent with "virtue", force, strength of a being. *"Is virtual what is, without being real, what is operatively equivalent to the real »* [4] As an example, a virtual world can have properties which are going to be real as the reflection in a mirror will bring effects on reality. The virtual image of a light is really adding light. A plane simulation will really train a future pilot. "*There is no double dimension, virtuality and reality are indiscernible along "general principles""* [5] The virtual belongs to a same array of phenomenon which can only "easily be differentiated from the real by any normal person resorting to another sensori-motor channel.

Therefore, virtual reality is a member of virtuality which is a kind of phenomenon happening in reality, similar to it but different in some empirically defined other ways.

3. ONTOLOGICAL MODEL OF VR

3.1 The virtual and the actual in VR

This technical model of virtuality is opposed to a so called "ontological" one: *"these authors [...] seek to highlight an ontology by granting concepts a predominant role*" [6] states Nannipieri.

In this conception, developed by a majority of philosophers, Bergson, Deleuze and Pierre Levy who applies it to understand development of cultures, typically of transformation of reality by technical means, virtuality is understood as a pole opposed to actuality. Concepts denotes a metaphysical realm devoid of phenomenal expertise. *« It is mainly the effects of the virtual as a phenomenon which interests me and its conception related to technology: the effects which I can watch as well as their implied transformations"*[7] explains Judith Guez aiming towards creation of illusions between virtual and reality along an approach of digital magic.

However, these concepts originate in the need to explain observations. The opposition between potency (versus virtuality) and actuality in Aristotelian philosophy stands as a model of reality complex generation. It has been worked through by scolastics, arrives in modern days through philosophy and sciences with Leibniz. Virtual and actual are ways of being of the real. Reality exists in a virtual way when it is a latent potency. Reality exists in the present when its virtuality is actualized, manifested.

The fact of virtuality/ actuality as being a computer quality is attested in a digital artistic reflexion, in Couchot's writings.

"To put it simply, we will say that the virtual in the computer exists in potency- a potency capable of updating in sensitive forms (images, sounds, texts or perceptive stimulations) during the dialogue man-machine. The virtual thus appears as the mode of being of simulation. It is not opposed to the real, but to the present." [8]

The virtual is an attribute of simulation, which is computer generated. Virtual is taken in a clearly philosophical, Aristotelian definition. A computer generates a kind of reality which is not limited to one temporal dimension, the present. Its force is to be able to generate versatile present effects through real-time interaction with a human. This would be impossible if there was no latent power which held alternative simulation models. Hence, one is able to describe the array of its simulations.

Therefore, virtual is the mode of being of simulation. Computers algorithms are potential generations made actual through interfaces. Actualizing is a result of movements being impulsed by user-machine interaction through interfaces, by its processing. No processing could happen if there would not be calculating means in potency, latent algorithms waiting in the dark for their activation. It is quite obvious that ontological concepts are operational to understand and plan virtual phenomena.

3.2 Dialogy: reality outside the computer, inside the computer, virtualization, actualization

The interest of keeping a virtual/actual differentiation of the real is that it manages to design a dynamical production of reality. In a very general way, reality is perceived as being divided in two processes, one which stands inside of a being as a potential rule, the other which defines the being at one present state. The first state is the virtual one, the second the actual one. The actual state is produced by the virtual rule. As a reaction, the virtual rule will react to its actualization, etc.

Reflecting about VR, Couchot has named this movement of reality a "dialogy". In this sphere, it is the relation between the user and the machine, between external reality, the plane of the user and internal "virtual" reality, the plane of the computer. *"The necessary relationship that it establishes with the real, on both sides of the interfaces, is a dialogical relation. The interfaces are the places where reality is virtualized and where the virtual is actualized."* [9] It is a dialogue between virtuality and actuality. "Real life" reality has been "virtualized", translated into algorithms. Users' interactions with computer's virtual, potential simulations make them "actualize", manifest in their specific declinations on different sensori-motor and cognitive displays. VR introduces a kind of dialogue within reality between differing layers. They are all real but with a different coefficient which interrelates with one another.

4 VIRTUAL REALITY AND VIRTUAL IMAGE

"Virtual" and its actual counterpart have shown their validity in describing computer generations. But the virtuality of virtual reality has yet one more dimension to investigate.

4.1 Virtual image and VR: optical meaning

The point here is to compare virtual images and virtual reality and to wonder what would be a coherent way to understand it. A "virtual image" is an optical term formed in XVIIth century physical sciences. It characterizes an image which is impossible to project on a material plane by contradistinction to a real image. A virtual image is a physical phenomenon, but an intangible one, as an illusion.

Optically, a virtual image is defined as the point of convergence of the continuation of the line of reflection from the real object in the imaginery space of the mirror and the line going to the point of view. The eye is integrated in the model of a virtual image. As the point of reception of the virtual image, the eye actualizes the image. But, a virtual image in a mirror would never exist if there was no intelligence to distinguish its ontological source. Animals watch real objects not images. According to psychoanalysis and animal ethology, understanding an image requires having passed through the "mirror stage", which very few living being besides infants do. This optical potentially illusionary property is an important vector for fantasy as shown in Lewis Carroll imaginative use of the "looking glass"[10].

In a similar way, Grau shows that Virtual Reality only exists as an effect in someone's brain.

"In virtual reality, 3-D images are projected in HMD monitors as two 2-D images. The spatial effect results from stereoscopic vision and is formed in the observer's cortex. Thus, the images leave their media in a twofold sense: a 3-D image, which has no physical

existence except, perhaps, in the excited neurons of the brain, forms a constitutive unit together with the observer and is non separable from him or her." [11]

VR really produces an illusory 3D reality. The screen can only show 2D images. 3D image exists only for the viewer, in his cortex. The brain is the technological device able to give its reality status to virtual environments.

4.2 Virtual Reality, models, displays and virtual 3D images

We shall understand this idea in analogy with the model of optical sciences. When Grau assumes that VR really exists in the brain, it means that a dissociation must be made between screens and brains. It is in the brain that the 3D image of the virtual model becomes real. It is real as virtual reality, as the only way an actualization of a virtual model can reach reality, which is in a consciousness.

However, a virtual model does exist in a computer as the effect of a certain number of algorithms. The brain only sees one part of the virtual model, the one which is perceived and could be called "projected world", following G. Desmarais' world distinctions: "*Between the real physical world (PW) and the projected world of sensitive manifestation (PW), there is an impassable hiatus"* [12] The reality of virtual reality belongs to a kind of perceived reality, a highly scientific, cultural one, not a raw physical reality. Yet, in a dualistic realistic conception, a perception is a kind of image of a reality. Therefore, we would deduct that 3D sensori-motor effect in the brain is the place where the optical virtual image lies. It is virtual in the physical science sense of not being projected on a screen. It is located in an unprojectable space, a neural interrelated unpositionable place which Stéphane Dehaene has called "neuronal global working space". [13]

Therefore, VR model could be explained as follows: "VR" in the computer should be named Virtual Model of Reality. It is not a real object as it has no tangible material existence but it stands as one of a kind. It is a 3D model standing in the place of the real object of the optical virtual image model. And it is virtual in the ontological meaning of being a latent processor which is going to be actualized through real-time interactions.

Secondly in the actualizing moment, this virtual model is projected on screens and other displays, realizing immersive effects like CAVE, HMD, Force Feedback Systems, with a movement of 2D images. As the definition of what is projected on a screen, it is a "real image", a materialized one. These are images actualizing the model but not the virtual image itself of the virtual (real) model (object) which needs a 3D perception/action. How could one call "virtual" these projections on screens? It would not be conceptually coherent with the scientific use of an optical virtual image. 2D screen images have a kind of transactional status, being the sensori-motor means communicating machine states to the mind.

Thirdly, virtual reality is really watchable by the synthesis of the cortical visual center and other parts of the brain, keeping the first sense of "virtual image". In the synthesis of the brain, there is an actualization of the virtual model in interaction with the user's input. This actualization has a depth; it is a kind of 3D moving image of the model. This is the equivalent of the virtual image of the optical model.

The "virtual 3D image" in the brain plays with a sense of reality which, going back to Desmarais' analysis stands for the "Perceived World" [12]. The "Perceived World" stands as an actualization of the "Real World", the modeled world, the simulated model. It exists in the virtual part, the computer. Therefore, the modelled world can be called "Virtual Reality" as it stands at the optical model "real object" place and is virtual as a computer generated object. "

4.3 Virtual 3D Image and PVR

Virtual Reality has been elucidated as the equivalent of "Real-World", but one has to add that it is a kind of image, a simulation of the world. Still it stands as the objective side of the subjective side of the image which lives in the mind. It actualizes itself in real images which produce virtual 3D images in the brain. Presence feeling is comparable to virtual 3D image. Writing about spectators' experience in a theatre, Merleau-Ponty describes the mental movements and perceptions.

