THE FOURTH VIRTUAL DIMENSION

Stimulating the Human Senses to Create Virtual Atmospheric Qualities

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Abstract. In a move away from the ubiquitous ocular-centric Virtual Environment, our paper introduces a novel approach to creating other atmospheric qualities within VR scenarios that can address the known shortcoming of the feeling of disembodiment. In particular, we focus on stimulating the human body's sensory ability to detect temperature changes: thermoception. Currently, users' perceptions of a 3D virtual environment are often limited by the general focus, in VR development for design, on the two senses of vision and spatialised audio. The processes that we have undertaken include developing individual sensory engagement techniques, refinement of sensory stimuli and the generation of virtual atmospheric qualities. We respond to Pallasmaa's theoretical stance on the evolution of the human senses, and the western bias of vision in virtual engine development. Consequently, the paper investigates the role our senses, outside of the core 'five senses', have in creating a 'fourth virtual dimension'. The thermoception dimension is explored in our research. A user can begin to understand and engage with space and the directionality within a virtual scenario, as a bodily response to the stimulation of the body's thermoception sense.

Keywords. Virtual Reality; thermoception; sensory experience; immersion; atmosphere.

1. Introduction

Experience, more precisely Human Experience, is set against the backdrop of the perception of space. Yet, the concept of spatial comprehension is difficult to grasp - simply because we cannot place our finger upon it (Watts 2019). The relationship between our body and the spaces we inhabit is a fundamental part of any architecture experience, yet we often neglect the complete set qualities of space itself. Understanding the qualities of space is a difficult proposition for the western culture; primarily due to an ocular-centric paradigm which has provided us with our primary understanding of the world. However, the domination of vision within the human sensory experience has only originated throughout the last few centuries. The human sensory experience was primarily dominated by

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hearing; with a recent shift towards vision occurring gradually (Pallasmaa 2005 p. 24). The shift from hearing to vision is a change attributed to the western culture shifting from oral to written speech (Holl 2006 p. 30). A shift that is relevant in the research context as a shift from sound space to visual space.

The development of Virtual Reality (VR) systems over the last 50 years have allowed VR to become a global operation with a wide range of implementations from medical training to gaming. However, much like human sensory experience, VR systems are heavily ocular dominant, wherein tactile and auditory engagement is often treated as secondary functions to vision (Slater and Sanchez-Vives 2016). The prevalence of vision-based reality is a problem for VR systems as it limits the level of presence which a user can experience whilst inside a virtual scenario. Presence is a necessity for VR systems as it allows users to step into an immersive boundless reality. However, without an adequate sensory data substitution and an active engagement of the human sensory system, a user consciousness' can never be expected to completely embrace a virtual scenario (Slater and Sanchez-Vives 2016 p. 4, Ranasinghe et al. 2017 p. 1732). This absence of certain sensual stimuli in virtual environments has in the past have been characterised as a lack of ”otherness”. We represent a limited set of senses in VEs and consequently failed to represent the others, that in the real world, the human is fully aware of.

Our paper captures a new aspect of sensory experience within VR, which provides insights into the different ways the human thermoception sense, or the sense of temperature changes, can help enhance a VR users' experience of virtual space. Existing research within the sensory experience realm has often focused on auditory, tactility, scale, virtual bodies and positioning of the user within a virtual scenario (Bicchi et al. 2008, Cooper 2020, McCosh 2020, Rogers 2019a). Bailey (2020) discussed the importance of sensory perception in VR to achieve a 'synchronous reality' for users that enhances the immersion. The research carried out in these author's respective fields are explorative and provide insights into the different ways that the human body can be directly engaged whilst in a virtual scenario. The publication 'Reimagining Relativity' (Rogers et al. 2019b) highlights the importance of interconnected design processes when generating environmental inhabitation in VR. The reimagining of the body as a virtual inhabitant necessitates that VR systems must reproduce atmospheric qualities to create realistic virtual environments, and inherently virtual experiences (Rogers et al 2019b) (Figure 1).

