Do active haptic devices improve a users sense of presence when applied to simple tasks within a virtual reality environment?

Callum Pankhurst

***Abstract*—This paper examines the use of active haptics in a virtual reality environment to increase a users sense of presence with simple task management. There has been research into whether haptics can increase a users sense of presence within VR but not so much with simple tasks, users seem to need more complex tasks to absorb themselves into which increases their presence.**

I. Introduction

THIS paper will look at researching literature surrounding the topics of immersion, virtual reality and haptic devices. This paper will look at developing an artefact that will utilize a force feedback system using computer hardware such as the *Arduino* and a Virtual Reality(VR) headset like the *HTC Vive*[1]. This will allow the user to ”feel” objects in the game world with more focus on immersion than with the standard haptic feedback from *Vive* technology. To maintain a sense of where their body is in the environment humans utilize several types of sensory modalities (visual, somatosensory, proprioceptive, tactile and auditory)[2]. They use these sensory experiences to perceive themselves and engage in goal orientated behaviour[3].

The human haptic system is unique from the other senses as it allows two-way communications between humans and interactive systems, this allows bidirectional interaction between the user and their environment. Specifically, interactions with haptic devices offer the brain a new independent sensory channel to increase a users experience in a multimodal environment [4].

Haptic interfaces can be broadly split into two categories: force feedback devices and tactile feedback devices. Force feedback devices will display force/torque and allow the user to feel a force, friction, roughness, etc[5]. Tactile devices allow the user to feel sensations such as temperature, vibration, pressure, etc. [5] In its current state haptic feedback within VR systems is quite poor and does not represent a naturalistic way of interacting with objects in virtual space[6].

II. Related Works

A. Haptic Interfaces

Haptic interfaces at the moment are not very advanced especially within commercially successful game devices such as the *Wii*, *PSP*, and *Nintendo DS* which only provide simple vibrations to the user. Especially due to the success of the *Nintendo Wii* and haptic phone which provided tactile feedback which leads to other companies integrating haptics into their game devices[7]. Haptics was introduced at the beginning of the 20th century due to research conducted within the field of psychology which was aimed at understanding human touch[5]. Many low-cost haptic devices produce a vibration. This force is very simple to manipulate and create and requires less complex equipment that more sophisticated haptic feedback devices would need [8]. Tactile augmentation is a very simple, safe and inexpensive way of adding physical texture and force feedback cues to virtual objects[9].

B. Pseudo-haptics

Haptic sensations can be induced without the use of a haptic device by influencing another sensory modality such as vision[10]. This is where visual cues create haptic sensations without physical haptic stimulus. Such as enhancing pseudo-haptic textures with a stripe pattern that provides a vibro-tactile stimulus. Various haptic sensations can be generated with pseudo-haptic feedback[11] for example the stiffness of a virtual spring.

In an experiment by Hachisu et al[10] two techniques for producing pseudo-haptic feedback. The first technique simulates a striped pattern with vibro tactile feedback. The second technique simulates material stiffness using vibrations and vision which should generate novel pseudo-haptic effects. These were implemented on system consisting of a PC, a PC monitor and a tactile display. The tactile display consisted of a PC mouse and an audio speaker that served as a tactile vibrator. The PC would receive the mouse event and send a waveform event signal to the audio speaker, and the visual output to the monitor.

C. Wearable Haptics

Wearable haptics has only begun to be recently designed, in theory, these haptics would make it possible to feel objects within a virtual space such as feeling the texture of virtual materials [12]. There has been a large advancement in the research towards wearable haptics such as the *Google Moto 360* and *Apple Watch*. These devices function the same as a smartphone but are still limited to simple vibrations to provide feedback to the user [13].In order to represent a sense of realism haptic devices must be able to present two types of information; kinesthetic force feedback (Explain more) and cutaneous tactile feedback(Explain more)[14]. While a large amount of research into wearable haptics has been made they are mostly made for devices to be worn on the fingertips which allow for devices to be fitted with an array of pins that apply direct stimulation to the fingertips, this allows for certain patterns to be reproduced which simulates texture[15] such as in an experiment by Solazzi et al [16]. They developed a 3-DoF (3 Degrees of Freedom) wearable display for the fingertips which has a force-sensitive resistor on the plate of the device which stimulates the fingertip (Fig 1).

