Hardware Interfaces for VR Applications: Evaluation on Prototypes

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Abstract - ***The advancement of recent developments over the VR with the expansion of new Head Mount Displays (H.M.D.) such as Oculus Rift and Morpheus have opened new challenges in the already active research filed of the industry of Human-Computer Interaction (HCI) by exploring new means of communication with the support of the new hardware devices adjustable to body movements and hand position. The paper explores the hardware interactivity and VR H.M.D's through two games designed to use the latest Oculus Rift SDK technology with alternative methods of hardware communication. A usability evaluation study was conducted with 18 participants and the results presented and discussed.***

Keywords—Interactive Learning Environments, Head Up Display (H.U.D.), Virtual Reality, Head Mount Display (H.M.D.).

I. INTRODUCTION

In the last few years videogames graphics look very realistic. Environments design and graphics quality are helping players to have a better feel of the game compare to the past. The next step is to have players feeling as part of the game. The Oculus Rift by Oculus VR is a Virtual Reality Head Mounted Display (H.M.D.) that enables the player to do that, to live the game, not just playing it.

One of the most important parts of a game is the game experience. The player will remember a game because of the adventure and the story lived. VR toolkits like Oculus Rift managed to upgrade this concept to the next level. In traditional game playing players were just looking at the screen like a window inside the game. Now, using VR technology, players are inside that window taking part into the game with complete interaction. This technology has been primarily invented for games, but it will have huge applications in other sectors such as training, education and illustrations.

The design of the game should be driven by the idea to create interfaces within which the user can interact spontaneously without explanations [10]. In the process of developing a kinaesthetic interface in a human-computer interaction system, most methodologies: ***(a)*** -Use interaction and interactive design methods [11], which can be distinguished on: (i) *Research & inquiry*, (ii) *design & evaluation* and ***b***-Follow some standard criteria [12].

When someone refers to a good VR system the following four criteria must be take into the account: 1) The user will be provide with a full field of vision display, usually produced by the wearing of a H.M.D., 2) Tracking of the position and attitude of the participant's body, 3) Computer tracking of the participant's movements and actions and 4) Negligible delay in updating the display with feedback from the body's movements and actions.

II. HARDWARE INTERFACES AND VR

Having described the general framework that governs the HCI systems the following section explores a set of modern hardware devices used as an approach to extract user feedback data to be used for various game fields. These devices are using either some type of sensors for motion and orientation detection or with the means of Visual/Hand-Held or Hybrid Recognition they do extract desirable set of features that can be interpret from the appropriate software as a specific user feedback motion.

A. Visual Recognition

Microsoft Kinect Sensor: One of the latest motion detection and interaction engines with human gestures is the Microsoft Kinect Sensor. The Kinect is a motion detection device of Microsoft for the Xbox 360/Xbox1 and Windows PCs. Is in essence a peripheral input device that has lenses-cameras and audio sensors that allows users to control and interact remotely without having to touch them with another controller. The interaction takes place using gestures and spoken commands via the user's natural environment. The visual extracted features are translated in a form of model objects to recognise behaviour [1, 2].

Examples of such a technique is shown in the work of Oskoei and Huosheng [5], where the authors develop a HCI technique based on optical signals for Xbox. For this reason they used the Lucas and Kanade pyramidal implementation [3] to detect the characteristics to locate the Visual information flows in a series of picture frames. For the design of the system it was taken into account that it should work alongside the game console controllers, and more specifically to control a car through Xbox. The system detects the movements of the head and hands and skips some commands of the control of the car, using the commands from the user's movements. The system runs in parallel with the normal software and the overrides where needed.

Teixeira et. al. [4] presented a 3D graphics game with theme the martial arts, which supports interaction through gestures. In fact, this application was implemented to test and analyze the interaction with gestures in the context of a game that needs a fast, short and reliable response times. The work analyses different factors influencing the implementation, such as the effects of interaction with gestures caused the pace of frames in the animation control response time that users make.