"This virtual body moves the real body to the point that the subject no longer feels in the world where he really is, and that instead of his true legs and arms, he feels the legs and arms that one would have for walking and acting in the reflected room, he lives in the performance" [14].

Extrapolating from Merleau-Ponty's conception of a virtual body, a virtual 3D image is like a mental body giving a feeling of presence in a fictional reality. Virtual perceptions and movements take the place of "real", actual ones since they happen in a purely mental world as well as they give the illusion of "being there". Theatre is a paradigm of fictitious spaces which carry imagination and puts the spectator inside of a kind of virtual world, a world existing only in minds, where virtuality and actuality become simultaneous. In a virtual 3D image, virtuality of the image combines itself with its inner simultaneous actualization.

Associating presence feeling, virtual/actual inner body and virtual 3D images show that virtual reality does not exclusively belong to the objective side of computer simulation model. Going back to Desmarais' distinction[12], a real world (RW) is always associated to a perceived world (PW). In this sense, we find a virtual 3D image is a mental virtual reality. The importance of this part of reality as being the only side which is conscious and to which all VR is focused, thinking in terms of subjective VR, "PVR" (perceived virtual reality) is a step forward.is

5 CONCLUSION

The position of partial indiscernibility between virtuality and reality, the parti of putting aside concepts as not being effective to understand what happens in the world of experience is simpler, looks more empirical, but lacks precisions. Taking into account the optical model of "virtual images", the virtuality of VR denotes a computer generated simulating model which stands as a reality model. Virtuality points to an ontological concept designating a potential part of reality as opposed to its actualization, referring to the materially existing reality, the part of reality which has been realized. VR devices are seen as "real images" of VR models, transactional realities which lack the true 3D reality of the model. Virtuality of VR truly exists as a virtual 3D image, as a mental state in the user's brain. Close to theatre, Virtual Reality relates to the complex of simultaneous virtualizing/actualizing in the inner world. Therefore, VR really is a PVR (perceived virtual reality). VR researches area could profitably englobe several other sciences as e.i. neural sciences, cyberpsychology and sociology in its domain.

REFERENCES

[1] FUCHS, P., MOREAU, G., & GUITTON, P. (2011) *Virtual Reality: Concepts and Technologies* p. 5

[2] FUCHS, P., *Virtual Reality: Concepts and Technologies*, p. 6

[3] FUCHS, P., Ibid.

[4] BERTHIER, D. (2004). *Méditations sur le réel et le virtuel*: Harmattan. p. 85.

[5] BERTHIER, *Ibid*., p. 75.

[6] NANNIPIERI, O. *Les paradoxes de la présence dans les environnements immersifs : de la réalité à la réalité virtuelle,* Thèse, Université de Toulon, dir. Philippe Dumas, 2013.p. 132.

[7] GUEZ, J. (2019). *Illusions entre le réel et le virtuel (IRV) comme nouvelles formes artistiques : présence et émerveillement.* https://www.theses.fr/195162412Gue, Judith in her PhD thesis p. 79.

[8] COUCHOT, E. (2007). *Des images, du temps et des machines, dans les arts et la communication*. N.mes: J. Chambon, p. 201

[9] COUCHOT, *Ibid*. p.11.

[10] CARROLL, L., ((1865)-2009). *Alice's Adventures in Wonderland* and, *Through the looking-glass*.New York: Penguin Classics.

[11] GRAU, O. (2003). *Virtual art : from illusion to immersion*. Cambridge, Mass.: MIT Press, p. 251.

[12] DESMARAIS, G. *Dynamique du sens*. Septentrion, 1998, p. 16.

[13] DEHAENE, S. (2019). *Code de la conscience* - Éditions Odile Jacob.

TAMED CLOUD: Sensible interaction with a swarm of data

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ABSTRACT

Faced with an overload of dematerialized information, would it be possible to propose an aesthetic, sensitive, even affective relationship with a cloud of information, thought of as a living and malleable entity? Would it be possible to interact in immersion with my data, to tame it, to sculpt it, to reclaim it for myself? Our purpose is to create such an aesthetical, sensible and affective relationship with a set of data, based in particular on gesture and speech interactions, inside an immersive virtual reality environment. The Tamed Cloud project aims at proposing new modalities of accessing, processing and memorizing these vast amounts of data. We present in this paper our research, and our first results, a functional virtual reality experiment, currently under evaluation.

Keywords
Virtual Reality, Immersive experience, Artificial intelligence, Data design.

1. INTRODUCTION

The project *TAMED CLOUD, sensible interaction with a swarm of data*, was born from the observation that we are currently in an era of an overloading of dematerialized information. These huge amounts of data overwhelm us, making us lose touch with them, in both our professional and personal lives. The volume of data to consider has reached a critical threshold. Traditional visualization techniques fail to simultaneously, allow access to specific pieces of information, provide a comprehension of grand ensembles, and favor the discovery of unexpected associations. For this reason, new visual representation models need to be conceived. Such models should include possibilities for interactive manipulation and processing of these large sets of data, to tailor experiences better adjusted to the body dimensions and to the spaces derived from them.

In this article, we detail our research intentions and explain the methodology we followed to produce a prototype, which should soon lead to a Proof of Concept (POC). The prototype we have realized consists of an immersive experience in virtual reality, offering the possibility to interact with an ensemble of pictures from the MoMA's (Museum of Modern Art, New York City) collection, according to gestural and postural modalities, as well as voice conversation, thanks to the IBM Watson Cognitive Platform.

2. HYPOTHESIS

The intention of our research team is to explore a new approach to digging, exploring and manipulating unstructured data, based on an intuitive gestural and verbal interaction language. Our hypothesis is that it is possible to propose an aesthetic, sensitive, even emotional relationship - based in particular on gesture and speech recognition.

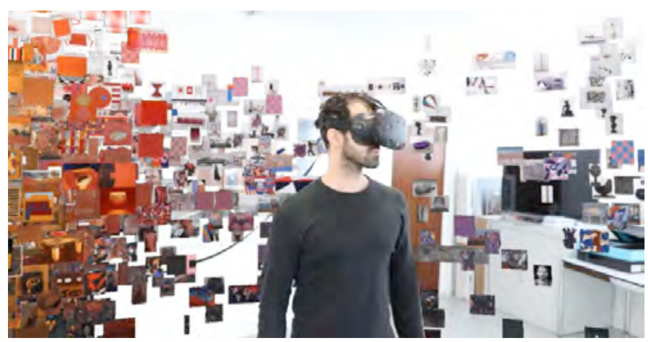

Figure 1. user in the TAMED CLOUD environment (Composite picture).

The project is to create an immersive installation for visualizing data presented in the form of a 3D cloud with autonomous and reactive behavior that will be taking shape according to the user's movements. The user - in VR immersion and acting as a researcher, a collector or a curator - will be invited to manipulate, sculpt this "vaporous" mass of data and tame it plastically with her gestures. She will be able to make gesture selections of data groups in the cloud and organize them spatially, according to non-predictive rules and conventions. Through speech, it will be possible to ask the cloud to organize itself according to different criteria, or even to extract groups of data and present them according to some of their specific characteristics. The cloud behaviors would then promote certain data matching at the user's request, but they would also generate unexpected and intuitive associations that the user would not necessarily have thought of.

This approach could meet our objective of providing better access to large amounts of data and open the door to new ways of accessing and processing them.

In this research, we will examine two main issues:

- How can proprioceptive sensitivity contribute to data mining work? We want to study the advantages and/or constraints that may arise when a body in immersion (visual and proprioceptive perception) is engaged with data, in tasks such as sorting, selecting and categorizing them.

- How could a behavioral data organization stimulate the user in her data mining work?

Our hypothesis is that the user will adopt de facto singular postures towards the visual organization of the data. The analysis of these postures will give us the possibility to modulate the data behaviors and re-shape the interaction relationships between user and data.

To carry out this project we have gathered a multidisciplinary team of researchers from the fields of information science, data design, cognitive science, behavioral objects, and art and interaction design.

The developed functionalities would be assisted by artificial intelligence technologies, (Alchemy Language, Visual Recognition, Natural Language, Machine Learning etc.)