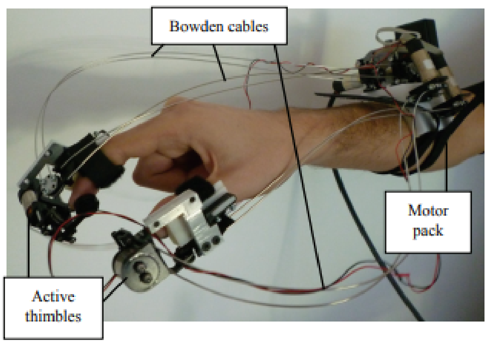

Fig. 1. Salazzis' haptic device fitted on a users arm [17]

This allows the user to feel a more accurate feeling of touch[17]. A novel way of using wearable haptics created by Nordahl et al was to create a pair of shoes (Fig 2) in theory this would allow the user to feel realism at feet level[18].

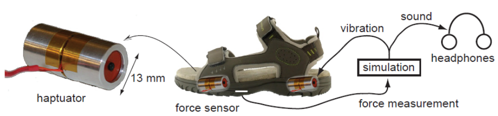

Fig. 2. Nordahls [18]

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D. *Haptic System Physiology*

Fig. 3. lists the characteristics of tactile mechanoreceptors, which are sensory receptors that respond to mechanical pressure or distortion [19] they are divided into two groups: slow adapting and fast-adapting.Slow-adapting receptors detect static force while fast-adapting detect vibration and acceleration[20]. The main skin type that will be looked at is the *Hairy* skin type, which covers most of the body, it has three active mechanoreceptors. While it has a low spatial resolution meaning that it can't distinguish specific textures or patterns well. However can detect vibrations and static force effectively thus actuators that are used to convey vibratory can be placed anywhere on the body [4]. In terms of what is going to be tested later in the paper, this is perfect as vibratory haptic feedback devices are low cost[4] and as mentioned earlier in the paper can be deployed anywhere on the body, allowing for potential testing with a number of tasks utilizing any part of the body.

III. IMMERSION

A. *What is Immersion?*

It is extremely difficult when trying to understand what is meant by 'Immersion' and whether research into the concept of 'Immersion' is even talking about the same subject. Within the sphere of games, immersion is mostly synonymous with virtual reality[21]. Though immersion seems to be understood by the gaming community no one really knows how to define it or how it is achieved[21] [22]. A book that is frequently cited for the definition of Immersion is *Hamlet on the Holodeck* by Murray (1997)[23] her definition is:

"Immersion is a metaphorical term derived from the physical experience of being submerged in water. We seek the same feeling from a psychologically immersive experience that we do from a plunge in the ocean or swimming pool: the sensation of being surrounded by a completely other reality, as different as water is from the air, that takes over all of our attention, our whole perceptual apparatus". (Murray,1997, p.98)

In order to understand immersion better, Brown and Cairns(2004)[21] collected qualitative data by interviewing seven gamers and request that they talk about their experiences playing video games, they found that immersion is used to describe the level of involvement one has with a computer game. They also found a selection of barriers that could limit levels of immersion within a player these were found to be a combination of human, computer and contextual factors such as gamer preference and environmental distractions. Brown and Cairn[21] also identified three degrees of immersion for gameplay. Ranging from "engagement" via "engrossment" to "total immersion"[24][21] While it may be plausible to see immersion as a step by step phenomenon that builds up while playing a game, the study does not have a clear definition for what presence or immersion is, which causes confusion between terms that are used interchangeably but may not be the same[25]. The three degrees of immersion are as follows:

1) Engagement: In Brown and Cairns[21] study they found that the first stage of immersion is engagement. This understandably is the lowest level of participation with a game and must be the first to happen before a player can experience engrossment and total immersion. Engagement is dependent on the players willingness to invest time, effort and attention into a game. Interviewees indicated that the level of effort they thought they had put in should be rewarded with the same level of rewards[26]. An initial barrier before engagement can even begin is access, this refers to a gamers preference if the player does not like the game they are playing they will not even try to engage with it[21]. Access also applies to the controls of the game, "'controls and feedback need to correspond in an appropriate manner so that the user can become an expert, at least at the main controls"[21].

The second barrier that users may face is the investment that the player puts into the game. The amount of time that the player invests is comparative to the game and the player. The gamers that Brown and Cairn[21] interviewed spoke about how they ”become focused” and ”if they played for ages” they would become more involved [21]. A feeling of guilt arises from the players if significant time is invested [26] meaning that a player can still be highly engaged with a game but still be aware of other responsibilities like needing to quit the game to get the bus for example[22]. Attention must also be applied to the game that the player is experiencing, this can best be described as a willingness to concentrate. The player must pay attention to the game like trying to learn any other type of skill, the player must be paying conscious attention to specifics within the game (for example, characters involved, powers that can be used, different weapons, different environments etc)[27]. Brown and Cairn[21] found that the demand for attention is far more needed in engrossing and totally immersive games compared to engaging games. At the beginning of play this can be attributed to player investment but as time goes on the game must provide something for the player can attend to.