The introduction of thermal systems within VR research is not unique to our paper and has been the subject of many previous studies. The primary application of heat within most of these studies has involved the placement of heating 'nodes' onto the user's skin, often on the rear of the neck or within haptic hand gloves (Kim et al. 2017, Ranasinghe et al. 2017, Ranasinghe et al. 2018). The research situates itself apart from these papers. It approaches the application of temperature by introducing 'spatialised heat'; treating temperature as a tactile response to virtual environments and as a critical atmospheric quality of the virtual environment. Through the production of a virtual atmosphere, this research produces what it defines as a 'fourth virtual dimension', an experiential medium which connects the 3-axial dimensions and allows a user to experience a continuous 360° understanding of the virtual environment.

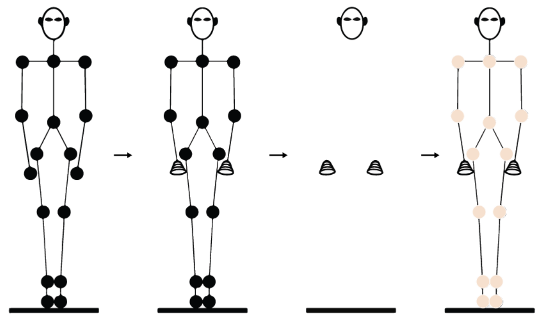

Figure 1. Re-Introduction of the body control points through thermoception. Adapted from (Rogers et al. 2019b).

2. Defining the Fourth Virtual Dimension

"By altering atmospheric conditions, the immaterial is materialised, the invisible becomes visible, what was absent becomes present. Space itself is rendered, not only visible but palpable, substantive"; Blau (2010 p. 106) suggests when considering Olafur Eliasson's artworks. Our research finds itself in a unique field of contemporary theory that attempts to bridge the fields of psychology and architecture. Through the critical review of relevant research papers and theorist's, a better understanding of how the human body perceives space through all of its senses simultaneously, and how no singular sense can act independently from the collective conscience can be generated (Montagu 1971 pp. 1-5, Hillier 1996 pp. 29-33, Pallasmaa 2005 pp. 16-21). The review provides the basis for our paper's methodology, where it becomes apparent that the balancing of individually engaged senses is crucial when creating a fourth virtual dimension that the user can experience.

The experience of space, or in this context 'the fourth virtual dimension' is an idea which has been explored predominantly through art during the previous century. James Turrell creates light works which allow his observers to experience the intangible. Turrell achieves this experience by carefully reproducing light within controlled environments. Turrell's works allow his audiences to visually observe an empty medium, or in fact; the empty medium of space (Adcock 1990 p. 220).

Our paper introduces Spatial Experience and Environmental Psychology's research fields to new technologies that can create or enhance our fourth virtual dimension experience. The three-axis' which we observe reality through is the primary subject of this research. The introduction of a thermal environment to the virtual realm is utilised to understand virtual space. It is also used to understand the extent to which a thermal environment creates a new non-visual form of directionality within the fourth virtual dimension. The three-axis we observe reality is the combination of our bodies location in space and the shape of that space, whilst Figure 2 demonstrates the fourth virtual dimension, as the connection between body and space.

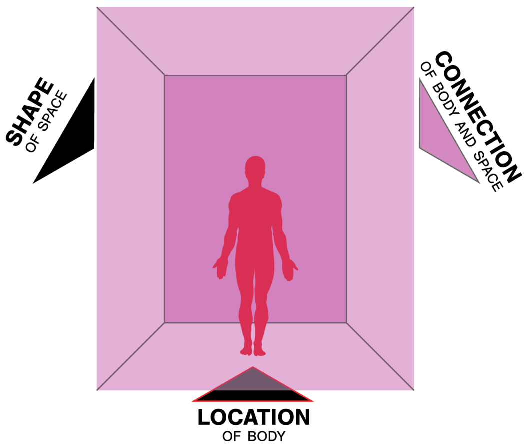

Figure 2. Illustration of ‘fourth virtual dimension’ connecting the 3-axial dimensions.