2.1 Data design

Data behaviors will be of two main types, semantic data behaviors built on the basis of the meaningful relationships that bind them together and behaviors that depend on the quality of the interactive exchanges between the user and the data. One of the main research axis opened here refers to the dynamic visual-graphic arrangement of the dataset, according, firstly, to their intrinsic meaning relationships and, secondly, to the functional, interactional possibilities that it proposes. In short, it becomes interesting to study what could be the good or relevant data patterns for each data arrangement and behaviors. We could then find new affordance principles at the crossroad of meaning expression and interaction possibilities. Such a study supposes reactivating open questions, and concepts developed earlier, between data design and cognitive science (behavioral psychology). Key initiators of such an approach include Stuart K. Card, Jock D. Mackinlay, Ben Shneiderman (Card et al., 1999), George G. Robertson (Robertson et al., 1989), John Stasko (Stasko, 1993, 1996), James D. Hollan (Hollan et al., 1986) and Edwin Hutchins (Hutchins, 1995, Hutchins et al., 1985) or George W. Furnas (Furnas and Bederson, 1995), also various laboratories (HCI) attached to the Xerox PARC Research Center (Palo Alto), the University of California (San Diego), the University of Maryland, the Georgia Tech Institute (Georgia Tech), the University (Virginia Tech), IBM, AT T and Bell laboratories, etc.

Initially we will focus on the consultation of visual data - paintings and photos - for which our approach seems particularly suitable. However, in the long term, we hope to be able to dynamically use any form of data potentially available in the cloud, whether numerical, textual, audio or visual (photos and films).

The online MoMA database counts more than 200 000 references, in various artistic specialties. In our first prototype, we used 4000 paintings and pictures issued from it, as well as some accompanying metadata, such as title of the piece of work, name of the artist and date of creation. In order to enrich this database, we plan to include later, additional information on the works and artists, in particular texts and comments written within the exhibition catalogues published by the museum, such as biographies, reviews of works, views of artists or collectors and so on.

2.2 Behavioral objects

2.2.1 *Autonomous behavior of the cloud*

We imagine a cloud of data animated by spontaneous movements. Much as a swarm of birds or a fish bank, spontaneously organizing into emergent states (Sumpter, 2006; Couzin, 2009), the cloud could display a self organizing behavior with expressive variations. Designing behaviors for an autonomous artifact is about channeling human intuitions about movement (Levillain Zibetti ; Hoffman Ju, 2014). It is about creating movement patterns that an observer may construe as goal-oriented, possibly intentional actions (Heider Simmel, 1944; Scholl Tremoulet, 2000). In addition, the representation of a collective behavior solicits other intuitions, such as the possibility to compute properties of an ensemble (Ariely, 2001), or Gestalt qualities attached to a set of moving elements (Britten, 1992; Williams, 1984). Besides the immediate empathic connexion promoted by a self-generated behavior, giving spontaneous movements to a cloud of data is of interest from the point of view of data visualization. In relation to the data structure, the cloud's behavior may serve the purpose of highlighting different data sets and connexions between those sets. The cloud could for instance organize as a collection of distinct swarms, each corresponding to a data set, or it could use properties of alignment between the elements of the cloud to represent gradients. The cloud could also shape into recognizable figures, and display the data according to known formalisms, based on the relationships inside the data structure (hierarchical, discoidal, concentric or eccentric organizations, tabular, matrix, etc.).

2.2.2 Engagement behavior of the cloud with the user

The engagement behavior of the cloud corresponds to its transformations in response to the user’s proximity and actions. Maintaining an engagement with a user is one of the foremost issues in social robotics. By giving some social abilities to the artificial agent, such as facial and gesture recognition capacities, or the ability to predict and adapt to the user's response (Anzalone et al 2015), a form of connexion with the user may be initiated and maintained, involving the control of the user's attention and motivation. With a cloud of data, such an engagement behavior may consist in reconfiguring the cloud to facilitate the interaction, for instance by enveloping the user or displaying the data on a single plane. It may also consist in prompting the user to interact with the data, possibly by highlighting some data immediately accessible, or display meaningful configurations, for example by aggregating similar data. Finally, elements of personalization could be added to the cloud's behavior, such that the cloud would respond differentially depending on the user's personality, as manifested for instance by the way she explores the environment, the hastiness or delicacy of her gestures.

2.3 Interaction design

For more than a century, research has reaffirmed the central role of the body in the processes of perception and understanding of the world, in philosophy (Poincare, 1902; Merleau-Ponty, 1945), in cognitive science (Varela al, 1993) or in art and communication, particularly with the emergence of digital media (McLuhan, 1964; Grau, 2003; Jones, 2006; Couchot, 2012).

It has been shown that the gesture and particularly the gripping gesture can be considered as a meaningful contribution to the exploration and memorization of our environment (Berthoz, 1997, 2013), these perceptual capacities being of different natures, depending on the degree of proximity of objects in our environment (Hall 1971; Bennequin, 2017)

These principles have been applied in virtual reality (Fuchs, 2018) and have demonstrated the ability of digital paradigms to produce for the user the senses of presence, agentivity and embodiment (Heeter, 1992; Lee, 2004; Slater, 1999, 2009), that stimulate body engagement and vice versa.

When discussing about virtual reality experiences in design, many researchers and artists highlight the importance of the storytelling, the behavioral feedback and experience learning (Bilda Al, 2008; Wright McCarthy, 2008; Tramus Al, 2003) and the natural user interfaces (NUI), as all these components stimulate the user's engagement in creative tasks. (Vertegaal Al, 2008; Wigdor Al 2011)

2.3.1 User interaction behavior

In Tamed Cloud, interactions with the data cloud are guided by certain gestures, partly based on gestures made in the physical space, with a view to preserve as much as possible the user's intuitiveness. The instrumentation - user's handheld controllers – is calibrated according to the body and proprioceptive field and will serve as an extension of this body and proprioceptive field. Our aim is to propose new visual representation models, ones that offer intuitive interactions that immerse the user in the virtual world. We seek to provide the user a tailored environment in which she is invited to create a personal relationship with the data, through various interactions, in a fluent and intuitive way. We nevertheless are faced with the technological equipment required to achieve an immersive VR experience. Although the public is getting more and more familiarized with this kind of technology, its integration often poses inevitable questions around the complexity of its usage, as well as the target group of the final application. Wearing an HMD and holding the controllers, all the while having to deploy multiple buttons and gestures in order to achieve certain interactions, may have a certain advert effect on the immersion process. To avoid the complexity of the usage of the VR controller, we have implemented the majority of interactions through the use of just a single button and also, by realizing certain interactions through gestures inspired from the user's everyday life. We chose to avoid the use of a complex graphical user interface (GUI) that would provide the necessary information and explanations around the controller's usage. The above solution is inspired of a more general problem related to the interface technologies, as nowadays they tend to separate the functions of our body and as a result, to put us out of touch with ourselves and the environment around us, whether it is real or virtual (McLuhan, 1964). The reception of the majority of the information that comes from the digital world is made through devices that we carry on with us. These devices tend to remove us from our surroundings and demand our attention. Inspired by the principles behind natural users interfaces (NUI), many researchers are concerned by this fact and try to create more calm technologies, where the interactions are more fluid and intuitive and take place in our periphery, drawing our attention rather than demanding it. Such interaction styles try to take advantage of the users' preexisting knowledge and experience of everyday life, as well as some communication models that are already familiar to the user. (Georgakopoulou et al, 2018)

We already implemented some of these principles in our prototype of Tamed Cloud, through simple gestural and speech interactions that we describe in detail here under (Paragraph 3. The Prototype realized).

We also consider implementing other gestural interactions in the experience, such as:

- Individual data selection, zoom and display of properties: The user can designate a data, validate its selection and bring it to the foreground and then access the metadata describing the selected image.

- Aggregation in the form of a data trail: The user can select a data from the cloud, pull it in a certain direction and extract it from the cloud. The selected image becomes a leader and attracts data with similar characteristics behind it, forming a data trail that the user can stretch as she wishes. Data enrichment by Artificial Intelligence takes place in this selection phase. The aggregate data within the trail being identified by AI as having aspects of similarity, according to the analysis of certain of their characteristics.

- Data trail cut: After stretching the data trail, the user could break it (e. g. by mimicking a cutting action) and thus isolate the data from the rest of the cloud, making it available for new interactions. In addition to the three selection and aggregation functions described above, we also consider two other "high-level" functions.

- Data shifting: The user has the ability to filter the data still in the cloud, or the data previously extracted from the cloud, by adopting appropriate gestures (e. g. shaking the device), thus causing the aggregation of data with similar characteristics.

- Depositing and memorizing: Another way to reclaim our data, after the processes of selection, organization, and sorting, is to perform a gesture of deposit/attachment of a group of the processed data in a dedicated storage space - either a pre-designed scenography or a customized space, for example by a 3D scan of an intimate space. This operation of memorization via a place (Topos) will be based on the specific cognitive capacities related to spatial memory. The aim is to implement and invoke in the digital spaces techniques of memorization (Ars Memoriae) and appropriation of information (Curiosity cabinets).