Once investment and access have been lowered the user will start to feel engaged with the game they are playing. This experience lacks an emotional level of attachment which can be found at deeper levels of immersion.

2) Engrossment: Further from being engaged in the game players can be deeper immersed in an experience this is called engrossment, this is where the game features combine into a coherent experience that can interest the player at an emotional level[26]. The barrier to becoming engrossed in a game is game construction, game features need to combine in such a way that the players emotions are directly affected by the game they are playing and that the controls become ”invisible”[22]. Accordingly, the player does not need to pay attention to the controls as they have become automated. Allowing the player to focus entirely on the game world[27].

3) Total Immersion: While total immersion is used mutually with the concept of presence, a condition facilitated by feelings of empathy and atmosphere, this links immersion to elements such as graphics, plot and sounds. Alongside emergent gameplay[25]. This experience was reported by the players as fleeting and not the most consistent way of playing[28]. One barrier that is given for total immersion is that the player must identify with the characters of the game, it is possible to experience total sensory or systematic immersion while playing *Doom* or Atari’s *Battlezone*. Consequently, total immersion does not have to apply exclusively to heavily story oriented games[29].

B. Presence

The word presence is currently used to indicate a successful feeling of being in a synthetic environment. Matthew Lombard and Theresa Ditton define presence as ”the artificial sense that a user has in a virtual environment that the environment is unmediated”[31]. They looked at the literature on presence and

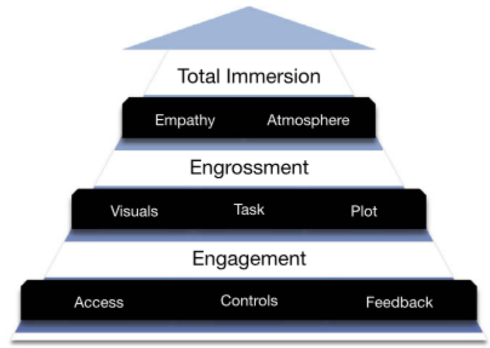

Fig. 3. Brown and Cairns[21] Immersion Model of the barriers(shown in black) that prevent a user from reaching deeper levels of immersion [30]

discovered that other researchers had categorized presence as the result of one or all of six factors. These are quality of social interaction, realism in the environment(Graphics, sound etc), from the effect of transportation, the degree of immersiveness generated by the interface, the users ability to accomplish significant actions within the environment. the social impact of what occurs in the environment and users responding to the computer itself as if it was intelligent[32]. In a study by Banos et al [33] they tested sixty participants to study ”the role of immersion and effective content on subject sense of presence” they manipulated the following variables:

- **Immersion** - A head mounted display, a semi-immersive video wall and a PC monitor
- **Affective Content** - Two virtual environments were designed, one that would induce sadness(emotional condition) and the other where no mood changes were expected(neutral condition.)

They used the environment of a park that could be found in any city or culture in the real world, this ties in with Lombards [34] theory that to make a user feel present within a virtual reality world they must see objects that they would normally see in the real world. The researchers manipulated the lighting parameters of some objects in the park to make them seem sadder. They also made it so that sad music was playing, the trees had no leaves and there were no people in the park.

In a study analyzing immersion between participants playing a video game, the researcher had some participants play on a display with a lower resolution and lower quality. While other participants played on a display with higher resolution and higher quality. The study found that the group who played with a higher quality display reported a higher level of immersion than the lower quality display participant group[35]. This was attributed to what was called int the study ”spatial presence”, which usually applies to the gamers level of self-projection into the world of the game that they are playing. However, another study conducted by Cheng et al [36] found the opposite, players were made to play in a world that was split in two. One side was highly realistic in terms of gravity, physics and looks. While the other side was exactly like the original game such as physics and graphics which were cartoon-like. The hypothesis was that once the players moved from the realistic side to the cartoon side, the players immersions would be broken. This was found not to be true and immersion seemed to be relatively unaffected.

The results showed that although the HMD is a fully immersive system, it created more negative effects such as nausea and dizziness than the other conditions and that the users felt more emotional when using the big screen and monitor which shows that the sense of realism may be dependant on what type of interface the user is viewing on[33]. This links with Wilcox-Netepczuk et al [35] who looked at different resolutions of the screen having effects on a users immersion, the HMD in this context is a lower quality screen.

1) Increasing Presence with Haptics: Although a number of research centres have developed new computer-simulated force feedback techniques, tactile feedback is lagging behind visual and VR input technologies[37].