B. Hand-Held

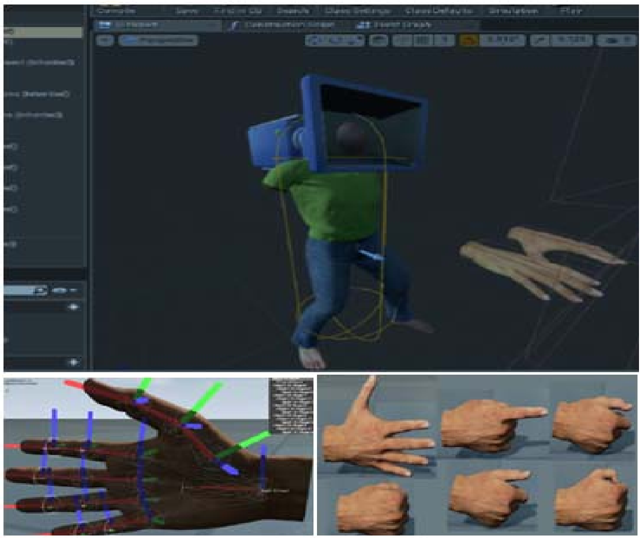
3*MotionTM*: An interesting technique presented by Keir et. Al. [6] with the name 3*MotionTM*, which refers to a 3D interactive gesture system consisting of low-cost materials and from a general-purpose software. This proposed system that is good to use in cases where monitoring systems are classics too costly or impractical because their requirements. The system consists of a three-axis accelerometer which constantly transmits data to a device via Bluetooth. Software receives the signal and data and attempts to match the information in a database of three-dimensional gestures to activate the appropriate function. More specifically, the system presented consists of three parts, a mobile device for detection of ID software, hand gestures and implementation.

The system is using an accelerometer that transmits real-time measurements on a platform to extract hand movements. The platform can be a computer, a cell phone, a game console, etc. on the platform running a reconstruct of shipped information program, which is compared with the data that already exist in a database in order to find what the corresponding movement was. The software used for identification and comparison of gestures was a non-parametric search algorithm and curve mapping that has previously been used in other applications

Nintendo Wii: Another similar system that has been shown is the Nintendo Wii. The strong point of the console is that it handles and controls the human gesture via the usage of accelerometers. More specific, so far hand-held devices are accustomed to the common gamepads. Wii makes a difference as the handling is done through two segments: with the Remote that looks like a remote control and the Nunchuk, which is a classic joystick in a smaller size.

Examples is serious games using Nintendo Wii and Nunchuk can be seen in [7] where the authors designed a simulation game that attempted to replicate a terrestrial E.O.D. drone as part of the investigation and disposal of bomb threats. The Razer Hydra controller is basically what everyone expected from the Wiimote. It tracks exact position and rotation of your hand in 3D space.

Hydra: Hydra as a controller is willing to support the new set of Augmented Reality Devices such as Oculus Rift, where the user has a limited view of the game controller and therefore the need of vast movement is essential. The Hydra is a device that works fairly similarly to the Wii Mote, but it offers a much higher level of precision. It consists of a Base, and two controllers connected to it with a wire. The controllers are interchangeable and look exactly the same. Some of the device limitations are that its wires might interfere with the user's movements and the tracking range is limited: when passing 1 meter the precision lowers, and when below 20 centimetres from the base, the controllers return an extremely wrong rotation. On the other hand it gyroscope move, user gesture and buttons can be adjusted through appropriate modelling to produce a set of artificial hand extensions for the user to interact within the game (Fig.1)



movements adjusted on user's feedback using the Hydra controller

C. Virtual Reality

With the advent of all these new devices, software houses are developing games supporting Head Mounted Devices. VR games are mostly developed by independent companies, because they don't have the pressure of selling millions of copies like the major companies so they have the possibility to experiment on new technologies. Major companies very likely will follow and release some AAA games as soon as the technology becomes wider available.

Head Mounted Displays are the threshold of new game hardware technology. The new generation of Virtual Reality is dominated by Head Mounted Displays (HMD). Everything started in 2012 when Palmer Luckey developed the Oculus Rift. In that year he started a kickstarter campaign for the development of the first Oculus Rift SDK, available for all the developers interested in VR applications but mostly games. The campaign was a huge success. The Oculus Rift was released for all the developers in September 2012 with the DK1. In March 2014 the announcement of the DK2 arrived, this Version of the Oculus rift has: higher resolution, low-persistence AMOLED display, higher frame rate and head position tracking.