3. Methodology

Our methodology approaches the fourth virtual dimension as a problem of sensory refinement. This problem created a framework for our research approach; based on prior research, and relation to the fourth virtual dimension, four sensory inputs were selected (Visual, Auditory, Locomotion and Thermoception). Each sense was assessed individually at each stage of the research before the respective next stage of development occurred. Understanding each sense’s role in creating and perceiving a virtual atmosphere and the extent to which each sense should be stimulated are the primary assessment criteria for the research.

The *HTC VIVE PRO* VR-headset was the device used for the testing of each research stage. This device allowed the user to move freely within each scenario as the VIVE PRO is a wireless VR unit. Initially, locomotion was implemented through an *HTC VIVE* controller, utilising the default teleportation mechanism discussed in Rogers et al (2019b). However, Initial testing with the thermal system presented an issue where the user could not effectively sense heat through the hand holding the controller. The integration of a *Microsoft Kinect 2.0* resolved this problem sufficiently. The Kinect has full-body tracking capabilities and allowed the user to move freely within the virtual space.

Each virtual scenario was developed through a combination of *Unity3D* and *C-sharp* coding techniques. Unity3D actively controlled the thermal environment, allowing it to respond to user action and changes in the *Head-Mounted Display (HMD)* position. The thermal environment is composed of *Magic Living's 375w Infrared Heat Lamps* connected to a *Theatrelight DMX dimmer. HOG 4 PC,* a PC based lighting console program, actively controlled the dimmer unit. Unity3D calculated changes in the HMD position, creating a percentage value for each heat lamp. Open Sound Control (OSC) protocols communicated this percentage value with HOG 4 PC, which allowed real-time updating of each respective heat lamps intensity value.

4. Stage One

Commencing the fourth virtual dimension experiment, the researchers began with a blanket engagement of all four selected senses. Each sense was equally stimulated through a dynamic abstract experience. The researchers decided to start with a blanket engagement, as it allowed a rapid understanding of each sense's role in creating and experiencing the fourth virtual dimension.

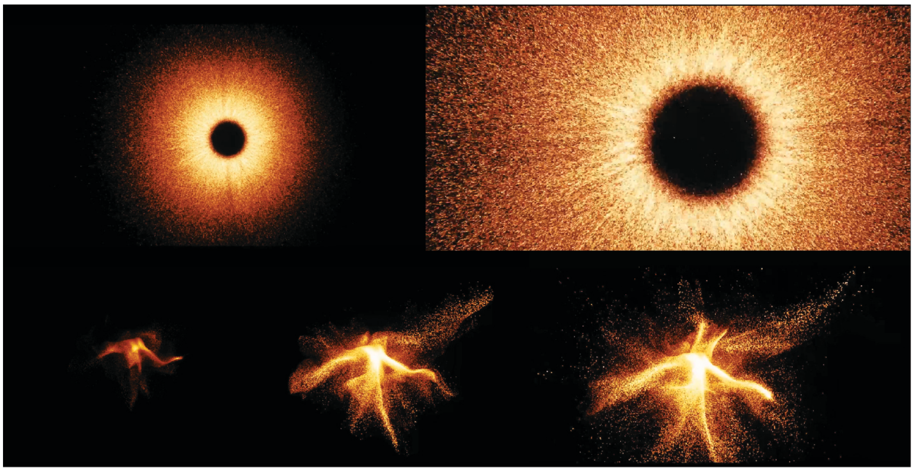

Figure 3. Multi-sensory testing through vfx driven simulations .

The VFX-graph tool in *Unity3D* can create high-quality particle effects for VR (Figure 3). The tools ability to create dramatic and dynamic visual stimulation in 3D environments allowed the rapid creation of stage one's virtual scenario. The orchestral music of Camo and Krooked (2020) controlled the particle effects, allowing the integration of the dynamic visuals and the auditory sense.

The Kinect 2.0 sensor has the capability of recognising recorded movements of the human body. Due to the cosmic scale of stage one's virtual experience, it became necessary to provide locomotion through a set of arm movements which would accelerate the user forward or backwards depending upon the action performed. The Kinect 2.0 also tracked the user's hands, allowing them to interact with the VFX particle effects, creating an inferred presence of body within the virtual scenario.

