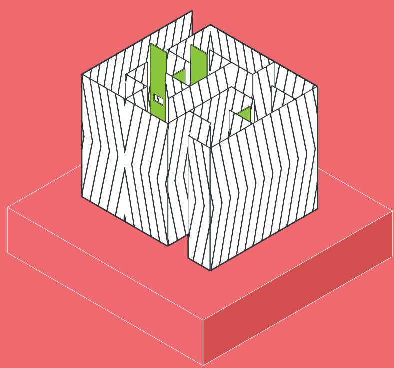
MAKING THINGS FOR PEOPLE :

An Iterative Design Procedure Informed by Human Behaviour



BRANDON WANG

MAKING THINGS FOR PEOPLE : AN ITERATIVE DESIGN PROCEDURE INFORMED BY HUMAN BEHAVIOUR

BY

BRANDON WANG

A 120-point thesis
submitted to the Victoria University of Wellington
in partial fulfilment of the requirements for the
degree of Master of Architecture (Professional)

Victoria University of Wellington
School of Architecture

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Fig 001. Image of Final Review

Fig 002. Image of Final Review

i . Abstract

Technology inevitably evolves and develops rapidly in the modern era, industries and professions continue to strive in integrating, adapting and utilising these advancements to improve, optimise and improve the process of design to manufacture to the user-experience.
Although disruptive at first causing a reluctance of technological adoption within a workplace and ultimately progression of an industry, the eventual impact and benefits noticeably outweigh the initial time and cost within industry adoption, adaptation and development. Architecture and design is not immune to this phenomenon; from computational 2D and 3D modeling, BIM and cloud based data to physical prototyping with 3D printing, laser cutting and automated CNC routing, these are a few select examples that has forced the industry of design to rethink processes, possibilities and realistic opportunities where none existed prior.

One such system that fits into this category is the advent of Virtual Reality and Augmented Reality. The numerous possibilities to which these visually and spatially immersive systems opportunes for immense innovation often lacks direction or an ultimate goal thus rendering this piece of software to often be little more than a visualisation tool.

This thesis recognises the unique position that VR allows and seeks to interrogate and deconstruct current, traditional design processes to better utilise VR in aiding and reinforcing the idea of partial testing of ideas and concepts throughout the design cycle. Different sciences such as psychology, processes and automation from computational design and considerations within software development will be employed and injected into the broader architectural context in which this research presides. In addition to the VR headset, external hardware that better capture human metrics such as EEG, eye tracking, GSR will be considered to developed a seamless tool and workflow that allows us, as designers to better interrogate clients behaviour within our designed digital representations which leads to validations, evaluations and criticisms of our actions within the architectural realm.

ii . Dedication

It is my previlage and pleasure to have the opportunity to dedicate this research towards those whom I respect, love and look up to the most.

First and foremost, my parents Li Chuan and Kuan Four Wang. Two of the hardest working people who has sacrificed almost everything to get me and my siblings to where we are to be able to achieve all that we have and much more.
They have supported me every step of the way whether it was warm meals at home or encouraging me while I was 18,526km away in The Netherlands, working and experiencing all there was. If anything, this publication marks the end of my Master's of Architecture and fulfills one of many promises I have made.

Thank you, mum and dad.

Secondly, my wife and life partner, Jiayi Huang. There was never a time when you were not by my side throughout work, study and life. There is no ones hand I would rather hold as we step into the next stages of our lives, careers and journey through this world, together.

iii . Acknowledgements

There are a countless number of people whom I would love to recognise and acknowledge though I will attempt to restrict myself.

Tane Moleta and Marc Aurel Schnabel; my supervisors and mentors throughout the past year. Never stopped pushing me to question all there is and allow myself to be content with mediocrity, forcing me to produce the absolute best that I can. Thus, I can say whole-heartedly, throughout every challenge, disagreements or questions we posed throughout the year, I have two things I can truely be proud of. This fantastic piece of work and the friendships and life-long relationships I have been previlaged enough to forge with the both of you. Hears to many, many more years of fishing, banter and experiences.
Sincerely, thank you Tane and Marc.

Friends and family from Architecture School; thank you all for the support, but more importantly, being the competition. We all strived to be the best but never did we neglect our fellow colleagues. We made it... eventually. Now to go for beers after work instead of... nevermind.

And lastly, Darren Wang; the older brother who is prehaps the harshest critic, coach and teacher of mime. In everything from games to sport to study, boy... did you push me, but you also taught me to push back harder and fight with blood and sweet. No tears. I would not have been half the man I am without this guy lighting the road ahead. Thanks mate.

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6 FINAL DESIGN

1 THESIS INTRODUCTION

Introduction

The introduction of virtual and augmented reality environments into the architecture profession has produced a new wave of representation.
However, the utilization of virtual environments and the potential it offers has not often ventured out of the representation stage of design. The ability to test and track the activities within a design will have large implications for architectural design if conducted and understood.

The acknowledgement of this potential is what led to this thesis. Initially, the thesis began as a research project done in collaboration with Aurecon, New Zealand. The research was designed around gathering non-bias data autonomously and passively by simply wearing the HTC Vive, a virtual reality **[VR]** headset and experiencing an architectural scene. The research resulted in producing a primitive tool that the thesis then set to improve, refine and package into a user-friendly tool that will aid in the integration of psychological studies into the realm of architectural design decisions.

Background

The initial research posed a question to whether Virtual Reality systems can be used for more than an advanced visualisation utilisation. By moving the process of VR earlier into the design process, treating Real-Time Virtual Environments (RTVE) as another digital design tool allowed for the creation of background scripts, processes and manipulation of additional hardware for the coalescence of multiple data sets in order to begin recording, detailing, reviewing and critiquing the journey and experience of the user.

The evolution to the next step for the project was always to incorporate eye tracking and/or use of pupil data and seeking to integrate and autonomising basic psychological studies surrounding eye and pupil data in order to increase the user-friendliness, ease of use and accessibility to those without a formal or higher level background in Psychology. This step allows designers to further understand the mental and psychological influences of our design solutions. Until the advent of VAMR, single frame 'rendered' moments has traditionally been the preferred method of architectural visualisation with the increase and commercialisation of computational and graphical power along with three dimensional, digital modelling. This method allowed for greater control by the architect to dictate and direct the experiences of the client while providing a visually stunning yet immersively disconnected experience. However, with the introduction and development of VR headsets, the client experience has shifted to one that can be visually stunning while immersive but creates a disconnect with the architect. Relinquishing control of movement, sight and overall experience to the client, which in the context of this research and tool, is a greater strength then the control designer's naturally asserted.

Research Question

It is this new shift of experiential characteristics that VR allows that this body of research seeks to explore. The question

"How can we as Architects and designers better understand what our clients perceive in our design solutions?"

primarily seeks to explore how design perception and experiences differ between clients, designers and users by gathering and representing non-bias biometrics when a participant is presented with the digital realm with tasks, objectives and minimal guidance input from the designer.

The work further speculates on how the designed workflow can be implemented to study the behavioural characteristics, stress and cognitive loads within design processes to inform future design decisions that will be better tailored to client's needs and focuses. By presenting the task of navigating and moving towards a destination via a digital landscape in VR; behavioural and sub-conscious characteristics caused either by the design or method of representation are found. This is then contrasted with an iterated design with tasks and objectives for participants to resolve. Results will detail and recreate the participant's journey, focuses and experiences within a journey.

The aim of this research is to develop a tool and methodology that will capture, represent and help to understand the client's mental and psychological states when in a digital representation of architectural design. The project seeks to incorporate new technologies such as eye tracking hardware and VAM systems together and utilise a 'dualistic culture' of research between architecture and psychological sciences. The results include a tool and works detailing movement between the conceptual design stage, to testing within VAM to interpreting and using the testing for future iterations.

What this:

Thesis IS

- *How can we improve an architect's understanding of a design from a client's perspective?*
- *How can we begin employing studies and research done in the other sciences and utilising them for the betterment of architecture?*
- *Looks to incorperate heavy commputational design elements with psychological data in an Architectural context.*
- *Producing a developed tool and an autonomous methodology that works with Virtual Reality to capture and export one's experience.*
- *Heavy focus on the conceptual and development stages of an architectural design process.*

Thesis ISN'T

- *Use of the developed tools and methodology to produce a final design.*
- *A focus on the representation or visual virtual experience using Virtual Reality.*
- *A test into the Virtual Reality's ability to accurately portray or emulate a real world situation.*
- *Heavily focused on deeper philiosophies and styles within architectural design.*
- *An experiential display within Virtual or Augement Reality.*
- *Using eye tracking nor the science of psychology to assess built or heritage structures. The scope is aimed at the design process itself.*

Role of Research

The role of this piece of research is to not only celebrate the new technologies but to explore their applications outside of representation. Many means of representation in the current project workflows like single frame renders either advertently or inadvertently, allow the architect to control and influence how the client interprets designs.

The HTC Vive allows for an immersive, full design experience, but the isolation and lack of architect's direction of the experience now allow for clients to create their own experience to create better feedback and primitive inhabitation simulation. This tool and research now help designers to analyse individual importance from different perspectives and better help understand the needs of those they seek to serve.

Subsequently, the research also begins to critique and offer a new solution to how architects may evaluate designs and design choices. The method of real-time data gathering, autonomous data pipeline and minimal architect influence within VAM makes this method quick and efficient for practices but also keeps data consistent and reliable throughout for future research purposes. In order to understand the academic context and nature in which this thesis resides, understanding past research and progress into this area of computational design is paramount.