Other competitors in the market presented new HMD's in the latest Game Development Conferences as well as support SDK's for Oculus. Razer announced their HMD. It is the OSVR (Open Source Virtual Reality), a fully open source development kit. Sony presented a new version of Project Morpheus and announced a release date for early 2016. Valve showed its Steam VR in partnership with HTC. It will be strictly connected with the Steam Machines.

D. Auditory

Adding "value" to the users' ears. This is the main reason for the appeal of stereophonic sound. Just as two visual perspectives make a 3D view, two audio perspectives can make a 3D soundscape. However, with free-standing stereo speakers the left and right sounds are mixed: both ears hear sound from both speakers. By using headphones and presenting the correct acoustical perspectives to each ear, many of the spatial aspects of sounds can be preserved. HMDs often have headphones built into them.

E. Kinesthetic

Additional displays can be used to engage other senses in VR. There are some companies that offer force-feedback devices where you can actually "feel" different sensations. Since there is not much of a demand for such things as smell or taste generators, you generally have be creative and figure out your own way of catering to more senses than just vision and hearing.

III. GAME PROTOTYPES

For the purpose of exploring the integration of new hardware devices to support VR, a set of 2 games were developed. Both games have been designed to work using the latest release of Oculus Rift SDK2. Project Erebus is using a standard Xbox1-wireless controller for the user to interact, while project DREAMS is using the hydra controllers. Both games have been developed using the latest Unreal Engine 4. The selection of UE 4 was because of the support over the new 3D graphics technology that helps Oculus Rift perform outstanding, includes a BSP Brush Editor to support terrain editor while the developing using the new blueprint technology helps developers to manage physics, animations easier in the game (Fig.2).

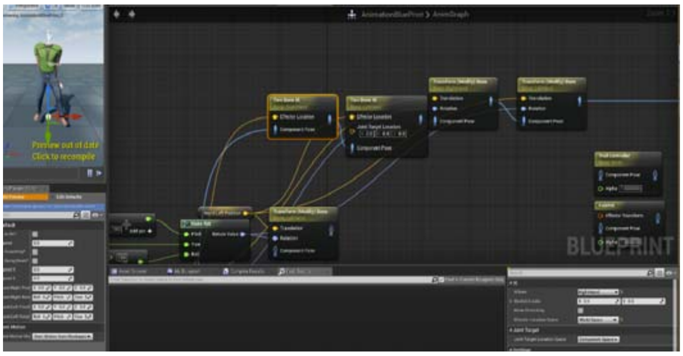


Fig.2: Project DREAMS: Character Animation Blueprint

For both projects the graphic style is coherent and cohesive for the game during its play-through. Both game designs have followed game design narratives [13] to provide a relative physical bond between the player and the game by keeping the game interest and player's emotions in a high standard.

A. EREBUS

Erebus is an Action-Adventure game based on the Greek mythology developed taking in consideration the main features of the Oculus Rift such as looking for a world atmosphere quite dark and charismatic, transforming the game world in a character itself. The ancient Greek tomb was perfect for it, and an interesting story has been developed to engage the player against some of the most well known mythological creatures in the world.

The game has a set of 10 different levels, with interesting interaction for the user. These include map exploration, Interaction and combat mode (Fig.3). For the game the graphics that were used were close to the mythological theme while a set of sounds supported the game environment based on users/enemies actions. The selection of different enemy creatures such as Herpes, Medusa and Minotaur provided to the user a different set of interaction with the controllers, while the use of the Oculus Rift provided the relevant atmospheric experience. Certain game activities, like platform jumping, waterfall diving were used as part of the evaluation