Finally, the thermal environment was produced through a singular heat lamp placed in front of the user. The heat lamp would increase and decrease its intensity depending upon its intensity and the user's proximity to each particle effect system.

The stage one virtual scenario provided the researchers with a clear understanding that a more delicate balance of sensory stimulation was necessary moving forward. Although this scenario was highly immersive, it became overwhelming at times, and what can be defined as sensory overload became apparent at stages of the scenario. The stimulation resulting from intense graphics, increased auditory engagement and thermoception incitement led to an overwhelming experience, which initially maintained immersivity. However, after about 30- 40 seconds, the users' engagement in the experience began to reduce. This lack of engagement between the user and the virtual scenario was a surprising finding which altered the approach to sensory interactions in future stages. The constant engagement of the senses and the single directionality of the heating system also did not help the user establish a 360° understanding of the virtual scenario. The research paper concluded stage one by understanding that if a fourth virtual dimension were to be effectively experienced, there would need to be more emphasis placed on the stimulation of the body's thermoception sense.

5. Stage Two

From the previous exploration of sensory engagement in a virtual scenario, the researchers wanted to better understand the qualities of heat itself. By understanding what qualities heat provided to a VR user, and what qualities were absent, the researchers could produce a more resolved understanding of how to create an experience of the fourth virtual dimension.

The researchers decided that the Kinect 2.0 sensor was not an effective means of delivering locomotion within this research context, as it created unrealistic expectations of heat and scale, which the heating system could not actively provide. As an alternative, the VR experience took place in a small room (3.5m x 2m), where the user could move freely within the bounds of the space.

Stage two replicated the sun's day-cycle, rising from the right of the user and setting to the left. To test the extent to which the thermoception sense can accurately perceive directionality and spatiality, the HMD displayed a black screen with no audio.

Four heat lamps were mounted around the user (Figure 4), and Unity3D calculated the sun's position to the user. The calculation allowed a percentage of angle for each heat lamp to be created and transmitted through the OSC-protocols.

By individually stimulating thermoception, this stage effectively demonstrated the role of heat in creating spatial perceptions of a virtual scenario. The introduction of the thermal system as the sun rises, caused the user to move towards the heat lamp, embracing the warmth and exploring the changes in temperature as they moved around the light. However, the absence of all other sensory stimuli created a virtual scenario that became unsettling and displaced the VR users' perception of space. It became possible to navigate the space throughout the virtual scenario; however, it was not easy to discern the room's bounds, nor was the user able to establish a complete 360° understanding of the virtual scenario. The stage highlighted an issue to the researchers, where the VIVE PRO headset effectively removed the perceptions of heat to most of the face and head. However, when the user turned around, the heat experienced on the neck's rear was highly effective and immersive. This stage's results allowed the researchers to approach the final stage of the research paper with a more comprehensive understanding of the role thermal changes can have on a VR experience.

Figure 4. Interconnected heating installation.

6. Stage Three

The previous stages of virtual scenario design provided our research with an understanding of sensory balance's significance in creating an experiential fourth virtual dimension. This research's final development stage built upon the findings so far and re-introduced visual and auditory senses to stage two's virtual scenario. The researchers created a 'meditative' alternate reality that provides the user with minimal auditory engagement and limited visual stimulation while focusing on a thermal system's refinement.

The researchers addressed the ocular sense by providing it with a minimal stimulus, an approach to emphasise thermoception. The HMD was placed in the centre of a slowly rotating night sky and an endless lake of lapping water. A forest of dark trees sat in the water around the user, which allowed the sun's visualisation to be displaced during sunrise and sunset. Limiting the auditory sensation to the sound of lapping water against rocks, combined with the minimal visual stimuli, allowed the thermoception sense to become the primary sensory input.

The auditory sensation was limited to a quiet sound of lapping water against rocks. The combination of dark, mysterious visual cues and auditory sensations was utilised to emphasise the warmth slowly introduced into the environment.

Much like the previous stage, the VR experience took place in the same room (Figure 5). The researchers placed a 700mm x 900mm platform on the floor for the user to stand on, which limited the users‘ movements within the room. Represented as a 3m high podium in the virtual scenario, the podium's introduction into the scenario engaged the users' sense of presence by creating a point of reference, connecting their physical and virtual movements.