2.4 Artificial intelligence and deep learning

During further development, we will also integrate artificial intelligence and machine learning functions, simulating cognitive functionalities. These tools aim to facilitate user interactions with the data by promoting intuitive interactions. In our case, speech and gesture interactions, AI will assist the user in her sorting actions, her research in the data, as well as in modulating the behavior of the cloud, according to the user's actions and biometric criteria.

Verbal interaction: integration of Voice Recognition and Natural Language functionalities will allow the user to establish a dialogue with the data, without going through menu-type interactions, or keywords. Gestural interaction: Integration and development of tools for qualitative analysis of the gesture associated with learning tools, will allow a personalized recognition of the user's gesture and its semantic (the meaning of the gesture) and psychological qualities (the user's stress state).

Data and metadata structuring assistance: Integration of Visual Recognition tools will provide assistance to the user when searching and organizing metadata, as well as when selecting a corpus among online data.

Experience management: Integration of machine learning tools will control and modulate the cloud's behaviors, according to the user's experience level, behavior, and biometric data.

3. PROTOTYPE

The first exploratory phase of the four major aspects of the project described here above, led to the realization of a prototype in the form of a functional immersive virtual reality experience.

3.1 Scenario and Protocol of the experience

3.1.1 Behavioral functionalities of the cloud

When she enters the virtual environment, the user is presented with a cloud of about 4000 pictorial and photographic works that shows an active and reactive autonomous behavior towards her. When the user approaches and comes into contact with the cloud, the latter organizes itself around her and reacts to her presence and gestures, according to the nature, intensity and rhythm of the user's behavior. The Tamed Cloud installation provides several types of interactions through gesture and speech.

3.1.2 Gestural interaction functionalities

One case scenario for the gestural interactions that we implemented in Tamed Cloud is the controller-as-an-imaginary-object function. The user is invited to imagine holding the adequate object to perform each kind of interaction. For example, a magnifying glass is a tool which is used to closely examine the details of an image or a text.

The gestural operations are partly modeled on the gestures performed in a real physical space, thus promoting intuitiveness and a sense of presence. The interaction tools - the controllers, that act as an extension of the body and proprioceptive field, as well as the real-time responses to the user's gestures and commands, guarantee an optimal immersion.

Figure 2: selection and deployment of a group of images.

By gesture - using the controller - the user can select a group of images, move it, isolate it and deploy it. By isolating the packages of artworks she has selected, and by placing them away from the cloud, she can sketch out a first approach to the functions of organization and memorization.

During any time of the experience, the user can activate the functionality of the magnifying glass, which allows her to focus and examine something more closely. All she has to do, is to perform the gesture that she would perform when holding this object. Then the controller-as-magnifying-glass is activated. According to her gesture, a pointer appears in order to help her visualize and demonstrate the point of focus of the controller inside the virtual environment. The user then can focus on an image by magnifying it and simultaneously reveal and consult its metadata.

Figure 3: consultation of metadatas with the magnifying glass function.

She can also chase away the images selected in the cloud, with a single movement. The user can therefore manipulate and sort this mass of data, by taming it plastically, physically and emotionally.

3.1.3 Verbal interaction functionalities.

When she enters the virtual environment, the user is faced with the cloud of data, out of his reach and behaving like an autonomous swarm of birds. She is right away invited to use vocal commands to engage in a relation with it.

Figure 4: selection of an image group by criteria, by voice recognition.

Using voice control and the functionalities provided by the IBM's Watson cognitive platform, the user can ask the cloud to change its position and formation. According to each given command, the cloud will react in a specific way. More concretely, the user can ask the cloud:

- to come, the cloud will accordingly approach and stand idle in front of the user,

- to go away, the cloud will then move away from her and enter in its original state of autonomous behavior;

- to reorganize itself either to the dominant color of the depicted artwork or by chronological order of the dates of the artworks.

As a result, for each of these commands, the cloud will accordingly reorganize itself either in a circle of colors or a spiral of time. For both these cases, the cloud will form around the user wherever she may be, inside the virtual environment.

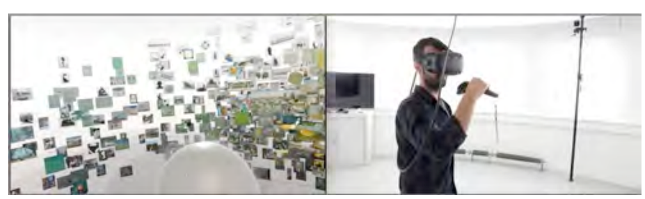

Figure 5: selection of the image organization mode, by voice recognition.

As an added extra layer of voice interactions, the user can ask the cloud to isolate a subassembly according to a color criterion, i.e. red, green or blue color. The use of natural language through conversation and vocal commands towards the cloud constitutes a bridge between the real and the virtual that enhances the feeling of immersion in the user's environment. To this end, we implemented in Tamed Cloud a set of artificial intelligence and machine learning tools provided by the IBM's Watson platform.

Again, in this usage scenario, we had to, first of all, find a way to integrate these tools in the virtual reality interactive environment and then, invent a way to seamlessly and fluently activate these functionalities, when needed from the user. Here once more, we referred to our everyday activities and real life experience in order to create a natural interface for the user through her gestures. The user, in this case, is invited to imagine holding a microphone and performing the adequate gesture that would allow her to talk in an actual microphone. Accordingly, the representation of the controller inside the virtual environment changes to a sphere which helps her understand and visualize the recording of her voice. The gesture allows for the activation of a process which will send data over to the Watson service and wait for the response, which may trigger interactions with the cloud of data.

3.2 Technical description and development

In terms of software, Tamed Cloud was developed using the environment provided by Unity 3D. Additional tools, plugins and frameworks were implemented, in order to create the immersive virtual world and the interactions inside it, such as the IBM Watson SDK for Unity, which is used to develop and implement the cognitive interactions that will be described below. The prototype is presented with an HTC Vive virtual reality headset, deploying both controllers for the necessary gestural and speech interactions. Nevertheless, along the development period we aim in producing a platform independent environment, able to be adapted in various cases and create seamless interactions across multiple virtual reality platforms. For the prototype, we chose to visualize a part of about 4000 images from the MoMA's collection. The works of art included in this collection are fully described with metadata inside JSON files, which are analyzed and accessed in real time throughout the immersive experience. The number of pictures showcased should by no means be considered as a limitation, as the handling of large amounts of data resides in the fundamental principles of Tamed Cloud. In order to enable our virtual reality platform to handle the visualization and interactions with such amounts of data, we implemented general-purpose computing on graphics processing units (GPGPU) algorithms, through the use of compute shaders in Unity. These types of algorithms serve to execute massively parallel tasks that run on the graphics card, outside of the normal rendering pipeline, thus accelerating parts of the virtual environment rendering and allowing us to significantly increase the amount of data to be processed and visualized.

Technical Information:

- HTC Vive headset - 90 Hz refresh rate - 110° viewing angle - 1,200 x 1,080 px - equipped with sensors, gyroscope, accelerometer and laser position sensors,
- Two wireless controllers with gyroscope, accelerometer and laser position sensors.

• Interaction simulator: Multi-platform game engine developed by Unity Technologies. One of the most widespread in the video game industry, as well as in the experimentation of art and science paradigms, due to its efficiency in prototyping.

• Written in JavaScript, C and Boo

• Artificial intelligence functions: Watson integrates a Docker container for Unity, and a SDK Unity.[1]

4. DISCUSSION

4.1 Feedback

The prototype was presented on October 5, 2018 in Paris at La Cité des Sciences et de l'Industrie, as part of the RT Day organized by the Institut Cognition. About fifty subjects were able to experience Tamed Cloud. We did not encounter any immersion-related disorders or discomforts in the various subjects. After a rather small phase of about 1 minute, during which the user was getting acquainted with the virtual environment and the handling of the controllers, the subjects moved and interacted quite naturally with the cloud. They seemed particularly attracted and thrilled by the mass of images surrounding them when they first came into contact with the cloud through their presence or gestures. The use of voice recognition has sometimes been made difficult due to the hustle and bustle of the physical environment in the demonstration room.

It is very encouraging to see that the experience we were offering aroused the interest of companies from a wide range of sectors. In particular, some of them identified a strong potential for improving business performance and supporting decision-making.

The general reception from the public was positive, however it is difficult to draw definitive conclusions from this first presentation.