Role of Research

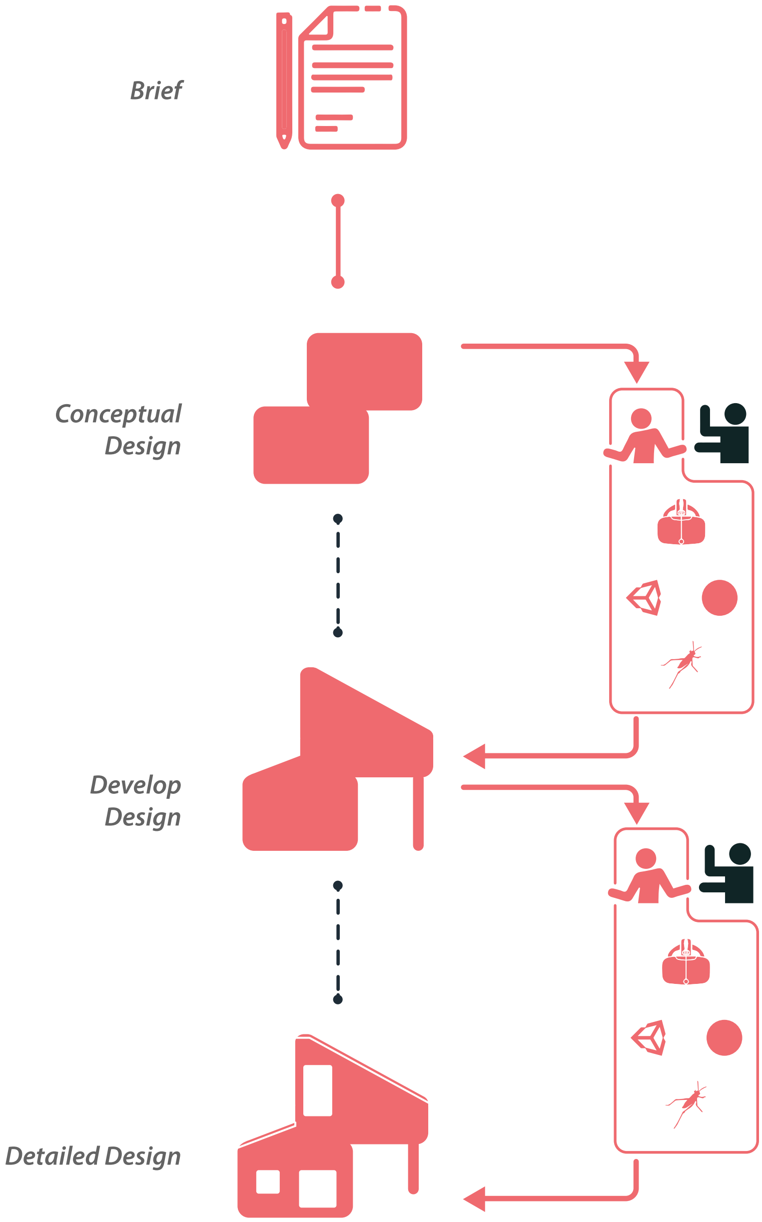


Fig 1.00 Workflow diagram detailing the role of the resulting tool .

2 LITERATURE CRITIQUE

Literature Critique

Literature are categorised into two positions in which they contribute towards this research. The first of these categories are “Influential Literature”; these papers frame the philosophical nature of the research and influence in the goal and end product.

The second is “Informative Literature”; these provide the scientific methods and data analysis types used or adapted for the autonomous and data structuralization.

Thomas Maver

Influential Literature Philosophical

Thomas Maver's 1995 paper and introduction of the concept of the

"Seven Deadly Sins in CAAD"

and Thomas Kvan's 2004 responding paper, "The Dual Heritage of CAAD Research" further introducing ideas of the 'seven virtues' and 'dual heritages' are the main bodies of text that guide this thesis, philosophically.

Maver is a researcher who has been "at the forefront of research and development in the field of information technologies applied to architecture and building design since 1970" ("Tom Maver", 2019). Maver's work and affinity lay heavily with computational design and the development of CAAD. However, Maver published the paper "CAAD's Seven Deadly Sins" in 1995, posting a critical view of the developments and research direction within the CAAD community. Maver expresses concerns over seven traits or 'sins' that are consistent with each iteration of research. These traits either seem to stall progression or lack of direction within the CADD research and academia.

Thomas Maver

The three sins and ideas that resonate most with this thesis are:

5. Failure to Validate

"Each new conference generates a plethora of ever more exotic claims" (Maver, 1995).
This sin coincides with an earlier sin; 1. Macro-myopia (each new technology or software promising too much). However, CAAD embraces the ambiguous nature of architectural design and follows the "culture of design in which discovery is observed as an ineffable act of creation, tested only in its manifestation" (Kvan, 2004). Maver observes that "In any other discipline the generation of hypotheses without some rudimentary testing" would be "laughed off the conference platform" (Maver, 1995).

6. Failure to Evaluate

Maver criticises the lack of recorded data or evidence of an investigation into a prototype's "usability and functionality in teaching or practice" (Maver, 1995). The lack of evidence or feedback to evaluate these prototypes within the practice or otherwise allows for 'academic drift' within future research and development.

7. Failure to Criticise

Again, this Failure to Criticise seems to be a product of a preceding sin outlined. "We have failed to exercise our critical faculties in relation to almost all of the research and development carried out by ourselves and by our peers in recent years" (Maver, 1995). Maver's second sin; 2. 'Deja Vu' speaks of recycling of ideas from past or forgotten works and rebranded as 'new' or innovative. These two sins have created a 'conspiracy' within the CAAD community to "condone, even encourage, self-indulgent speculation and solipsism" (Maver, 1995).

Thomas Kvan

Influential Literature
Philosophical

Thomas Kvan has worked internationally as a researcher and author in design, digital environments and design management ("Professor Tom Kvan - Melbourne School of Design", 2019). Like Maver, Kvan has heavy interests and is internationally recognised for his work in the "management of design practice and development of digital applications in design" (("Professor Tom Kvan - Melbourne School of Design", 2019).

As part of an issue of the 'International Journal of Architectural Computing' in 2004, Kvan published "The Dual Heritage of CAAD Research" as a response to Maver's paper. Kvan not only acknowledges the prevalence of the sins within the CAAD community but also the guilt of exhibiting and phrasing them as essential in Kvan's own work (Kvan, 2004). Kvan then proposes seven virtues that exist alongside the sins as a balance. These metaphorically frame the position of the architectural science that CAAD belongs to as opposed to the scientific methodologies and expectations of more traditional sciences.

This is where Kvan also proposes the idea of a Dual Heritage. A unique position that CAAD resides in where

"we find ourselves in the culture of design in which discovery is observed as an ineffable act of creation, tested only in its manifestation" and "the artifacts of our research must be expressible in the definitive and unambiguous clarity of data and procedures, to be evaluated in the integrity of their reasoning." (Kvan, 2004).

An interpretation of these writings can lead to an assumption of the Sins as a product of architectural science as the ambiguity of success can only be affirmed in it physical realisation. Subsequently, the virtues that balance out these flaws within CAAD are from "voraciously borrowing from other fields in the most liberal of manners." (Kvan, 2004). Adapting methodologies, unambiguous results and studies from other fields and sciences to fit and support the architectural narrative is one manner in which the sins of architecture are welcomed.

Ricardo Buettner

Influential Literature Psychology

Ricardo Buettner's background lays within computer science, industrial engineering and management and business administration. Buettner later received a PhD in information systems. Buettner has published work in various fields, one of which deals with Psychological Assessments, Human-Computer Interactions and Information Systems.

Buettner's understanding of the psychology behind pupil data and ability to frame data and information into bounds allows his literature and studies to be interpreted into tests within built algorithms. Recorded Pupil Data that were to be further used in the study was determined by Buettner's papers:

- *"Cognitive Workload Induced by Information Systems: Introducing an Objective Way of Measuring based on Pupillary Diameter Responses"*
- *"Analyzing Mental Workload States on the Basis of the Pupillary Hippus"*

Attributing cognitive states to fluctuations in the pupil diameter and hippus is a common practice within psychology as published by Jackson Beatty. However, Buettner's understanding of the computational space and what is needed to essentially, automate the reading of data now establishes the link between psychological pupil studies and the CAAD space.

Mihaly Csikszentmihalyi

Influential Literature
Analytical Concept

Mihaly Csikszentmihalyi is a researcher and distinguished professor of Psychology and Management at the University of Chicago. Csikszentmihalyi has also founded the "Quality of Life Research Center (QLRC)". The QLRC is a nonprofit research institution that focuses on the study of Positive Psychology; optimism, Creativity, Intrinsic Motivation and Responsibility. ("Mihaly Csikszentmihalyi ·Claremont Graduate University", 2019)

Csikszentmihalyi's 1990 paper details the philosophy about Flow and its contribution to find the optimal experience. Flow is described as

"attention is freely invested to achieve a person's goals because there is no disorder to strengthen out or no threat for the self to defend against" (Csikszentmihalyi, 1990).

During a given task, perfect flow is allowing a person to complete the task without distraction and complete control of one's behaviour and movement with immediate feedback or results. Dorta further used a concept of Challenges and Skills to determine the state of Flow one is experiencing within the museum.

Tomas Dorta

Influential Literature Analytical Concept

Studies and research that have demonstrated the benefits of embracing such a heritage into the architectural field Tomas Dorta's 2017 paper; Immersive Retrospection by Video-Photogrammetry. Dorta is a researcher and professor from Montreal, Canada. Dorta's research agenda and interests lays within "the design process and co-design using new technologies and the development of new techniques and devices of design in the virtual realm." ("About Us | Hyve-3D", 2019).

Dorta is also a co-founder of the Hyve3d system. Hyve3d is an immersive and interactive social augmented reality system. Using the Hyve3d in conjunction with Video-Photogrammetry, Dorta adapted research from Mihaly Cziksentmihalyi's psychology research on the concept of Flow in his paper Flow - The Psychology of Optimal Experience, 1990 to quantify survey results from focus groups. Dorta's research had a participant interacting with exhibitions within a museum. Their visit was recorded where they would later retroactively review and discuss their initial visit and flow states via a video-photogrammetry representation in the Hyve3D system.

Dorta's use of flow as a means to quantify experiences utilises a further concept of Skills and Challenges to determine the state of Flow. However, discussions, reviews and asking a participant to recall experiences, to articulate and rate them in a survey creates room for biases, filtered responses and skewed memories.

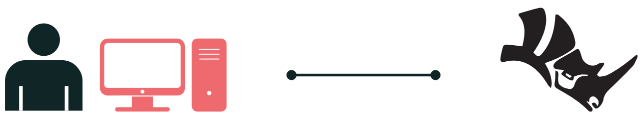
3 METHODOLOGY

Methodology

Due to the research topic and questions; methods regarding testing, participant requirements and recording of data will be kept consistent with the system, processing of data will also pass through the same software and scripts for interpretation and visualization.