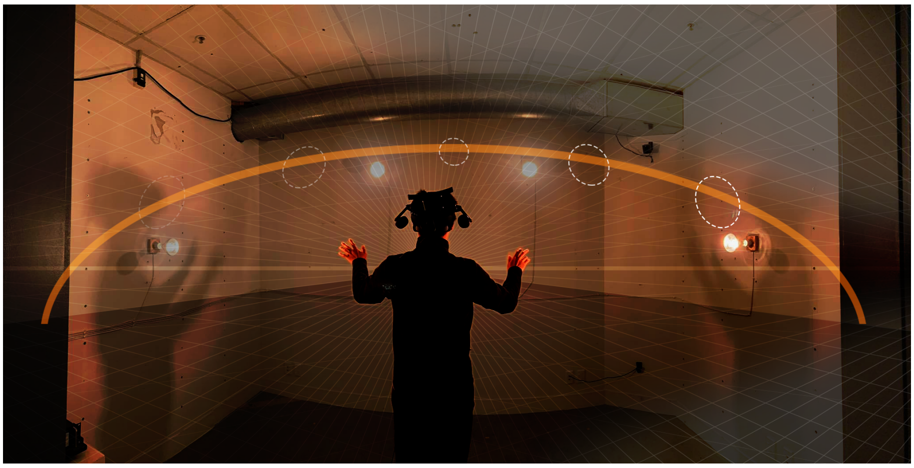

Figure 5. Mixed Reality demonstrating the suns path of travel around the user, with heat lamp connection.

The introduction of acute visual and auditory stimuli proved effective in creating an experiential fourth virtual dimension. The displacements of light shown allowed the thermal sense to take a primary dominance within users. As a result of the carefully balanced stimulation of the Auditory, Ocular, Locomotion and Thermoception senses, users' comprehension of the virtual environment becomes three dimensional and occurs concurrently. An example of this was during sunrise, where users looked away from the 'sun' or heat source. Thermoception's engagement allowed the VR user to understand changes to the virtual atmosphere in real-time, often prompting a reaction to view and experience the temperature change. Due to the room's small constraints, implementing our heating system to VR experiences is limited to situations where an active engagement with the environment is not necessary, such as cinematic VR experiences.

7. Conclusion

The introduction of spatialised thermal atmospheres for VR systems proved highly successful in this research. By introducing an atmosphere of heat around a VR user, our research allows a greater understanding of the role that temperature changes can have on our comprehension of space, whether it is contained to the virtual. A strategically organised process was designed and implemented to create a multi-sensory experience that researched Thermoception stimulation's role in the virtual environment. By first understanding that a delicate balance of sensory stimuli must be maintained to create a presence within a virtual scenario. Our research encourages limiting selected sensory stimuli, in this case, visual and auditory, to allow new sensory inputs to take a primary sensory dominance within the human body. However, our research proposes that overloaded sensory design could have broader applications within non-architectural discourses such as education and simulation of high-stress scenarios, where heightened active sensory stimuli are common.

The significance of virtual atmospheric qualities and the role of heat in creating them has enabled us to understand more effective ways to experience a continuous understanding of a virtual scenario. Classically VR systems only allow a user to perceive what is occurring in front of their eyes. The introduction of spatialised audio allowed this perception to expand to virtual actions/events around the user. However, these events are usually caused by preset animations or as a result of the user's actions. By introducing a heating system, we can begin to allow users to perceive changes to the virtual environment itself. Changes could include the rising of a sun or the change in a thermal environment as the user enters a virtual building.

Exploring new processes like this within virtual environments stimulates new excitement for designers, clients and the public by creating better unison between VR scenarios and the human body. The virtual environment creates a richer picture of the human brain to process. It thereby creates an environment that is more fully furnished with the senses that humans possess and employ to understand the environment they are inhabiting. By implementing more comprehensive atmospheric qualities in VR, we begin to design more completely immersive and engaging virtual art and architectural design forms.

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