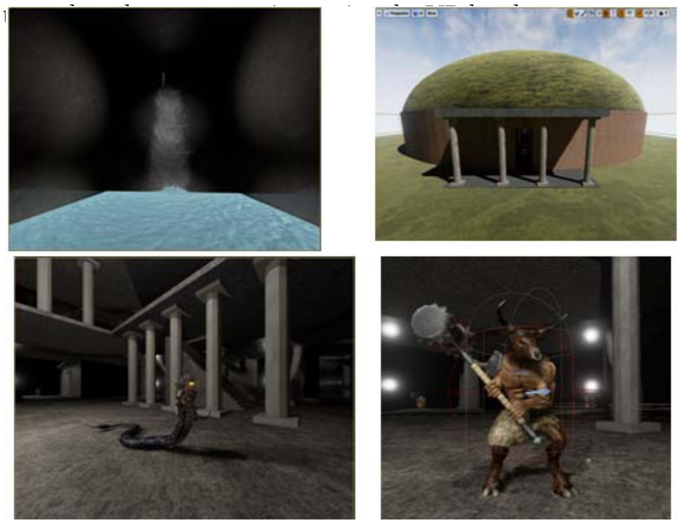


Fig.3: Project EREBUS: Game Level Design and Character Animations

B. DREAMS

Dreams is an immersive First Person puzzle game, set inside the character's own unconscious dreams back in high school time. The character is controlled through the razer hydra, his hands are directly controlled by its motions while his point of view is assumed in the Oculus Rift. The game concept is to drive the character through various dreams (levels), representing fears and immersing players' emotions with a set of puzzles, explorations and sounds. For this purpose a large variety of assets was developed to provide

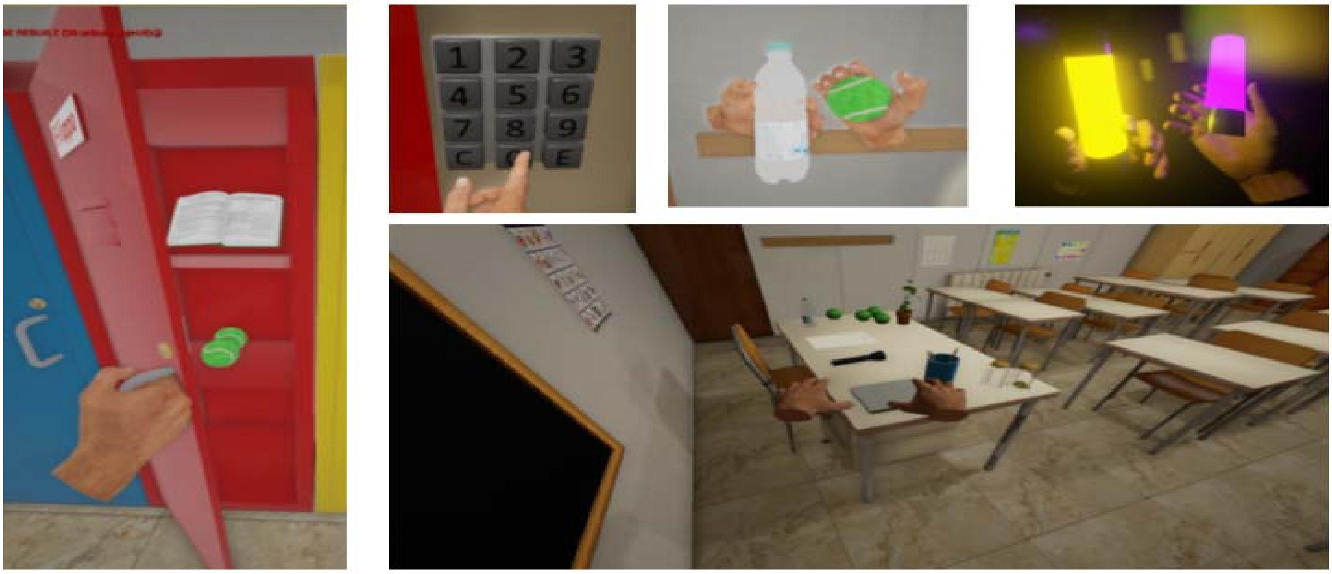


Fig.4: Project DREAMS: Level and user interactivity using the hydra controllers

complex scenario's for each level for the player to explore and interact (Fig. 4).