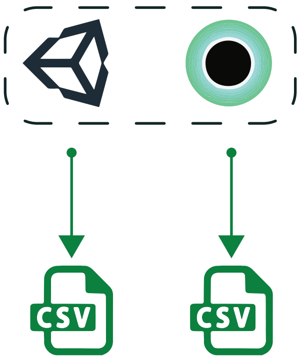
Results are to be non-bias as to ensure conclusions drawn from the tests are either concerned only with the VR system or design itself. Participants will be required to have experience with the HTC Vive to ensure the data or participant's behaviour is not influenced by one's awe of the technology or experience.

The environment is modelled and generated with Rhino 5.0 and Grasshopper which is then exported into Unity3D. The environment itself must follow the spatial restraints of the physical environment in which testing is done to ensure participants are moving as organically as possible as cognitive states and subsequently, pupil data is linked to physical activities (Zenon, Sidibe & Olivier, 2014).



Data from Unity surrounding head direction, sight and movement will be handled via a streamwriter coded within the scene that the experiment with taking place. All data will be exported and written while a participant is completing the tasks within the virtual environment, this will account for any discrepancy or system failures during or after the test.
Meanwhile, eye tracking and recording hardware from Pupil Labs will simultaneously streamwrite pupil data to a separate CSV file via the opensource software, Pupil Capture and the API developed for Unity.

Methodology



Both data sets are then linked into a Grasshopper script which produces data visualisation and representation in the Rhino 5.0 environment. The script will have functionalities built in that will help identify certain patterns that demonstrate a stressed state which will work in tandem with a journey slider system which will provide a visual recollection of the overall journey and points of interest.

The utilisation of the tool and data provided is then dependant on the user and their interpretation.

Other methods of extracting data and evaluating experiences within a virtual space would be to ask participants to describe and articulate their emotions, challenges, and experiences via number sliders and self-observation. Then standardizing these resulting values to Z scores to place on a normal distribution to highlight problematic areas.

Or, using the model of the optimal experience from Csikszentmihalyi and categorizing participants stimulation and psychological states based on the “skills” and “challenges” to determine their state of flow. However, detailed and personal data these processes provide, they are time-consuming in both the testing and processing stage and different opinions, experiences, and level of interest will influence the basic data received, potentially corrupting the results. Whereas this research is to allow for quick testing of multiple concepts and using primal reactions to validate

the success of the design or inform future design decisions.
The environment chosen for the context of this research is a maze. The concept of the maze is purely based around navigation. At any point, the structure allows for decisions that will either lead to a wrong path and subsequently, a dead end; or the right direction where more decisions are presented until the exit is reached. The concept of a navigational decision allows for architectural elements to be tested as a binary represented by the path that is chosen. Therefore, the design intention as the architectural designer is to mislead and misdirect participants to dead ends using architectural elements. The number of participant's that observes these and their decisions are then a primitive result which the tool developed allows for a deeper analysis and understanding of these elements, their traits and effectiveness.

Methodology

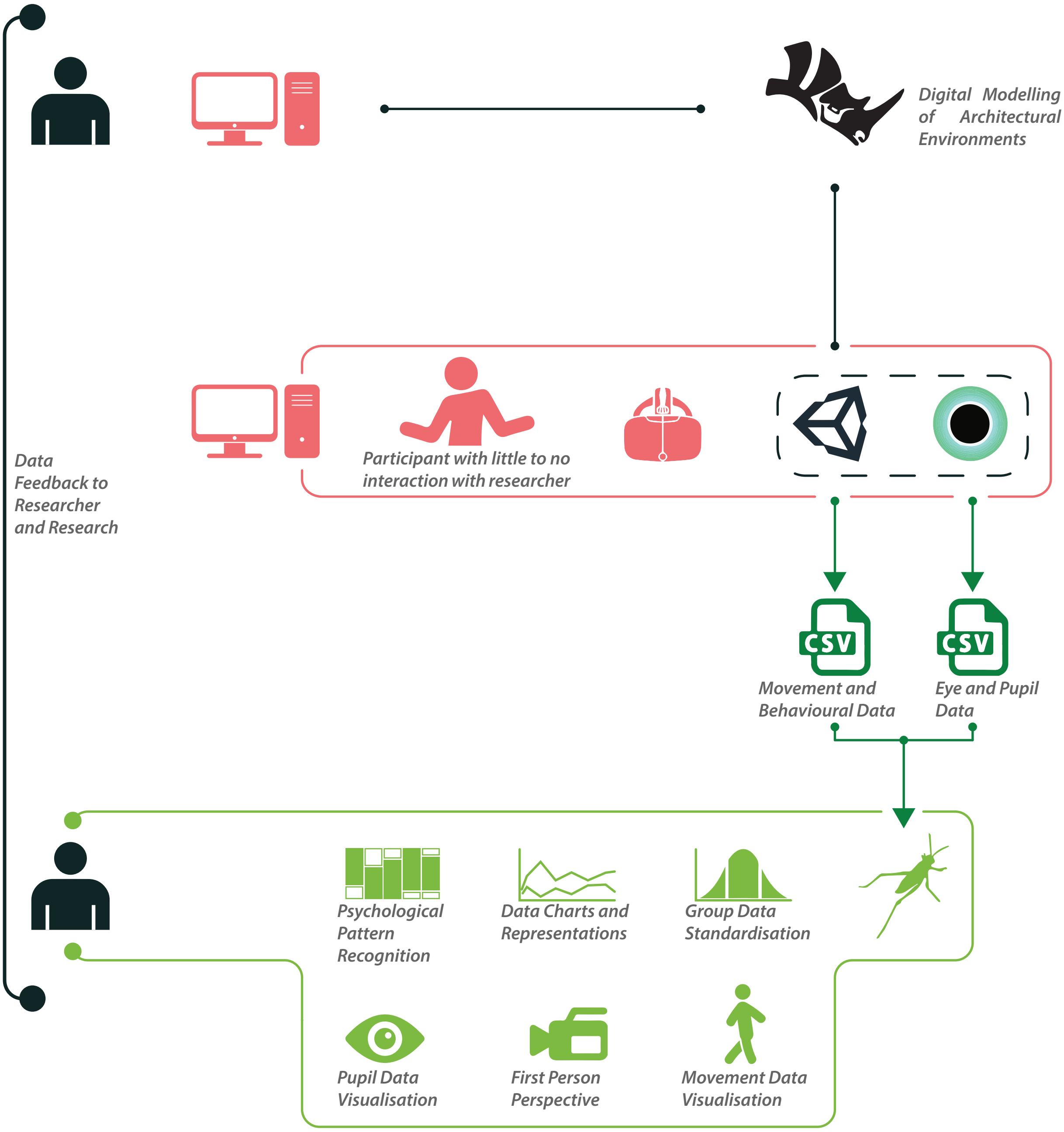


Fig 3.00 Methodology diagram consisting of the tool's relationship to designer and software.

4 PRELIMINARY DESIGN

Design of Tool Phase One :
PRELIMINARY DESIGN

The first design of the tool was concerned with establishing what was able to be intrusively recorded and appended to an external file from Unity3D, the RTVE chosen for the VR scene. This data then needed to be managed and integrated into a data pipeline that would reduce the number of steps needed to reach an analytical output, meaning the package to interpret, unwrap, sort and present data sets needed to be autonomous.

Secondly, sets of data from the eye tracking hardware; Pupil Labs VR HTC cameras, needed to integrate into the initial data stream from Unity3D. The advantage of Pupil Labs was the availability of open source code and SDK's ready-made for Unity3d. However, raw data that were desired was to be formatted and appended in the same manner of the Unity3D data for process streamlining and optimisation.

Other considerations included other external hardware needed to achieve and/or provide strong cognitive feedback and in which iterative scenario would be best for testing. Also considerations into the validity of such results and how accurate they would be to a real-world experience.

Debugging Environment - Supermarket

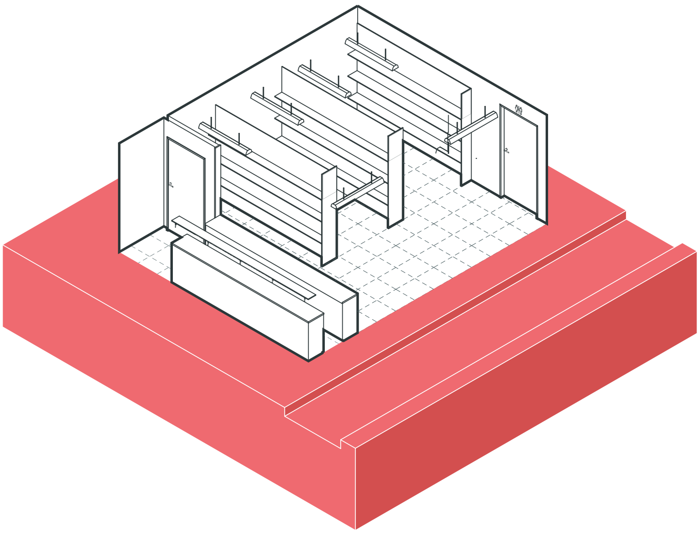


Fig 4.00 Supermarket environment to stress test Unity behaviour script and GH script.

3 Month Aims and Objectives

Within three months, the aim was to instate a basic framework to which data could be streamwritten out of Unity3D reliably, read and visualised autonomously within the Rhinoceros 5.0 environment with Grasshopper. Then behavioural studies into how one acts within VR in relation to the real world were also to be tested to ensure the presence of mind within the digital world did not interfere nor influence participant's behaviour. Ensuring accurate results that emulated real-world experiences.

The objectives were as follows:

1. Creating a script that will record and append users interactions and experiences to a common format.
2. Creating an autonomous data pipeline that will read and visualise all sets of data appended from the first objective.
3. Begin to understand the eye tracking system and the current data outputs.
4. *Gathering control testing results from an existing building in VR to validate differences between the real world and its digital counterpart.*

The first two objectives were straight forward and developed within a reasonable time frame. The data that was appended from Unity3D used the HTC Vive headset itself as a reference point for the person's position in space, the direction of head and line of sight.