4.2 Evaluation

The first phase of our research did not allow us to carry out an evaluation of the system. It is therefore planned as an important step of the second phase of the development which, at the time of this publication, is about to start. This second phase will lead us to a finalized and fully functional Proof of Concept version of Tamed Cloud, and it is that version that will be used in order to conduct the scientific evaluation with the proper user audience.

This second phase of the Tamed Cloud project, will aim to evaluate whether our system promotes optimized access and processing of the visualized data. We are currently working on defining in advance our evaluation protocol that will be used for the study of about ten participants. The data collection and analysis during this evaluation will constitute an essential link in our project, as it will allow us to define the next phase, which will consist, among other, of integrating new artificial intelligence functionalities, such as image recognition, e-learning and qualitative movement analysis. Moreover, we plan on measuring certain physiological data of the subject during the immersive experience, in order to use them to generate forms of behavioral interactions of the cloud and data in real time as a response to the emotional state of the user. This evaluation will allow us, in the long term, to better develop the concept of Tamed Cloud for applications in various and diverse fields.

As it stands, the Tamed Cloud allows the visualization of undifferentiated masses of data, without hierarchical representation, as well as the selection of data on the y. This type of data visualization has particular advantages (as well as disadvantages) that we need to define more precisely, in relation

[1] https://github.com/watson- developer- cloud/unity- sdk# installing- the- sdk- source- into- your- unity- project

to the exploration and manipulation constraints specific to professional tasks.

In particular, we would like to answer the following questions:

• For which type of task could non-hierarchical visualization of dynamic data masses be the most adequate?

• Does incorporation and living in the same space as the data have a particular impact on how data are represented and accessed?

• Which profession could benefit particularly from this type of visualization?

Through the comparison of the Tamed Cloud device with traditional 2D visualization methods, we will seek to evaluate the contributions of the particular visualization method introduced by Tamed Cloud.

We will thus propose to the participants a series of tasks to be carried out according to the two visualization methods; for example, locating a specific data, or ranking the data on the basis of criteria of different natures, for example well-defined vs. poorly defined, concrete vs. abstract, surface lines vs. structural vs. functional. Visualization methods will be, as a result, compared on the basis of measurements including the time required to complete a given task, the prerequisites required to complete it, cues of frustration in completing the task, etc.

4.3 Future development

Based on the above described evaluation methods and protocols, we will be able to better demonstrate to potential future partners the benefits that the use of our system could bring in their professional field, in order to recruit and involve them in its further development.

Our goal in the long term is to initiate large-scale partnerships, within the framework of a chair dedicated to Artificial and Cognitive Intelligence. We want to federate around this research a multidisciplinary team gathering over 3 years, researchers in art and design, cognitive sciences and computer science. The objectives of this research group will be:

• Research, develop and evaluate these new modalities of access to information and research within large data sets;

• Explore and develop the concept of Tamed Cloud to other potential application areas:

- In communication: consultation of visual or audiovisual data;
- In research: manipulation/analysis of scientific data;
- In medicine: treatment of memory and behavioral disorders;
- In the field of security: assistance in decision-making when dealing with digital data;
- Etc.

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6. REFERENCES

[1] Ariely, Dan 2001. Seeing sets: *Representation by statistical properties*. Psychological Science, 12 2 157–162. PMID: 11340926.

[2] Bennequin D, Berthoz A, (2017) *Several Geometries for Movements Generations*, J.-P. Laumond et al. (eds.), Geometric and Numerical Foundations of Movements, Springer Tracts in Advanced Robotics 117, DOI 10.1007/978-3-319-51547-2_2

[3] Berthoz A., *La Vicariance*, le cerveau créateur de mondes, Odile Jacob, 2013

[4] Berthoz A., *Le sens du mouvement*. Odile Jacob, 1997

[5] Bilda Z., Candy L., & Edmonds E., *Designing for creative engagement*, Design Studies, 2008

[6] Card S. K., Mackinlay J. D., Shneiderman B. (1999). *Readings in Information Visualization. Using Vision to Think*, San Francisco, Morgan Kaufmann.

[7] Couchot, E., *La nature de l'art* : ce que les sciences cognitives nous révèlent sur le plaisir esthétique, Hermann, Paris, 2012

[8] Couzin, I. D. (2009). *Collective cognition in animal groups*. Trends in Cognitive Sciences, 13(1), 36–43. https://doi.org/10.1016/j.tics.2008.10.002

[9] Fuchs Philippe. *Théorie de la réalité virtuelle*, les véritables usages. Presses de l'Ecole des Mines, 2018

[10] Furnas G. W., Bederson B. B. (1995). *Space-Scale Diagrams: Understanding Multiscale Interfaces*, *In Proceedings of CHI'95*, pp. 234-241.

[11] Grau, O., *Virtual Art: From Illusion to Immersion*, MIT press, 2003

[12] H. Britten, Kenneth, N. Shadlen, Michael, T. Newsome, William, and Movshon, J. Anthony 1992. *The Analysis of Visual Motion: A Comparison Psychophysical Performance of Neuronal.* Journal of Neuroscience, 12 12 4745–4765.

[13] Hall Edward T. *The Hidden dimension*, Doubleday & Co, 1966 / La dimension cachée. Seuil, 1971

[14] Heeter C. (1992). *Being There: The Subjective Experience of Presence*. Presence: Teleoperators and Virtual Environments, 1(2):262–271. xxvii, 25, 30, 31, 32, 34

[15] Heider F., & Simmel M. (1944). *An experimental study of apparent behavior*. The American Journal of Psychology, 57(2), 243. http://doi.org/10.2307/1416950

[16] Hoffman G., & Ju W. (2014). *Designing Robots with Movement in Mind*. Journal of Human-Robot Interaction, 3(1), 89. https://doi.org/10.5898/JHRI.3.1.Hoffman

[17] Hollan J. D., Hutchins E., Mccandless T. P., Rosenstein M., Weitzman L. (1986). *Graphical interfaces for simulation*. La Jolla, Institute for Cognitive Science of the University of California.

[18] Hutchins E. (1995). *Cognition in the Wild*. Cambridge, MIT Press.

[19] Hutchins E., Hollan J., Norman D. (1985). *Direct Manipulation Interfaces*. Human-Computer Interaction, 1(4), pp. 311-338.

[20] Jones C.A. (ed), *Sensorium: embodied experience, technology, and contemporary art*. MIT press, 2006

[21] Lee K. M. (2004). *Presence, explicated*. Communication Theory, 14(1):27–50. xxvii, 30, 31, 32, 33, 34, 35, 36, 68, 75, 76, 78, 81

[22] Levillain F., & Zibetti E. (2017). *Behavioral objects: The rise of the evocative machines*. Journal of Human Robot Interaction, 6(1), 4-24.

[23] M.-H. Tramus, M. Bret, E. Couchot, *La seconde interactivité*. In Arte e vida no século XXI, Organizadora Diana Domongues, UNESP, Brasil (2003).

[24] Merleau-Ponty *M., Phénoménologie de la perception*. Gallimard. Paris, 1945

[25] McLuhan M., 1964. *Understanding Media - The extensions of man*. McGraw-Hill Education, Canada.

[26] Poincare H (1902) *La Science et l'hypothèse*. Paris: Flammarion.

[27] Robertson G. G., Card S. K., Mackinlay J. D. (1989). *The cognitive coprocessor architecture for interactive user interfaces*. In Proceedings of SIGGRAPH'89, pp. 10-18.

[28] Salvatore M. Anzalone, S Boucenna, Serena Ivaldi, Mohamed Chetouani. *Evaluating the Engagement with Social Robots*. International Journal of Social Robotics, Springer, 2015, pp.1-14. <10.1007/s12369-015-0298-7>.

[29] Scholl B., & Tremoulet P. (2000). *Perceptual causality and animacy*. Trends in Cognitive Sciences, 4(8), 299–309.

[30] Slater, M. (2009). *Place illusion and plausibility can lead to realistic behaviour in immersive virtual environments.* Philosophical Transactions of the Royal Society of London B: Biological Sciences, 364(1535):3549–3557. 34, 55

[31] Stasko J. T. (1993). *Animation in User Interfaces: Principles and Techniques*. Trends in Software, Special issue on User Interface Software, 1, Chap. 5, pp. 81-101.

[32] Stasko J. T. (1996). *Future research directions in human-computer interaction*. ACM Computing Surveys, 28(4), Article 145.

[33] Sumpter, D. J. T. (2006). *The principles of collective animal behaviour*. Philosophical Transactions of the Royal Society B: Biological Sciences, 361(1465), 5–22. https://doi.org/10.1098/rstb.2005.1733

[34] Varela, F., Thompson, E., Rosch, E., 1993. *L'inscription corporelle de l'esprit*. Editions du Seuil. Paris.