In addition to the main game theme an introduction level was designed for the player to calibrate the hydra controllers and become familiar with the process of controller-gesture interactivity and game action (Fig. 5)

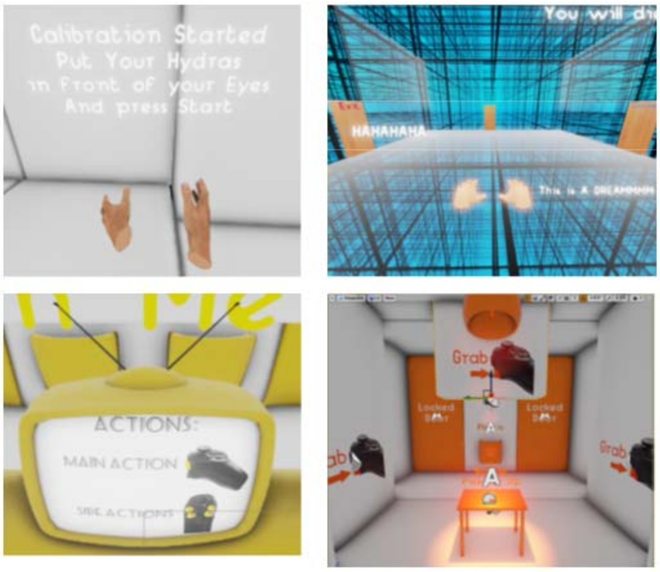


Fig.5: Project DREAMS: Main Menu and system calibration

IV. EVALUATION PROCEDURE

The pilot evaluation for both VR games was carried out with 18 university students (3 multimedia computing, 4 Computer science and 11 computers games development course) with experience in playing games but with no previous experience on interacting with controllers while having a VR HMD. Five students were 1st year undergraduates and the rest were 3rd year undergraduate students.

The study took place at the University of Westminster premises and each participant was tested individually. Each session lasted for approximately 20 minutes. The participants had to play the game for 15 minutes and then answer a short questionnaire. The questionnaire consisted of 18 questions in total (Table I) using Likert scale from 1 to 5. 16 questions was multiple choice on a Likert scale of one to five (one being the least favourable answer and the five the most favourable answer) and one open ended question. The evaluation focused on usability issues, motivational usability and usefulness of the approach. All participants used the same apparatus, a Windows 7 computer with Nvidia GTX 780 with 3 GB DDR5 RAM, PC Memory of 16 GB of RAM DDR3, Intel I7 4770K at 3.5 GHz.

V. EVALUATION RESULTS

A. *Usability Assessment*

12 questions were targeted in assessing the general usability of both games. The results revealed a very positive assessment regarding the usability of the game (Fig.6). Participants found easier to use Xbox1 controller rather than hydra, although after the tutorial sessions the overall complexity of adapting in both controllers was ambient. Additionally they felt very confident in playing both games and they were willing to use again Oculus Rift and hydra technology frequently in order to increase their knowledge behind VR. Students coming from non-game degree felt that knowledge behind using new technologies such as hydra should priori known to the user, although everyone felt very confident in understanding the Oculus H.M.D.