The outputs within Rhino and Grasshopper consisted of

- a graph detailing the person's momentum of movement and eccentricity of the head; these were then compared and categorised into one of three flow states; Flow, Stress and Boredom (Dorta, 2017).
- A three-dimensional view which abstracted and simplified the person, line of sight and space into a representation of experience. This abstraction worked on a slider system that allowed one to scrub through the journey and highlight time frames of interest.
- The position of the user were captured every 0.1 seconds. A raycast of 10 rays were also fired, originating from the VR sets and spreading out randomly within bounds of +- 5 degrees. Positions where these rays hits would then calculate the average point and the average RGB value of the colours registered.

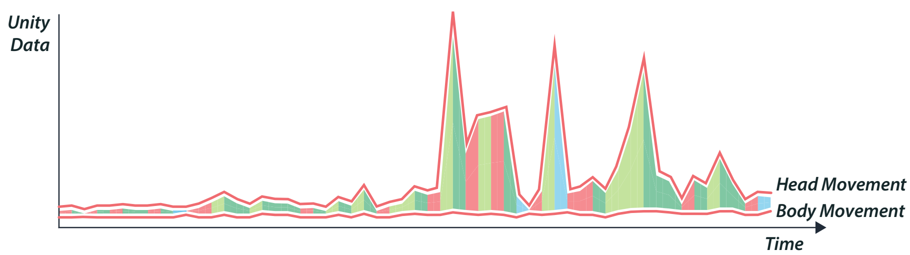


Fig 4.01 Flow Graph fragment comparing head and body movement.

3 Month Design of Research

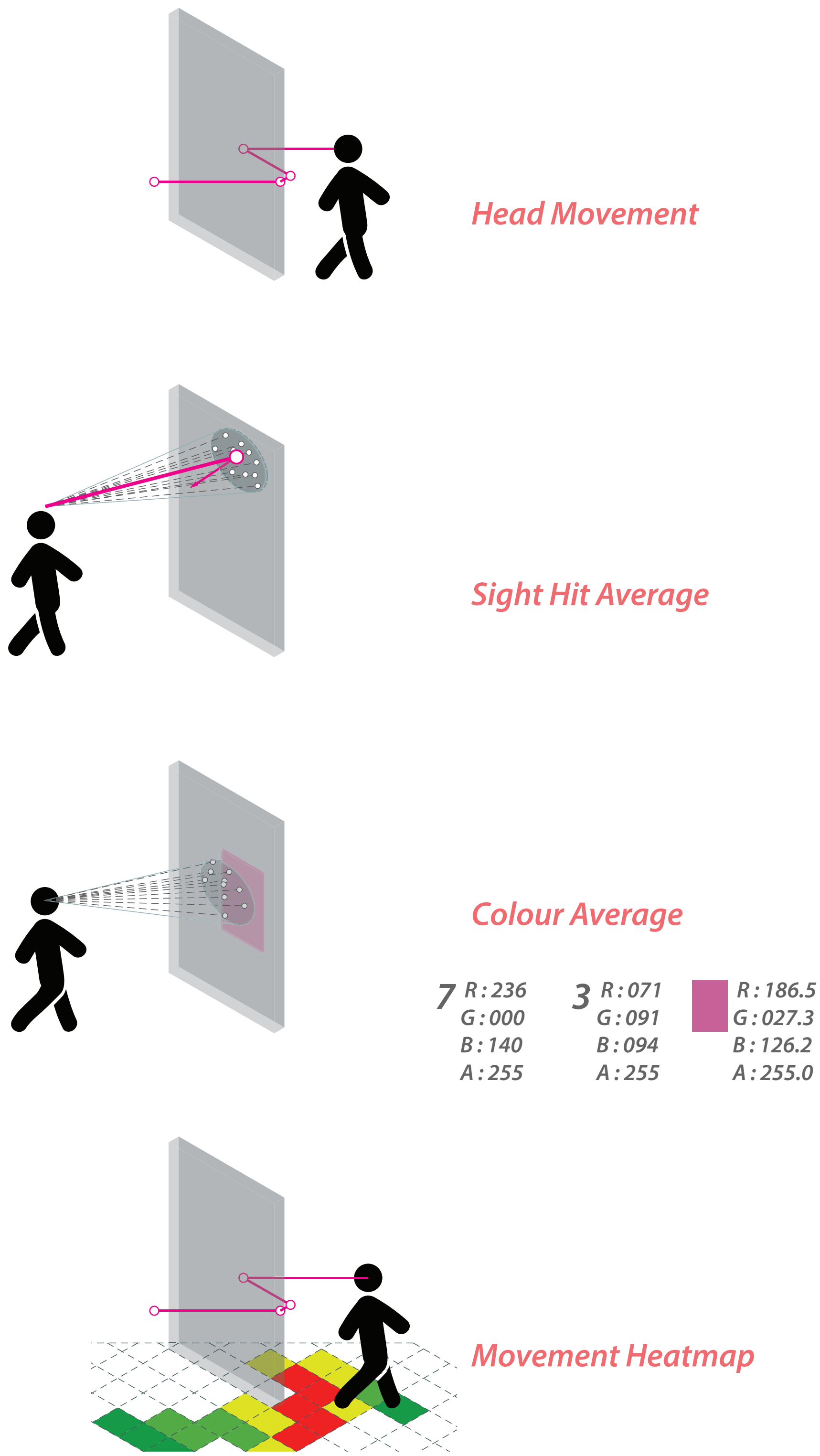


Fig 4.02 Depictions of data captured from Unity.

- A movement heatmap.

The eye tracking cameras also outputted copious amounts of pupil data using Pupil Capture, however, these were structured in its own folder system. These were then imported into Pupil Player, a secondary software which would then interpret and translate the initial folders into .csv files that Grasshopper could then read.

The University of Victoria, School of Architecture building was proposed to be the testing environment between the physical and digital. The advantages of would be the accessibility of the building for real-world testing and the convoluted system in which the offices would provide a maze-like experience to those unfamiliar. However, the size of the building alone would raise questions to how would one navigate it in VR as the use of teleporting or controller based walking would alter the experience of navigation. This objective was later reconsidered due to the limitations of the VR space and the amount of time and manpower available for the digital recreation of the Architecture building.

A set of objectives that the digital VR environment needed to fulfil was listed and categorised into three sub-categories; Limitations, Considerations and Purpose.

- Limitations.

Spatial Limitations, the VR studio where the research was conducted was a small area. Approximately 3m x 3m. The argument for navigating via true movement instead of relying on the Vive controller set the boundaries of the scene.

- Considerations.

Navigational and Visual Complexity, the environment needs a sense of direction while offering alternative routes for exploration. Therefore junctions may be targeted for architectural interventions and analysis of their influential effectiveness.

Defined Moment(s) of Success, paths needed a binary rubric to effectively measure 'right' or 'wrong'. For the user to realise an incorrect turn was taken and for designers analysing the results to conclude with definitive results.

- Purpose.

Finding or Identifying Objects in Space, adding another layer of complexity into the scene which would cause several routes to be taken in order to move forward to the end. Allows for the association of architectural elements and objects or objectives at hand.

The agreed step to then abstract the Architecture building into a smaller spatial design. The initial debug environment of a small supermarket created too much ambiguity within the goal of space/ experience and the architectural elemental effects on navigation through space. The sandbox nature of the experience needed to become more focused and centred on achievable goals within the space.

Therefore the concept of the maze from the Architecture building was translated into a small maze that fitted the spatial limitations of the physical architectural space. This allowed for a definitive goal of reaching the end via a series of navigation decisions influenced by different elements such as colour and geometry. Data captured and interpreted from the designer could then be fed back into future iterations of the maze until a design intent was achieved.

Testing Environment - Maze

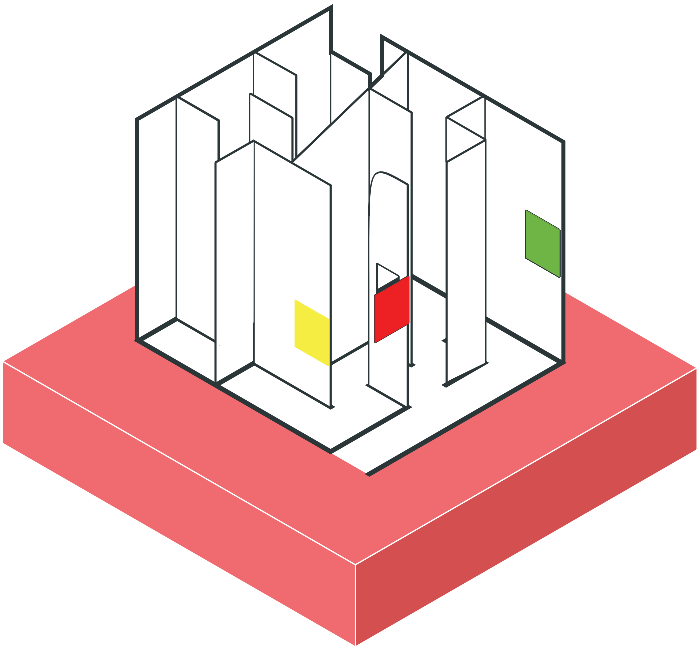
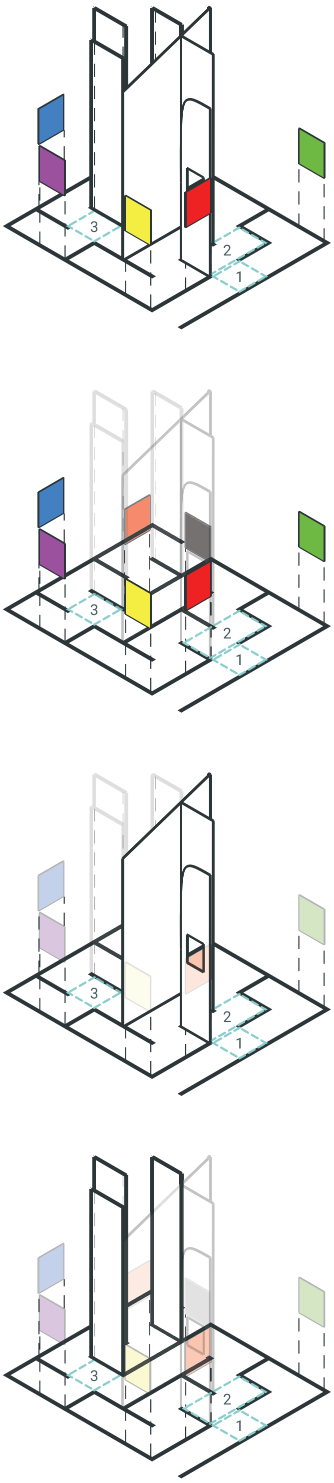


Fig 4.03 Maze testing environment to be used for research.