[35] Vertegaal R. and Poupyrev I., 2008. *Organic User Interfaces: Introduction to Special Issue*. Communications of the ACM, 51(6), pages 26-30.

[36] W. Williams, Douglas, and Sekuler, Robert 1984. *Coherent global motion percepts from stochastic local motions*. Vision Research, 24 55–62.

[37] Wigdor D., Wixon D., 2011. *Brave NUI world: designing natural user interfaces for touch and gesture*. eBook ISBN: 9780123822321

[38] Wright P. & McCarthy J. (2008). *Empathy and experience in HCI*. In Proceedings of the Conference on Human Factors in Computing Systems (SIGCHI),

Exploratory research on the gamification of exercise for Fibromyalgia using virtual reality

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ABSTRACT
Fibromyalgia (FM) causes debilitating pain and muscular stiffness, amongst other symptoms, which can be eased over time through regular exercise. As FM patients have an abnormal perception of pain, adherence to exercise programmes can be difficult due to the pain experienced whilst exercising. Virtual reality (VR) has been shown to distract users from physical and mental pain and therefore may be utilized to increase adherence to exercise. This project involved the creation of a VR game using the HTC Vive, designed to induce exercise at a moderate intensity and distract Fibromyalgia patients from pain experienced whilst exercising. This game was tested using 8 participants who completed a questionnaire regarding the enjoyability of the game as well as the intensity of exercise whilst playing the game. All except two participants felt as if they had exercised at a moderate intensity or higher whilst playing the game, with the remaining two participants just under the threshold for moderate exercise. All participants found the game to be fun, exciting, enjoyable and entertaining, and all except one would play it again and spend money on this or similar games. The participant who would not play this or similar games again fell into the 65+ age range, supporting research which states that over 65s have little interest in gamified VR. Half of the participants answered that their frequency of exercise (for at least 20 minutes) would increase if they owned this or similar games, with the remaining participants already exercising regularly.

Keywords
Fibromyalgia, Chronic Pain, Exercise, Mental Health, Virtual Reality, Motivation, Adherence to Exercise

1. INTRODUCTION
Fibromyalgia (FM) is the second most common condition that is seen by rheumatologists [1]. FM is a chronic condition which causes widespread, debilitating pain and muscular stiffness, along with various other symptoms and common comorbidities such as fatigue, insomnia and psychological issues [2]. Patients suffering with FM have an abnormal perception of pain, reacting strongly to stimuli that would not normally be thought to be painful. It is thought that the pain leads to anxiety disorders and fatigue leads to depression [3]. These symptoms associated with FM lead to a poor quality of life (QoL), with an average 'perceived present QoL' scored at 4.8 on a scale of 1-10 (1 being low and 10 being high) [4]. Although there is no standardized treatment for FM, treatment which consists of a combination of approaches such as psychological interventions, medication and exercise programmes are the most effective [5]. Psychological interventions generally include Cognitive Behavioural Therapy and medication may include painkillers, antidepressants and neuromodulating antiepileptics [2]. Drugs have recently been developed to specifically manage pain in FM patients, however these are thought to come with significant side effects and the efficacy of using them is questionable [5]. Exercise programmes for FM focus on increasing cardiovascular fitness, muscular endurance and flexibility [6][7]. Increased physical activity has been shown to lead to a decrease in reported pain as well as an increase in the response of pain regulatory functions within the brain. However, exercise programmes created for patients with FM generally have low adherence rates due to the increased pain experienced whilst exercising, leading to poor physical health and a poor QoL [8]. Gamification refers to the production of game-like experiences which promote flow, mastery, achievement and intrinsic motivation with an aim to alter the user's behaviour and perceptions [9].

This study explores gamified virtual reality (VR) as a means of increasing motivation to exercise, with game design focused for FM patients. The game was designed to provide a distraction to the physical pain experienced by FM patients whilst exercising, and increase QoL through increasing cardiovascular fitness and flexibility (as well as strengthening when used with body weights). Although the game has been designed for FM patients, it could also be used by able-bodied players to increase motivation to exercise, or simply for entertainment.

2. LITERATURE REVIEW
VR has been shown to distract users from anxiety, depression and physical pain, possibly even changing "the way that the brain physically registers pain" rather than simply the way it perceives painful stimuli [10]. Due to these benefits, the use of VR in the gamification of exercise would be beneficial to affect the motivation of FM patients to exercise and improve QoL. Recent research has proven the effectiveness of VR for improving the self-management of diseases, physical activity, distracting from pain and discomfort, rehabilitating neuro-cognitive and motor performance and assisting in the treatment of psychological issues such as depression and anxiety [11]. It has been found that the more immersive the environment, the more distracted the user is from physical and mental pain [12]. The near complete absorption into the environment whilst using a Head-Mounted Display (HMD), such as the HTC Vive or Oculus Rift, is best suited to help with more intense pain [11].

The most widely accepted model in explaining the mechanisms behind the pain relief induced by using VR is the 'gate theory' of attention, which states how VR absorbs and diverts attention away from pain, therefore reduces the perception of pain. Research into the cognitive-affective-motivational role of attention in pain processing supports the importance of gaming and play elements in VR interventions aimed at the reduction of pain [11].

Exercise interventions in FM patients have been shown to improve well-being through decreased fatigue, depression and pain as well as increased pressure that must be applied to a tender point before a pain response is triggered [8][13]. It is recommended that exercise should be performed at a moderate intensity (approximately 60% of maximum heart rate) 2-3 times per week [13]. Setting realistic goals and expectations is important to help deal with the condition throughout daily life. A positive mindset of the patient is important for actively endeavouring to reduce symptoms through methods such as exercise [6]. The assistance with depression and anxiety that gamified VR presents (especially when combined with exercise – a treatment for depression) should be able to help with this [11].

Conflict was found between patients and healthcare professionals due to the limited resources available (such as time for consultations), and psychological support was not provided in a meaningful capacity. A gamified experience of exercising, allows patients to take a more pro-active approach which may alleviate conflict between FM patients and healthcare professionals caused by time restraints. The use of gamified VR exercise may also reduce the need for psychological support, which is being sought from healthcare professionals who feel they cannot provide the required support [5].

Gamification of an exercise programme encourages participation and positively influences attitude and behaviour towards exercise whilst allowing for easy goal setting and progression [14]. Goh & Razikin [15] found that gamification of exercise increases motivation to participate by shaping behaviour as well as improving the enjoyment of and general attitude towards exercise. Gamification is thought to consist of three main parts – implemented motivational affordances, resulting psychological outcomes and further behavioural outcomes. Motivational affordances include aspects such as points, leader boards, achievements, levels, clear goals, stories, themes, feedback, progress and challenge. The psychological outcomes of gamified exercise include increased self-efficacy, improved attitude towards exercise and decreased perception of pain; all of which results in the behavioural outcome of increased participation in exercise [14][16]. These benefits are particularly important in FM patients due to the psychological and physical barriers to participation. Changing behaviour and perception of exercise may be the difference between inactivity, causing deterioration in QoL and an active lifestyle which vastly improves symptoms over time and increases QoL.

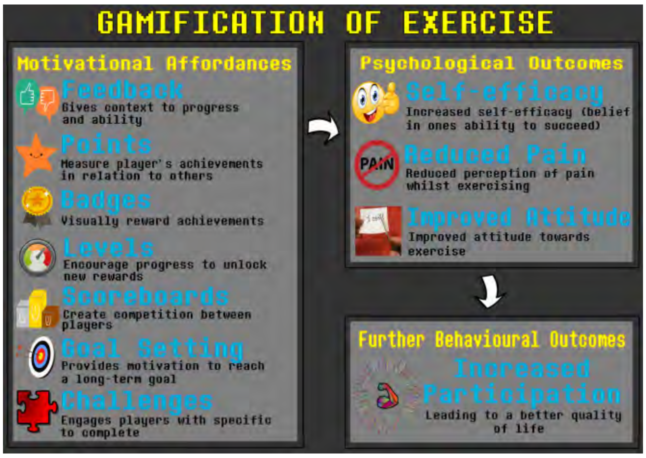

Figure 1: A breakdown of gamification in exercise

Although gamification mostly produces positive results, in some settings no effect is seen. This is thought to be down to a variety of factors such as the nature of the gamified experience, the motivation and preferences of the individual and design aspects [17]. Gamification may appeal to a large population of people, however there are populations and individuals that may not find these concepts as appealing. More consistently positive results have been found for individuals aged between 20-49 years, suggesting that this is the most effective age range for gamified VR. It is thought that people over the age of 65 have little interest in using VR [18]. These factors may affect the use of VR in therapy for some populations.