TABLE I. Overall Questionnaire results from the User Experience Testing

	USERS																	
	MULTIMEDIA			CS				GAMES										
QUESTIONS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Confident in using Oculus	3	3	3	4	3	4	4	4	4	5	5	4	3	4	5	5	5	5
Confident in using Xbox 1 Controller	3	3	3	3	3	3	4	5	5	5	5	5	4	4	5	5	5	5
Confident in using Hydra Controller	2	1	2	2	3	3	3	4	3	3	4	5	4	4	5	5	5	5
Clumsy in using Oculus	4	3	4	4	4	4	4	5	5	5	5	4	4	5	5	5	5	5
Clumsy in using Xbox 1 Controller	2	2	3	2	2	2	2	1	1	1	1	1	1	1	1	1	1	1
Clumsy in using Hydra Controller	3	4	4	4	3	2	2	2	2	2	1	1	1	1	1	1	2	2
Need to before how to use Oculus	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Need to know before how to use Xbox 1 Controller	3	3	3	2	3	2	1	1	1	1	1	1	1	1	1	1	1	1
Need to know before how to use Hydra Controller	5	5	2	3	3	2	1	2	1	1	1	1	2	2	2	1	2	2
EREBUS Tutorial was Sufficient	3	3	3	4	4	4	4	4	4	4	4	5	5	5	5	5	5	4
DREAMS Tutorial was Sufficient	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
EREBUS Technical Support needed	2	3	2	2	1	1	1	2	2	1	1	1	1	1	1	2	2	1
DREAMS Technical Support needed	3	3	2	3	1	1	2	2	1	1	1	1	1	2	1	1	1	1
EREBUS Complexity	4	4	4	4	5	5	5	4	3	4	4	5	5	5	5	5	4	5
DREAMS Complexity	5	5	5	5	5	4	5	4	4	5	5	5	5	4	4	5	5	5
Adapt on Oculus quickly	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Learned in using Xbox 1 Controller with Oculus quickly	3	4	4	4	3	4	4	5	5	5	5	5	5	5	5	5	5	5
Learned in using Hydra Controller with Oculus quickly	2	2	1	3	2	3	4	4	4	3	3	4	4	5	5	5	5	5
Confident in playing EREBUS Levels again	5	4	4	4	4	5	5	5	5	5	5	5	5	5	5	5	5	5
Confident in playing DREAMS Levels again	4	3	3	4	4	4	5	5	5	5	5	5	5	5	5	5	5	5
Novel Characteristics in EREBUS	4	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Novel Characteristics in DREAMS	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
EREBUS game stimulates further enquiry	4	4	4	3	4	3	4	4	4	5	5	5	5	5	5	4	5	5
DREAMS game stimulates further enquiry	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
EREBUS game was enjoyable	4	5	4	3	4	5	3	5	4	5	5	5	5	5	4	5	5	5
DREAMS game was enjoyable	4	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Felt motion sickness playing EREBUS game	5	4	4	3	2	4	2	5	5	5	5	2	2	2	4	5	3	4
Felt motion sickness playing DREAMS game	2	2	3	4	4	2	3	2	1	1	1	2	3	1	3	2	2	2
Felt in control using Xbox1 Controller	3	3	4	4	5	5	4	5	5	5	4	4	5	5	5	5	5	5
Felt in control using Hydra Controller	3	2	3	3	4	5	5	5	5	5	5	5	5	4	5	5	5	5

B. Motivational Usability assessment

Three questions were assessing the motivational usability of the game. The results here revealed some mixed effects (Fig.7). The participants found that both games incorporated novel characteristics due to the story/theme but at the same time there was an argument that Dreams game was more enjoyable and stimulates further inquiry due to the use of the hydra controllers.

C. User Interaction

The last part of the evaluation focused on the ease of using the VR and Hardware controllers in the game. The results here revealed (Fig. 8) that the participants felt the motion sickness effect of using the Oculus Rift H.M.D. more in the Erebus game (3.6) rather than the Dreams (2.1). This is because Erebus was an action game rather than a puzzle one but also because Dreams is using a better interface for the user to interact with the hydra controllers.