Testing Environment - Maze



1 . Colour
2 . Geometry
3 . Irregularities

1 . Colour
2 . Geometry
3 . Irregularities

1 . Colour
2 . Geometry
3 . Irregularities

Fig 4.04 Decisions implemented in Maze for testing.

3 Month Results

The results gathered from previous tests of the system has shown promise of non-biasness, autonominity and accurate standardisation of data. The current test utilises a maze structure that facilitates three decisions. Each decision uses different architectural elements to direct or misguide based on the designers' perception and digression.

The first decision tests influence of colour
The second decision tests the influence of geometry
The third decision tests the influence of irregularities

All elements have been placed in an attempt to misguide participants. Preliminary results basic concepts around colour and certain geometry types. In the three tests, Green misled all participants in the first decision. The window like penetration in the second decision also heavily influenced participant's movement, much more so than the high elements which were not observed. However, irregularities did not influence participants.

The concept of flow was integrated via the challenge verse skills test used by Dorta. However, it was adapted to the relationship between the movement verse head eccentricity. Different relationships were catagorised into sections -

High Challenge . High Skill	*FLOW*
Low Challenge . Low Skill	*FLOW*
Low Challenge . High Skill	*BOREDOM*
High Challenge . Low Skill	*STRESS*

Individual data were analysed and one second moments before decisions were made were determined. The individual flow states of each participant within the one second moments where collected and the results also reflect the primitive conclusions as the flow state exhibited were:

3 Month Results

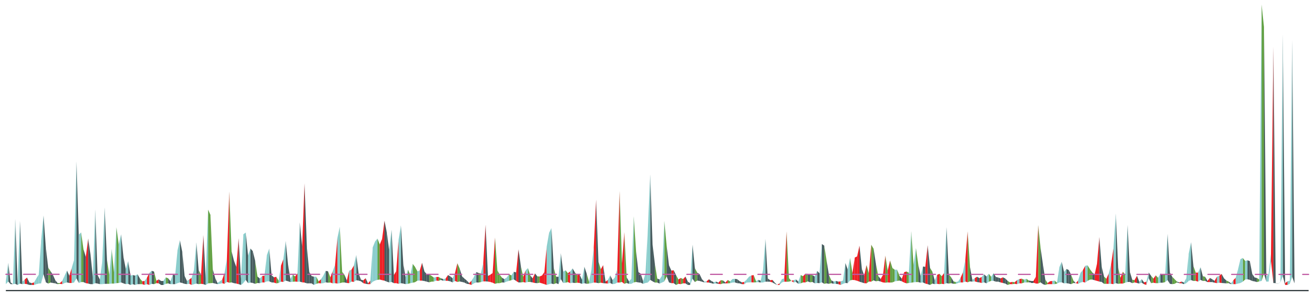
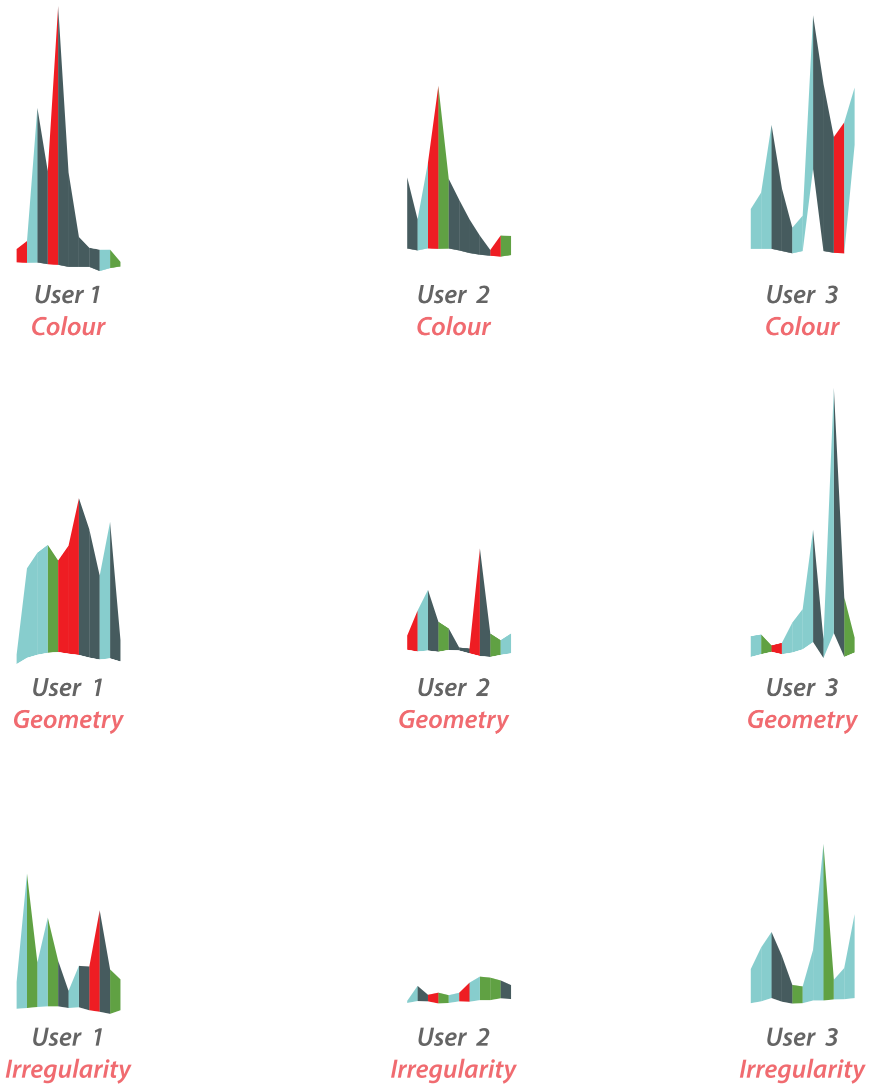


Fig 4.05 Complete Flow Graph



Colour

73.3% Flow
10.0% Boredom
16.7% Stress

Geometry

66.6% Flow
16.7% Boredom
16.7% Stress

Irregularity

63.3% Flow
26.7% Boredom
10.0% Stress

Fig 4.06 Flow Graph fragments representing flow states at each decision from three data sources.

3 Month Discussion

Current results from primitive testing show that the HTC Vive system in conjunction with the methodology established produces reliable and comparative data due to the immersive and isolative nature of VR.
This allows for an accurate representation of the architecture and architectural elements influences interactions and more so the experience of the VR system itself. The design elements within the virtual world were following a design intent of 'positive' elements to misguide and 'negative' elements to lead to the correct path of the maze.

Experiences with the colour Green and it's social associations of 'enter, begin or go' was most effective with attracting movement as opposed to Red. It was designed theories such as this from the designer with the design intent to mislead that were successfully tested alongside the effectiveness of each element.
The eye tracking data and the pupillary tasked responses also show correlation to the Unity data after processing and provide a deeper insight into the cognitive stresses and loads placed onto the participant. This allows the further analysis and validation between the flow state methodology and confirmation of hesitation or confidence that elements create when experienced during a task such as navigation or pathfinding.
The eye tracking data is a large part in bypassing articulation or participants recalling experiences. By monitoring and recording pupil diameter and pupil hippus, the body's instant and instinctual reactions are recorded to detail the current cognitive stress state one experiences. Any design agendas or preferences of the participant are secondary thus removing a large amount of bias present within a survey style data collection.

When put through both the Grasshopper scripts for data visualisation and representation, there is a strong correlation between the standardised data representation and the primitive results. The standardised data are strong for identifying and locating potential problematic or successful areas of design however, the individual representation is strongest for identifying the cause and reactions created.

The current data set is limited in the sense that it tests three participants within the same design. Results and conclusions drawn are only related to the current decisions made. As a result, these tests are control and different iterations focused on different areas or elements are needed before the effectiveness of certain decisions can be determined. However, as a control, it is successful in validating or invalidating three different architectural design theories from the designer.

As a part extension from Dorta's work with cognitive, immersive design; elements within Dorta's research has been adapted and redeveloped. Whereas Dorta's research was a retrospection using self-evaluation and a slider type survey from participants, this research aims for a tool that is able to be used during practice during the conceptual or development phase. The design of research also aims to be non-bias which is near-impossible to achieve by asking participants to retroactively express and articulate experiences from memories, especially within practices as participants may be other practitioners with strong opinions on design choices.

5 DEVELOPED DESIGN

Design of Tool Phase Two :
DEVELOPED DESIGN

The frame and foundation of the preliminary tool allowed for basic behavioural studies of stakeholders within a space. The results of which was successful in terms of highlighting spaces where users either moved slowly or quickly and detailed where one was standing and the direction of sight.

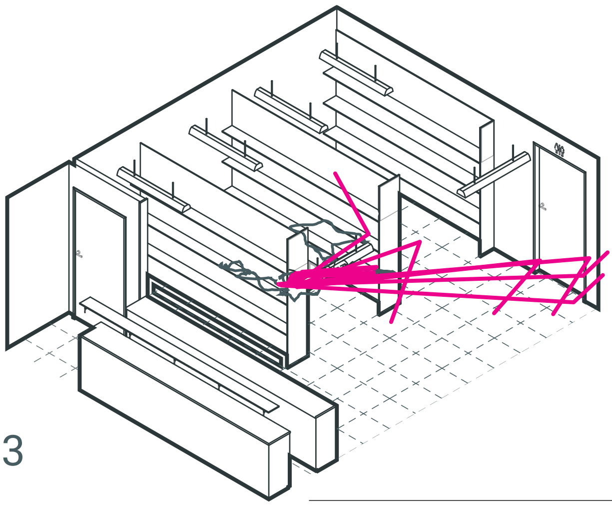
However, the process of translating and processing the pupil data into a format where it and the Unity data could be read simultaneously in Grasshopper was a large, inefficient and convoluted workflow. This along with making the psychological science and research associated with the pupil data more accessible and understandable for those not formally trained in psychology was a priority.