3. METHODS

3.1 Game Development

Unity (5.6.0) [19] with SteamVR [20] was used to develop and build the game and a HTC Vive was used in the creation and playing of the game. Microsoft Visual Studio [21], Blender 2.78c [22] and Audacity 2.1.3 [23] were also used in the creation the game. The game was designed to induce moderate exercise which works the whole body – legs through bending to pick up a snowball, arms and chest through throwing (throwing with both arms is the most effective method) and the core through dodging snowballs.

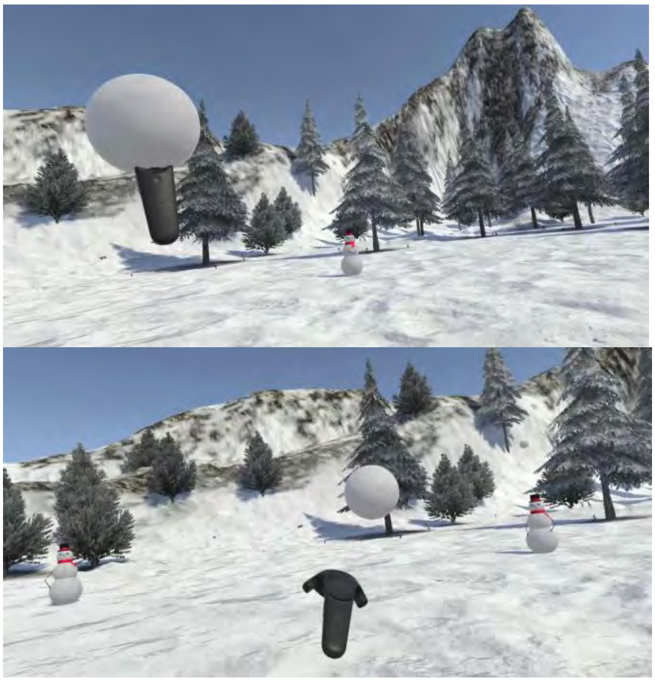

Figure 2: Screenshots of the game being played

3.2 Testing and Questionnaire

The inclusion criteria for participating in the testing of the game included; able-bodied or diagnosed with FM, physically fit enough to participate in moderate exercise and over the age of 18. Exclusion criteria included a diagnosis of any physical disability other than FM or chronic pain or any physical injury which may be affected by participation. Ethical approval was given for this study to be carried out. To ensure the safety of all participants, a risk assessment was also carried out and steps were taken to minimise the risks of participation. 8 participants were recruited who completed an informed consent form before participating.
The objectives of the game, the VR system and precautions to minimise the risks were explained to the participants before participation. Two 5-minute games were played – the first at an easy difficulty and the second at a slightly harder difficulty. After playing the game, participants completed a questionnaire containing 29 questions regarding the enjoyment, playability and effort put into the game. These were answered using a Likert scale with a section at the end for any comments. A table of showing the Rate of Perceived Exertion (RPE) scale [24] was also used to determine how hard the participant felt they exerted themselves whilst playing the game. The questionnaire was based off the 'need satisfaction' questionnaire [25] which evaluates exergames. Basic demographic data was collected to assess whether these factors may affect the answers given. In order to prevent bias, all answers were kept anonymous.

3.3 Data analysis

Frequency tables, bar charts and pie charts were constructed to analyse the data as well as to create a visual representation of it. This data was analysed both qualitatively and quantitatively.

4. RESULTS & DISCUSSION

The game was found to be fun, exciting, enjoyable and entertaining by all participants, as seen in figure 1.

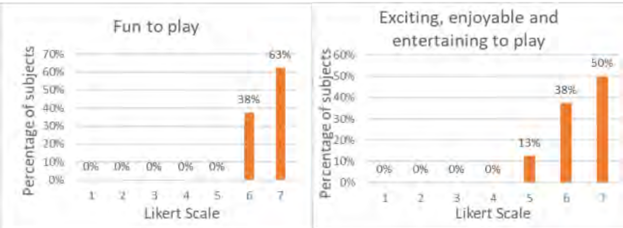

Figure 3. Bar chart showing questions regarding the enjoyability of the game. Likert scale: 1 = describes the game poorly, 7 = describes the game very well

Subjects 3 and 8 found the game to be boring; however, these participants also found the game to be fun, exciting, enjoyable and entertaining – which is contradictory. Subjects 3 and 8 also did not feel as if they had exercised at a moderate intensity, giving a rating of 11 on the RPE Scale (light exercise). This may imply that the game was too easy, which may be one reason as to why it was found to be boring and could be fixed by increasing the difficulty or adding in different game modes. The inadequate difficulty is supported by Subject 2's comment "if I was an actual gamer (regularly played console games) it would probably be too easy. Would be cool to have levels" as well as subject 4's comment "it would be more effective if there were more difficult levels". Subjects 3 and 8 also reported that the game was slightly uncomfortable to play. Subject 3 commented "maybe wireless goggles would be better", suggesting that the trailing wire was the cause of the discomfort – the wire will likely become obsolete over time as the technology develops. However, this did not seem ruin the immersion as subject 3 still answered that they felt immersed in the game. Although subject 3 found the game to be boring and slightly uncomfortable to play, this participant would still play this game again and spend money on this or similar games. Subject 8, whilst finding the game to be fun, exciting, enjoyable and entertaining, also found it to be boring and slightly uncomfortable to play - this participant would not spend money on or play this or similar games again. As subject 8 is in the 65+ age range, the answers given support research that has shown that people aged 65 and over generally have little interested in VR and may not benefit as much from VR therapy [16]. Although subject 8 had not been diagnosed with FM, she believed herself to have FM, which may have contributed to the discomfort of playing this game. However, since no formal diagnosis of FM had been made for subject 8 and no comments were written, no conclusion can be made regarding the reason for discomfort.

All participants, with the exception of subject 8, indicated that they would play this or similar games once a week or more. Half of the participants answered that their frequency of exercise would increase upon owning this or similar games, this is shown in figure 2.

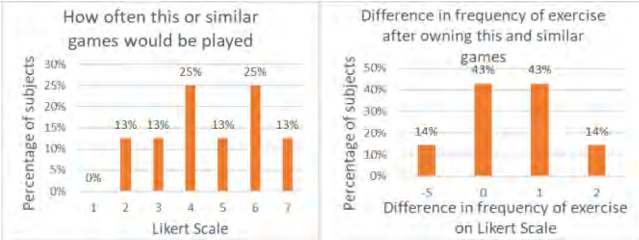

Figure 4. Bar charts showing questions regarding how often this or similar games would be played if owned. Likert scale: 1= never, 2 = occasionally, 3 = two or three times a week, 4 = once a week, 5 = twice a week, 6 = >twice a week, 7 = every day

Subject 8 answered that frequency of exercise would significantly decrease upon owning this game. This is thought to be an anomaly - possibly due to not reading or understanding the question correctly. The remaining participants answered that they already exercised frequently – two of whom were already exercising at the maximum frequency given in the question, therefore frequency could not be increased. The final participant, subject 3, already exercised more than twice a week and indicated that there would be no difference in frequency; which could be due to the large difference between exercising twice a week and exercising every day (the options given for 6 and 7 on the Likert scale). Therefore, if subject 3 would have exercised between one to three extra days extra per week, this may not have shown in the results of this question. This participant did however indicate they would play this or similar games more than twice a week, suggesting that their exercise frequency may increase. Subject 6, who already exercises daily, commented that the game was "surprisingly exhausting, however definitely a good workout and fun whilst being a challenge". Subject 1 also noted in the comments section "good way to distract someone, whilst getting exercise without thinking about it". This supports the gate theory of attention that the VR game acts as a distraction, taking away elements of attention that would otherwise be focused on pain or exhaustion from exercise. All participants also felt that they were immersed in the game. These points indicate that this game would likely distract FM patients from pain experienced whilst exercising – however further testing would be required to validate this assumption, and determine to what extent pain is eased.

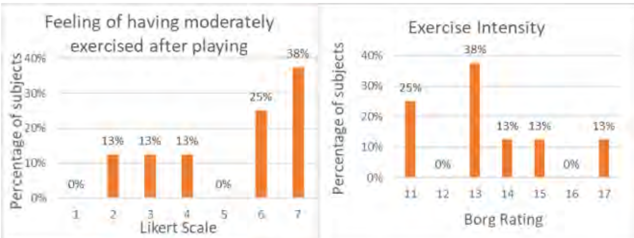

Figure 5. Bar charts showing the intensity of exercise whilst playing the game, using the RPE scale by Borg [24] & Likert scale: 1 = not true at all, 4 = somewhat true, 7 = very true

All except 2 participants (subjects 3 and 8) felt that they had exercised at a moderate intensity or higher. Subject 7, who indicated that they exercised intensely (17 RPE) commented "I would like to start with 3 minutes work time up slowly". This indicates that a wider range of difficulties and different lengths of time for each game is required to meet the needs of different people, which could be easily implemented.