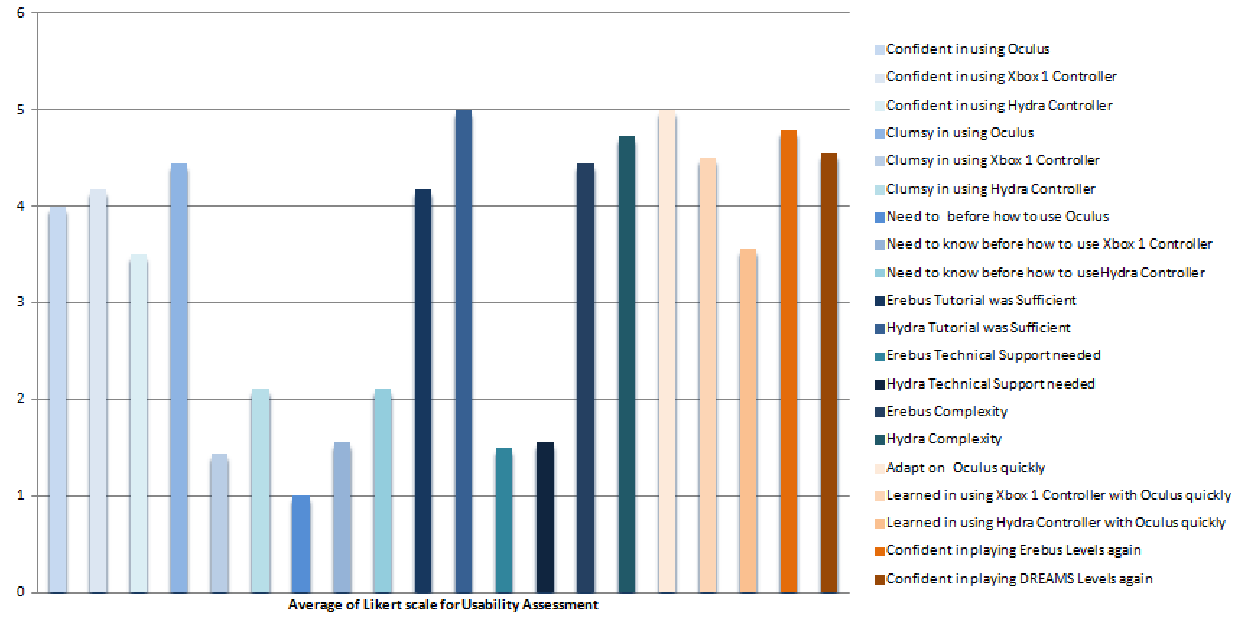


Fig. 6: Experimental Usability Assessment for both games. Questions with Oculus have been duplicated.

In both games users felt that they had the game in control using either of the interactive devices..

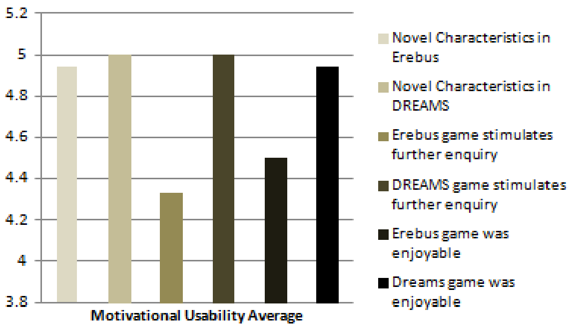


Fig. 7: Motivational Usability Assessment for both games

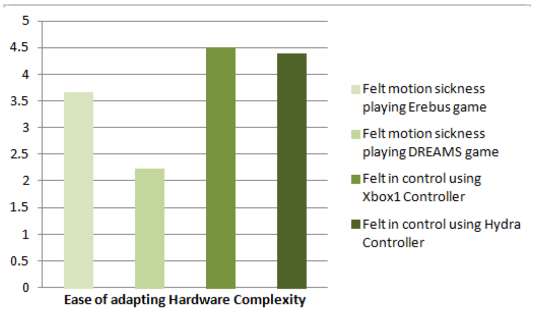


Fig. 7: Hardware Adaptation Assessment for both games

VI. DISCUSSION AND CONCLUSIONS

The evaluation of the two games with different user input interactivity revealed two important outcomes: 1) The effectiveness and strengths of the use of new immersive hardware interfaces to support user satisfaction and 2) Revealed issues raised from both the complexity in using them as well as the adaptation from the users body. Overall the users didn't need to have much of experience in using the new hardware technologies. The integration of the body gesture through the hydra controllers improved the overall game satisfaction as the users felt more emotional attractive to the game environment. Razer hydra compared to other gyroscopic hardware such as the Nintendo Wii provide more accurate feedback to the users gesture inside the game but at the same moment it minimizes the movement freedom as the device is not wireless. In both games a large number of users felt motion sickness. This happened more in the EREBUS where the Xbox1 controller was used rather than the DREAMS were the hydra controller was the input device. The ambiguity behind this might be also the case that the EREBUS game was a more action game compared to the DREAMS.

Over the next few months a number of new kickstarter technologies will be released to support the VR technologies such as SIXSENSE. PrioVR etc. These technologies will support full body motion with the usage of either wireless sensor attached to key-reference points across the player's bodies to obtain gesture activity (movement, jump, arm extension etc) or full body suits for more accurate data extraction. Other developments such as Control VR with the use of conglomeration of hardware, including harness, armbands and gloves that uses tiny proximity sensors to track the arm, hand and fingers. Other companies are pursuing another form of haptics approach towards kinesthetics: specially tuned subwoofers that you will attach to your chair, shirt, or head to induce powerful body-shaking vibrations during a game or an entire exoskeleton like suit where electrical impulses can force your muscles to contract in response to virtual impacts. All these immersive technologies could be the next step towards mapping player movements in the real world to the in-game avatar, which will open exciting possibilities for virtual interaction in the future.

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