6 Month Aims and Objectives

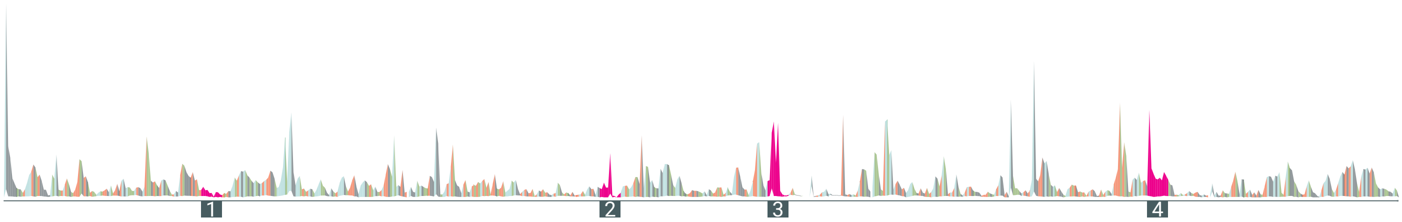
The state of the Tool at this stage outputted Visualisations and Representations of the Unity data. However, the method to record pupil data involved two of the open source software from Pupil Labs. Pupil Capture would be opened alongside Unity and would need to be toggled before or after Unity started. This created a shift in the recording start between Unity and Pupil Capture creating unreliable cross-referencing between data sets. Furthermore, the Pupil Captures outputs needed to be imported into Pupil Player to translate into a .csv format that could then be used alongside the Unity data.
One of the main goals for this thesis was to make the tool and workflow as autonomous and user-friendly as possible within the time frame, therefore, these developments were the natural steps in development life.

The objectives were as follows:

1. Merging the Pupil Labs eye tracking data stream with the data outputs from Unity, streamlining the workflow.
2. Further testing of the Unity data sets along with the pupil data sets to ensure accurate cross-referencing between data sets.
3. Integrating psychological studies surrounding pupil data into Grasshopper, attempting to automate the psychological analysis.
4. Determine and begin design scenario fit for context utilisation.



Data Visualisation



Data Representation

Fig 5.00 Outputs from Phase One : Preliminary Design

6 Month Developments

Pupil Labs had further released an open source APK for Unity, specifically supporting their hardware within the Unity RTVE. The provided APK package included the framework for which the Unity scene can be linked to the Pupil Capture software. Therefore, the introduction of Pupil Labs into the Unity scene meant the recording of both data sets will begin at the same time with the same toggle.

The type of pupil data selected to represent and provide the cognitive and psychological state of the user was from the 2D pupil data set. The pupillary Hippus "describes the oscillating pupillary unrest " (Buettner, 2014). Buettner then states that "it is known that this Hippus is strongly linked to a user's mental workload." This is captured and using base values from Buettner's research, patterns and values are coded into Grasshopper for it to begin recognising one factor of cognitive loads. To verify the validity of the Hippus, the pupil diameter is a secondary method used in this research. To ensure the hardware and software are working accurately, the pupil diameters are appended alongside the Hippus and when both meet the criteria; the time is stamped and recognised as a point of interest.
This method will miss areas of 'cognitive stress', however, it will verify the data integrity of the areas that are identified.

From the Informative Literature of Buettner, Beatty and Zenon, sets of bounds were determined for the analysation of the pupil data. "Analysing the frequency domain of the pupillary signal I hypothesized lower power values of the Hippus relevant bandwidth of 0-0.5Hz at the workload state (memorizing/ reproducing task) compared to the relaxation state (relaxing music and imagery task)" (Buettner, 2014). While the diameter response used values from Buettner's 2013 paper, Cognitive Workload Induced by Information Systems: Introducing an Objective Way of Measuring based on Pupillary Diameter Responses. Using values from Buettner's study and paper, a standardised method of measurements to adjust for natural pupil variations was created. Both of these objective measurement sets for both the Hippus and Diameter are implemented into Grasshopper where the pupil data sets are measured against.

Psychological states induced from metrics were then integrated alongside the Flow analysis graphs using the slider system. In addition, two final psychological based outputs were developed. One highlighting all the timestamps of psychological interest, these points of interests were annotated when the hippus and diameter values were in the range that was classified as 'stressed' or indicated heavier cognitive workloads. The second was a moment metric detailing system, where the time frame selected via the time-based slider inputs highlighted more specific and detailed pupil metrics.

Further tests would then use the same maze to run participants through. Results from this phase would be directly compared to those from the first phase with an emphasis towards the performance of the pupil data and autonomous analytical stage. While the accuracy and reliability of the tool were to be validated, a design brief in which the tool would be utilised was planned and started.

6 Month Developments

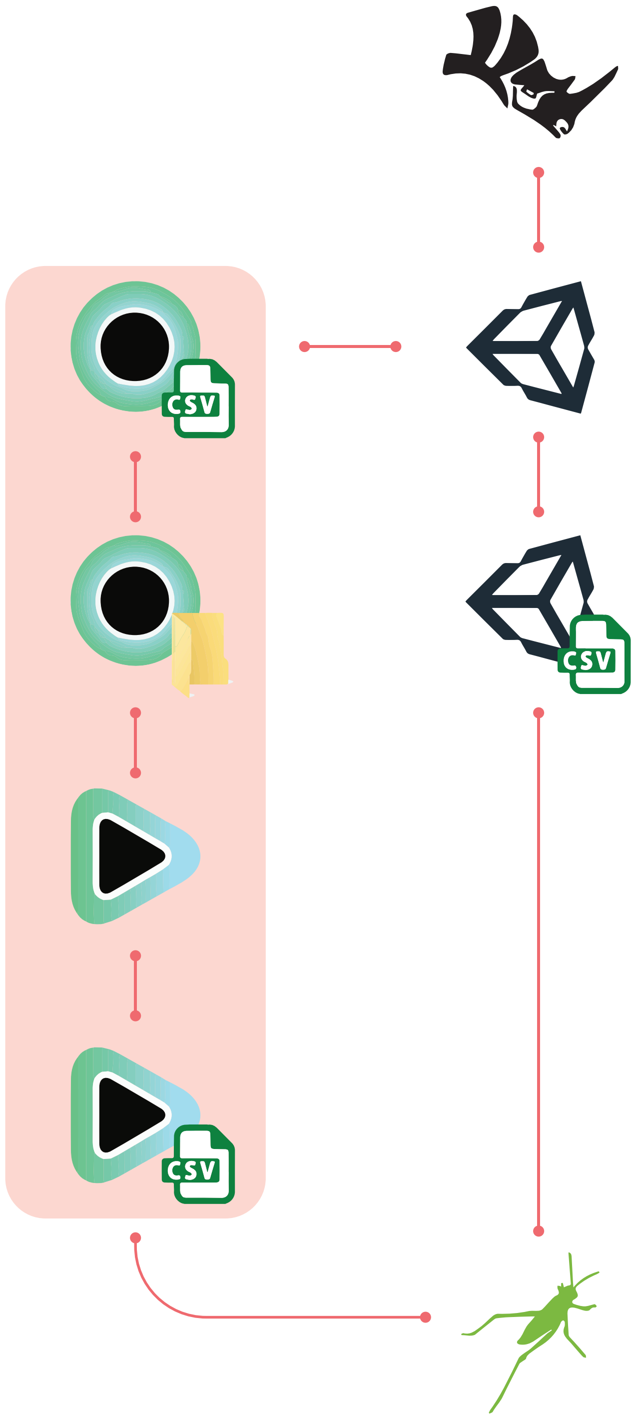


Fig 5.01 Initial data pipeline process with Pupil Labs eye tracking hardware.

6 Month Developments

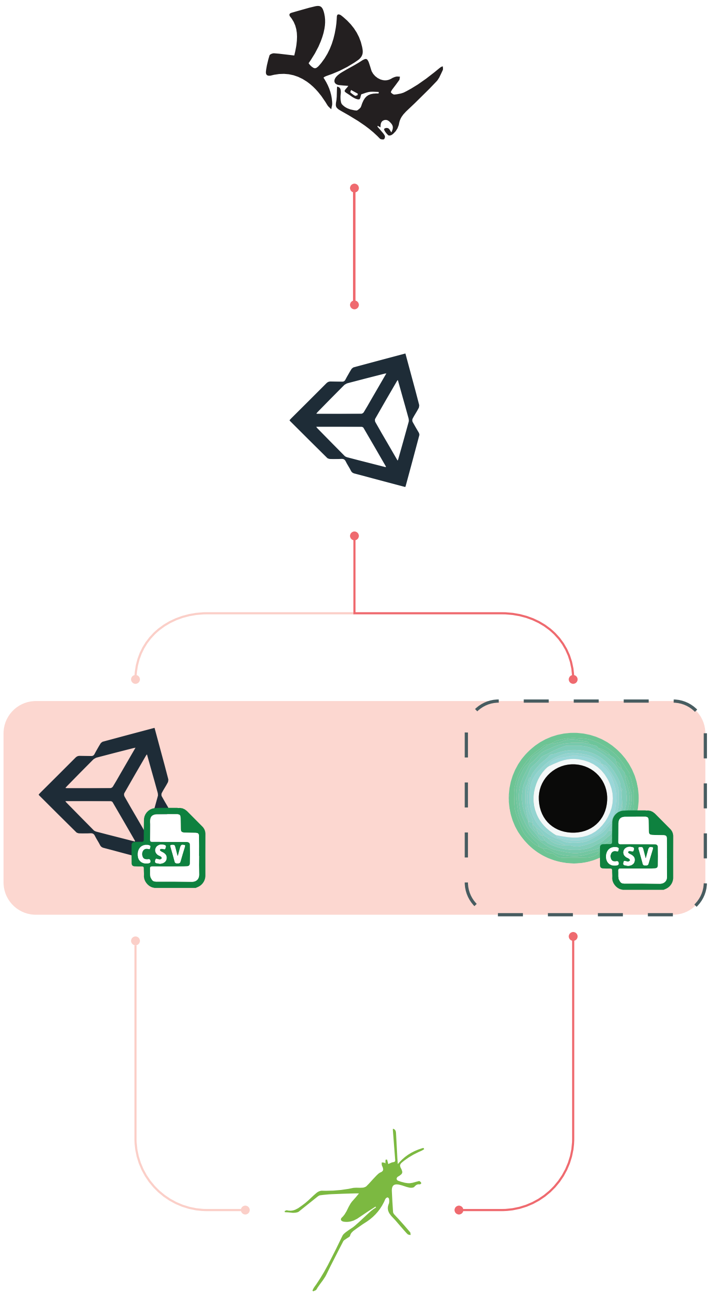
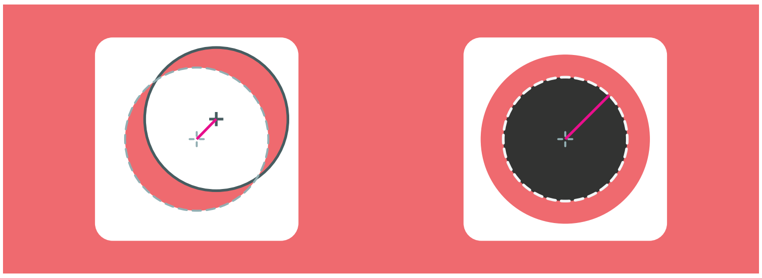


Fig 5.02 Developed data pipeline process with Pupil Labs eye tracking hardware.