All participants indicated that they were motivated to get a high score and put a lot of effort into the game, as shown in figure 3, each getting a higher score on the second, herder, level than on the first. This shows that the motivational affordance of the scoring system had a positive effect on participants motivation and effort put into the game.

Figure 6. Bar charts showing questions regarding motivation and immersion within the game. Likert scale: 1 = not true at all, 4 = somewhat true, 7 = very true

With the exception of subject 8 who did not answer the question, all participants answered that they would play this or similar games for 20 minutes or longer (up to 60 minutes) at a time. This meets and exceeds the 20 minutes of gameplay per session that this study was aiming for.

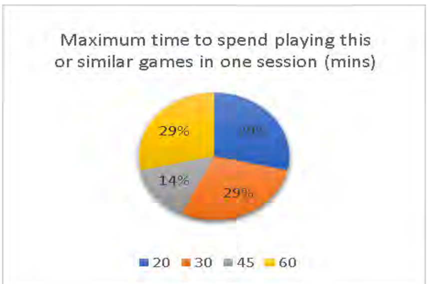

Figure 7. Pie chart showing the maximum amount of time in minutes that participants would play this or similar games per session

Overall, all participants rated the game as satisfactory to highly satisfactory. This, combined with the other results and comments, shows that the game was mostly successful at inducing moderate exercise in a fun and distracting manner, which was satisfying to play. Although these results are not generalizable to a wider population due to the small sample size, this gives a good basis on which to conduct further research in this area. As this study only focused on preliminary research into the effectiveness of VR as a means of exercise, it was more feasible to test the game using able-bodied participants than participants with FM. Future research should focus on patients with FM and include a larger number of participants, including participants of various age ranges, to obtain more generalizable and reliable results. This data could also then be used to determine differences in the effectiveness of using VR to exercise between various populations. To obtain more accurate results, future research in this area should also test a wider variety of difficulties and length of games.

There are a variety of extras that could have been added into the game, however due to time constraints and ease of testing, the game was kept simple. Extras should be added in at a later date to increase variability, difficulty and induce different types of exercise. The implementation of an online scoreboard and platform to track progress would allow both participants and health professionals to monitor progress and set goals.

5. CONCLUSION

The game has been shown to be fun, exciting, entertaining and enjoyable whilst immersing participants within the game and providing a moderate intensity of exercise. Although two participants did not feel they had worked at a moderate intensity, their RPE was on the upper limit of light exercise, which may have been increased by raising the difficulty of the game, as testing was completed at a limited difficulty. Subject 8 (in the 65+ age range) found the game to be fun, exciting, enjoyable and entertaining, however would not choose to play this or similar games again. This supports previous research stating that people over 65 are uninterested in gamified VR - however as the younger population grows older alongside computer technology, this may change over time. The remaining participants would play again and spend money on this and similar games, with the majority answering that owning this and similar games would increase their frequency of exercise. With the exception of subject 8 who did not answer, all participants stated that they would play the game for 20 minutes or longer at a time – the option of playing other games as well would lower the risk of the one game becoming stale, i.e. a decrease in motivation to play that game over time. The scoring system provided motivation and incentive, with all participants stating that they put a lot of effort into the game and were motivated to obtain a high score. Online scoreboards would allow for competition between players as well as the option for allowing easy access for health professionals to monitor patients progress. From the results of this study, gamified VR is a viable means of exercise which is fun, exciting, enjoyable and entertaining and would likely increase motivation and frequency of exercise. This study provides preliminary research into the effectiveness of using VR for exercise, with a focus on FM. However further in-depth research is necessary for the benefits - and any disadvantages - of gamified VR to be fully understood.

6. REFERENCES

[1] Clauw, D.J., Arnold, L.M. & McCarberg, B.H., 2011. The science of fibromyalgia. *Mayo Clinic Proceedings*, 86(9), 907–911.

[2] Bellato, E. *et al*., 2012. Fibromyalgia syndrome: Etiology, pathogenesis, diagnosis, and treatment. *Pain Research and Treatment*, 2012, 1–17.

[3] Kurtze, N. & Svebak, S., 2001. Fatigue and patterns of pain in fibromyalgia: Correlations with anxiety, depression and co-morbidity in a female county sample. *Brit. J. Med. Psychol.*, 74(4), 523–537.

[4] Centers for Disease Control and Prevention, 2015. *Fibromyalgia*. Available at: www.staff.science.uu.nl/~ooste108/ExpC/website5/v1/arthritisbasicsfibromyalgia.html. Accessed [25/07/17].

[5] Briones-Vozmediano, E., Vives-Cases, C., Ronda-Pérez, E. & Gil-Gonzales, D., 2013. Patients' and professionals' views on managing Fibromyalgia. *Pain Research and Management*, 18(1), 19–24.

[6] Hawkins, R., 2013. Fibromyalgia: A clinical update. *J. Am. Osteopath. Assoc.*, 113(9), 680–689.

[7] Redondo, J.R. *et al*., 2004. Long-term efficacy of therapy in patients with fibromyalgia: A physical exercise-based program and a cognitive-behavioral approach. *Arthritis Care & Research*, 51(2), 184–192.

[8] Busch, A.J. *et al.*, 2011. Exercise therapy for fibromyalgia. *Current Pain and Headache Reports*, 15(5), 358–367.

[9] Huotari, K. & Hamari, J., 2012. Defining gamification - A service marketing perspective. In *MindTrek*. Tampere: ACM, 17–22.

[10] Wiederhold, B.K., Riva, G. & Wiederhold M.D., eds. *ARCTT 2015: Virtual Reality in Healthcare*. 158–162.

[11] Trost, Z. *et al*., 2015. The promise and challenge of virtual gaming technologies for chronic pain: the case of graded exposure for low back pain. *Pain Management*, 5(3), 197–206.

[12] Tong, X., Gromala, D., Amin, A. & Choo, A., 2015. The design of an immersive mobile virtual reality serious game in cardboard head-mounted display for pain management. In

Proc 5th Int. Symp. Pervas. Comput. Paradig. Mental Hlth. Milan: Springer International Publishing, 284–293.

[13] Busch, A.J., Barber, K.A., Overend, T.J., Peloso, P.M. & Schachter, C.L., 2007. Exercise for treating fibromyalgia syndrome. In *Cochrane Database of Systematic Reviews*. Chichester, UK: John Wiley & Sons, Ltd.

[14] Hamari, J. & Koivisto, J., 2013. Social motivations to use gamification: an empirical study of gamifying exercise. In *Proc. 21st ECIS*, Utrecht, Netherlands, June 5–8.

[15] Goh, D. & Razikin, K., 2015. Is gamification effective in motivating exercise? *Human-Computer Interaction*, 608-617.

[16] Brauner, P., Valdez, A., Schroeder, U. & Ziefie, M., 2013. Increase physical fitness and create health awareness through exergames and gamification the role of individual factors, motivation and acceptance. In *Human Factors in Computing and Informatics*. Berlin: Springer-Verlag, 349–362.

[17] Hamari, J., Koivisto, J. & Sarsa, H., 2014. Does gamification work? — A literature review of empirical studies on gamification. In *47th HICSS*. Hawaii: IEEE, 3025–3034.

[18] Johnson, C., 2016. *The future of connected home health*, Great Chesterford: Plextek. 1-16.

[19] Unity (5.5.6), 2017. *Unity 3D*. Available at: https://unity3d.com. Accessed [20/03/17].

[20] Unity 3D, 2017. SteamVR Plugin. Available at: www.assetstore.unity3d.com/en/#!/content/32647. Accessed [20/03/17].

[21] Microsoft Visual Studio, 2017. Visual Studio. Available at: www.visualstudio.com. Accessed [07/06/17].

[22] Blender 2.78c, 2017. *Blender*. Available at: www.blender.org. Accessed [20/03/17].

[23] Audacity 2.1.3., 2017. *Audacity*. Available at: www.audacityteam.org/. Accessed [07/06/17].

[24] Borg, G.A.V., 1982. Psychophysical bases of perceived exertion. *Medicine and Science in Sports and Exercise*, 14(5), 377-382.

[25] Peng, W., Lin, J.H. Pfeiffer, K.A. & Winn, B., 2012. Need satisfaction supportive game features as motivational determinants: An experimental study of a self-determination theory guided exergame. *Media Psychol.*, 15, 175–196.

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