Tactile augmentation which is touching real objects while within virtual reality[38] can increase the realism of a virtual reality experience, increase how present a participant feels with the virtual environment and can help virtual objects feel more real[9].The strength of presence may be associated with the amount of detail that is drawn into the virtual world. The amount of detail drawn into VR is so high that it can distract burn patients from their pain during wound care [39]. Adding on to this a sense of realism is needed in terms of how real can the virtual environment represent objects, events and people to make users feel immersed[32]. Heeter [40] asked users of consumer virtual reality entertainment systems ”How real did the overall experience feel?” this approach of presence is used in an ambiguous way that fails to determine the two types of ”realism”, they are social realism and perceptual realism. Social realism is where the portrayal is plausible or true to life and reflects act that could or do happen in real life[34]. While perceptual realism applies to events that could not exist such as a science fiction program that may be low in social realism but the characters and objects within the virtual environment may look and sound like as if someone did think they did exist[34]. Although in terms of an animated presentation the social realism may be high because the characters or events are not photorealistic, they are low in perceptual realism.

In a study by Ku et al [41] participants were given a data glove that had a vibratory device built into it to produce tactile feedback during VR experiments. The participants were then put into a fMRI scanner to measure what the participants brains were doing during the experiments. The researchers found through questionnaires, behavioural performance and the images of the brain.

2) Tracking Tasks in VR: In a study by Chung (1992)[42] for testing different models of immersion on targeting treatment beams in radiotherapy treatment planning. Each subject was given an HMD some had head tracking enabled, later they were also given steering through handheld devices all subjects used each steering mode and found that there was no difference in between head tracked steering modes and non-head tracked steering modes. This may give some insight into whether Lombards [34] theory of the world having to be as realistic as possible to achieve presence is true, as a head-mounted display will give a user more sense of realism than a fixed screen[42].

IV. METHODOLOGY

The aim of this project is to investigate whether an active haptic device can be used to improve a users sense of presence within a virtual reality environment. This will be measured through the use of a questionnaire and an interview after participants have played each variation of the experiment, with and without the haptic device.

A. Hypotheses

My hypotheses for this experiment are:

- **Null Hypothesis** - The use of active haptics will not have an effect on a participants sense of presence.
- **Alternate Hypothesis** - The use of active haptics will have an effect on a participants sense of presence.

B. Testing

A repeated measures design will be implemented in this experiment as there will only be one group of participants testing two conditions (with and without the haptic device). The dependent variables will be a users sense of presence and time taken to complete the puzzles provided. The independent variable will be the device used by the participants either they will be using the device or not. This design was chosen as to see whether the users felt that they had more presence in the game world with the device or without as a set of different puzzles will be used when using and not using the device. This eliminates the participants gaining any sort of practise effect and solely focuses on whether the device helped to immerse them in their tasks. Another con of using repeated measures design is that there may be order effects, where the order of the conditions can have an effect on the participants, to eliminate this I will be using counterbalancing. which means for every other participant they will swap the order of the tasks that they perform.

For example:

- **Participant 1** - Completes tasks in order of device on for the first task and device off for the second task
- **Participant 2** - Completes tasks in order of device off for the first task and device on for the second task

Although order effects still occur for each participant, they occur equally so balance each other out in the results.

In addition, doing tasks in a row could make the participants fatigued which would affect results, this can be counteracted by taking a small break in-between each task with or without the device.

Depending on the type of realism talked about in Section III-B (social or perceptual) the participants sense of presence may be reduced or increased. The puzzles that I will be designing will be as realistic as possible to reflect ones that could be found in real life rather than one that would be found within a science fiction game.

A t-test will be used to check if the finding is significant enough. To determine what sample size will be required for the experiment an a-priori power analysis was conducted using G*Power[43]. A large effect size of 0.7 was proposed as it reduced the sample size to something more manageable for the time frame given for research. The sample size that the analysis produced was 24 participants.

C. Equipment

There will be two main pieces of equipment in this experiment, a *HTC VIVE* and the haptic device. The *HTC VIVE* is a suitable device as there is one available within the games academy where participants will be gathered, allows for games to be made very easily that are compatible with it and the haptics within the controller can be turned off if this is wanted which makes testing without haptics a lot easier. The use of the HTC VIVE[1] is good because it is a fully immersive system but also may skew results if the participants feel nauseous and dizzy. This could break their sense of presence so I will have to try my best to make it so that the environment they are in does show these negative effects such as in Banos et al study [33] which possibly skewed their results.

D. Data Collection

After each participant has completed the tasks with or without the haptic device, they will be given a questionnaire will collect only quantitative data with a series of Likert scales, this will make it very easy to analyze data and help prove or disprove hypotheses. They will also be given an interview with the researcher. This will help collect some qualitative data since the topic of presence will not easily be explained through just a questionnaire with Likert scales.

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