6 Month Evaluation

The current state of the tool had accomplished most of the objectives identified within the scope of this thesis. It is able to interpret data into visually heavy representations and visualisations with a Grasshopper script that is computationally low resource intensive, allowing for the swapping of data sets and computing quickly, adding to the efficiency of the system. Also, the processing and analytics of the pupil data and psychological sciences were automated successfully to simplify and increase the accessibility and user-friendliness towards those in the architectural profession.



Pupil Diameter *Pupil Hippus*

From current testing, there is a correlation between the movement heatmap, flow and cognitive stress data. The current hypothesis as the designer as follows:

[H1] Colour would be straight forward, again green would be favoured but mislead participants to a dead end, however, the placement of the colour panels may have been the success.

[H2] The geometry in the second junction will be the most observed, especially the penetration within the wall. The offering of a window of extra information, providing more knowledge to this path would again be favoured and again mislead participants to a dead end.

[H3] The irregularities would be not noticed as they are minimal and would not mislead but slow participant's down as the route would be tighter than normal.

Added to the hypothesis were where moments of cognitive stress would be expected to occur. These were to be at junctions and more so at dead ends as the reorientation and backtracking within such a tight space would cause some confusion.

The secondary goal was to test the flow state vs the cognitive state. Expected results would show the cognitive states supporting and offering a deeper insight into the states of flow and their causes. However, the sandbox and free exploration nature of the test will create moments of speculations from the designer as to what exactly causes individual cognitive states. The tool and visual temporal dimensions of the tool assists in making correct speculations, attention to the events that precedes and succeeds the moment of interest is needed to create a correct narrative for the architectural elements involved.

After more development testing, each hypothesis was evaluated against the results.

6 Month ***Evaluation***

[H1] was proven successful as all participants had observed both panels of colour but decided on Green but ultimately moving towards Green. Further analysis would also show that the matter of having to turn (Red) or continue in a forward path (Green) would be the next major factor as the colour themselves did not influence the cognitive state but reaching the junction and observing the possible paths did. Secondly, when reaching the dead end that Green inevitably led to and having to turn and orientate, cognitive states spiked into the 'high intense workload' state briefly.

[H2] was perhaps the most successful, the window-like penetration that were offered was observed by all and the heatmaps demonstrated that it was indeed the area where most slowed and used the most time to observe. The initial noticing of the penetration prompted higher cognitive workloads, however, during the time that participants were studying the information provided by the penetration, cognitive states reduced back to a semi-relaxed state until a decision was made.

[H3] was the least successful. Due to the repetitive nature of this path, there were little to no cognitive activity. However, the act of 'weaving' caused a state of flow early which dropped into boredom quickly after the pattern was recognised as expected.

6 Month Evaluation

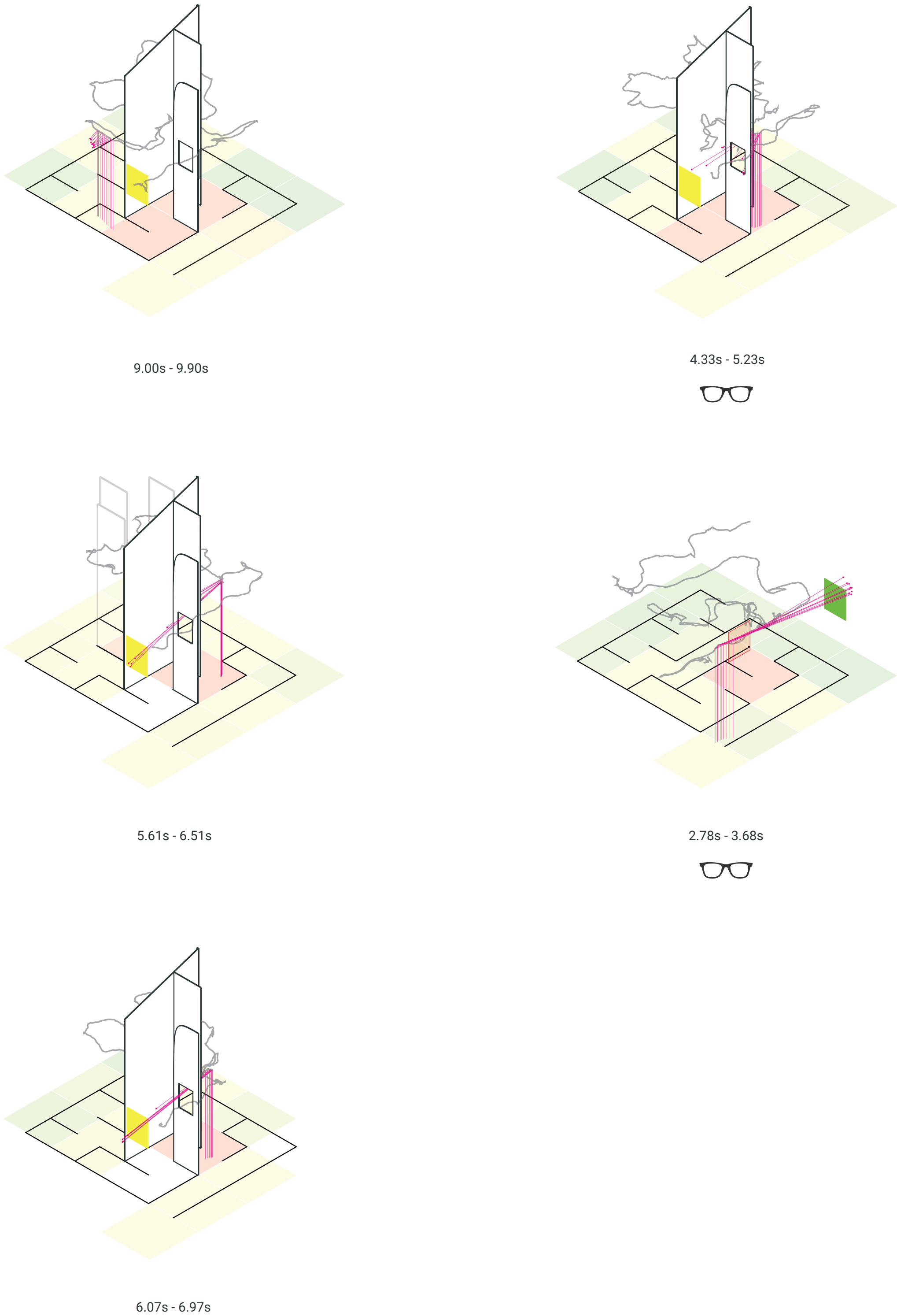


Fig 5.03 Snapshots from Five different data sources analysing a moment highlighted via the Cognitive Stress Recognition development

6 Month Discussion

The evaluation of the tool reached another step in its development cycle. Cognitive readouts and the results via Grasshopper's interpretation and calculations had produced results as the research designer had expected. However, the matrix to which the hypothesis was still speculations and therefore speculative but it does provide an understanding with the accuracy and consistency provided from the tool and legitimate relationships between the cognitive states and states of flow.

The advantage of this methodology as discussed prior was the digital sandbox environment that the VR experience allows. The freedom that users are granted allows for emulation of normal and expected behaviour within the space once the gimmick of VR wears off. This provides an easy understanding and identification into the elements or spaces that matter to clients the most and therefore creating a priority of design. However advantageous the freedom sandbox element is for the design, it hinders the process of data analysis as the data sets become completely independent from one another. Everything from the length spends to the path taken is independent within itself and standardisation over large sets of data is not possible without large alterations to ensure moments such as a person's decision at a junction within the maze matches with others. However, if the experience itself is guided to ensure moments of interest match up for the purposes of standardisation, it will contradict the core of the thesis itself which was to flip the freedom of VR and the digital space into a positive and potentially advantageous aspect for design.

6 Month Discussion

Thus the evaluation of the tool reached another step in its development cycle. Cognitive readouts and the results via Grasshopper's interpretation and calculations had produced results as the research designer had expected. However, the matrix to which the hypothesis was still speculations and therefore speculative but it does provide an understanding the accuracy and consistency provided from the tool and legitimate relationships between the cognitive states and states of flow.

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6 Month Discussion

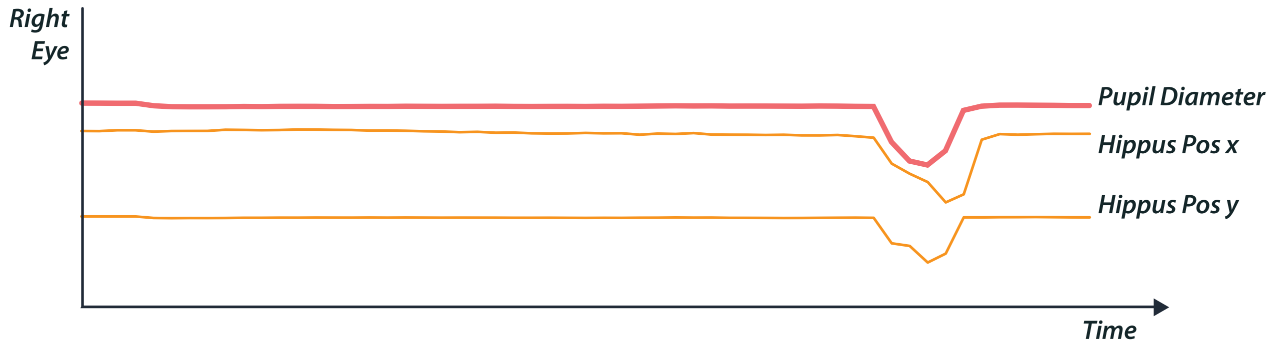
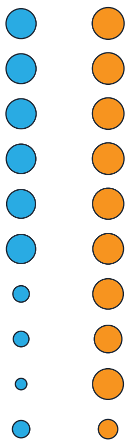


Fig 5.04 Pupil Data Graph fragment displaying Pupil Diameter and Hippus Trends



Two methods of visualising pupil patterns are implemented. Either by abstracted graph or a more visual representation of the pupil diameter and pupil hippus. These pupil models cycle with the slider.

Fig 5.05 Pupil Data graphs and visualisation outputs.

6 Month Discussion

Therefore, a design brief for the future that would place the current developed phase of the tool into a practical situation where it would be tested in terms of seamless integration into a design project and directly influence the outcome was proposed. This would then simulate a real-world situation where this tool would be expected to perform; testing time intensity of data collection and analysis, how relevant and effective the current features are to the design process and how understandable the cognitive and flow outputs when directly related and fed back into the architectural design process. The outcome of the design would not be the forefront but the evaluative notion from practice would focus efforts onto the weaknesses and strengths of the methodology developed.

Proposed Design Environment - Modular Hyperloop Station

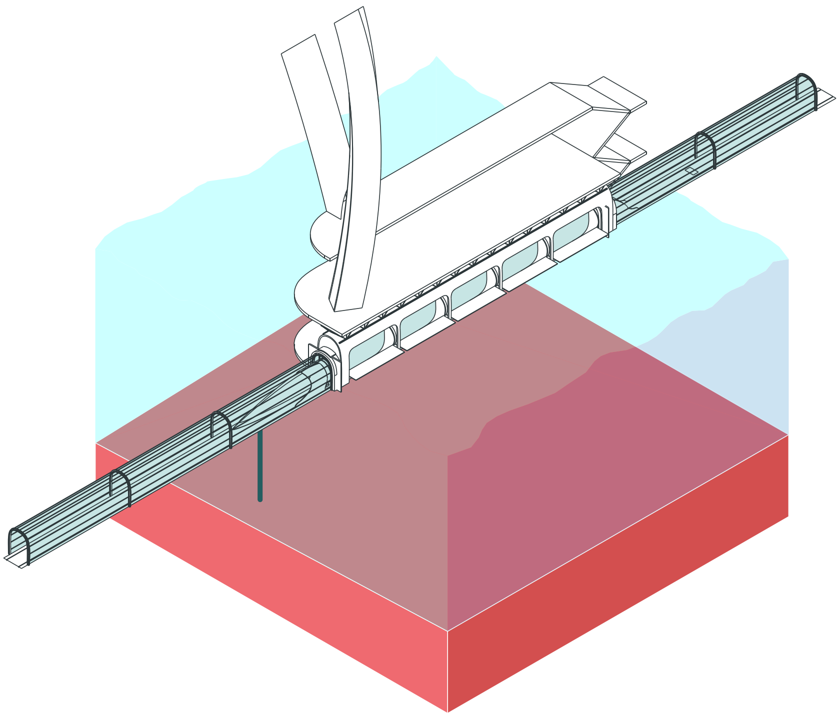


Fig 5.06 A modular hyperloop station design that was ultimately rejected as the next best step.

6 FINAL DESIGN

Design of Tool Phase Three :
FINAL DESIGN

Within the progress reviews and discussions into the final step, the decided final design brief proposed was a large transport hub, specifically a Hyperloop station. The design would consist of small platforms connected via escalators to accommodate the spatial considerations and the complexity of navigating from one platform to another would provide an intensive platform for the tool to evaluate and interrogate. The discussions into this step concluded that the jump in scale and complexity would strain the tool pass what is currently validated and tested therefore rendering the exercise obsolete with unreliable results.

9 Month Aims and Objectives

The discussed steps from the last review concluded as ineffective and too far fetched for this stage of the project. Agreeing with this sentiment, a new and more realised step were to be considered. Considering control data for the maze had been recorded and it had accounted for and fulfilled the digital environmental considerations so far, the maze was then elevated to become the design brief.

The purpose and experience were to be redesigned and introduce smaller incentives and objectives within the maze, however, the nature of the maze was perfectly suited to targeted iterations and architectural developments.

The objectives were as follows:

1. Respecify the design brief and final design intent with respect to the current conceptual maze work.
2. Use the tool and integrate the process of data capturing, analysing and interpretation into the design process.
3. Report the tools weaknesses and strengths and continual development to remedy issues with the tool and its application.
4. Iterate upon the maze with findings from the tool and rerun participants through to critique design decisions against the original design intent.

9 Month Developments

The original design intent was carried through to the iterated design. To mislead users away from the exit. This intention could have been flipped but due to the small spatial limitation and simplicity of the maze, this was decided on as a measurement of success. Furthermore, to evaluate the effectiveness and correctness of the designers interpretation of the preliminary results, only the architectural elements were altered while the course of the maze stayed consistent.

From the preliminary tests, a main behavioural observation was that participants tend to look at eye height. Behavioral characteristics that all participants displayed includes minimal vertical head movement. 35% of the time, line of sight was within 0.5m of the head height and 42.8% was within 0.5m to 1.0m. Meanwhile, only 1.2% of the time, were spent looking at the floor.
The exception to this was the penetration in the wall that most had ducked slightly to view.
However, even with bare walls the general trend where not to use the lines of the top or bottoms of the walls to guide but the differences perceived by looking forward.

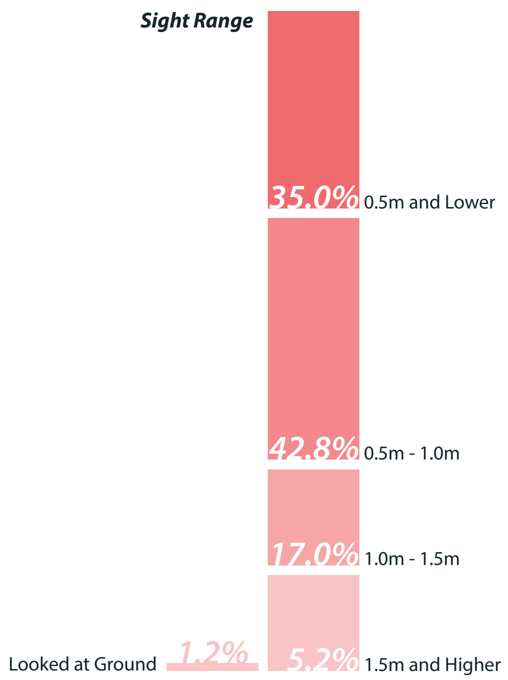


Fig 6.00 Visualisation of vertical gaze.

Iterated Testing Environment - Maze

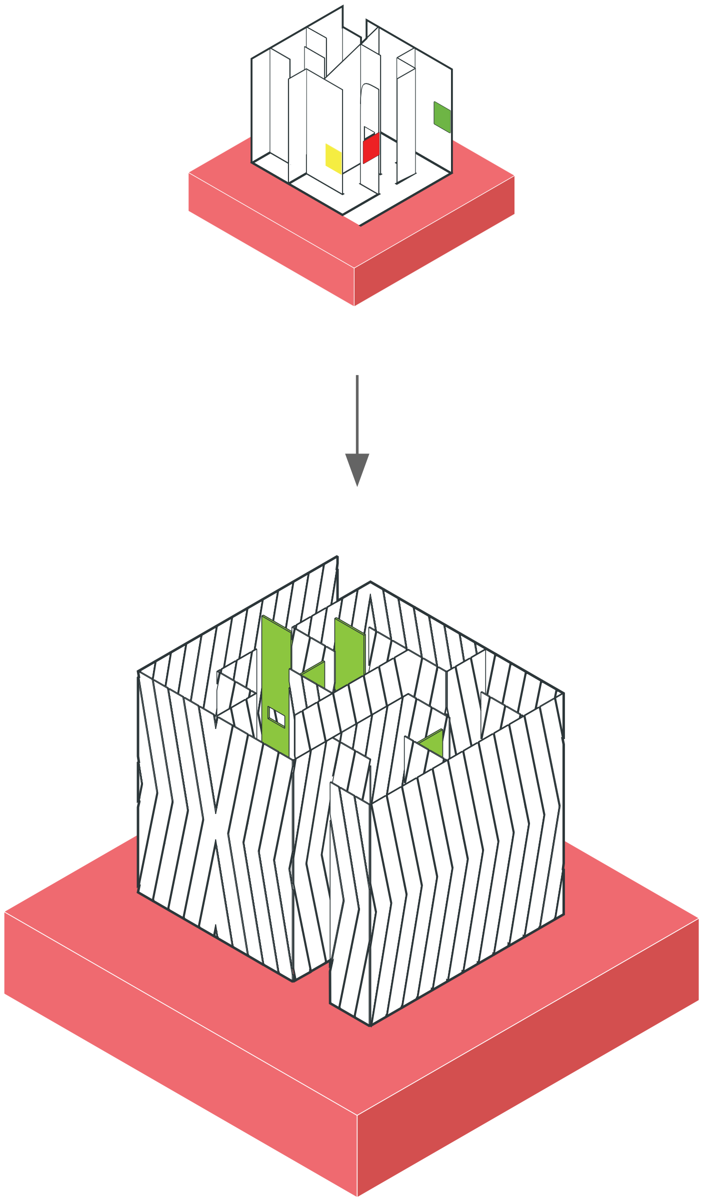


Fig 6.01 The initial Maze and iterated Maze.

9 Month Developments

The first change walls have been changed to a spaced chevron panel design. The nature of a cheron is similar to that of an arrow, therefore looking forward would yield a greater response from the architecture.

Secondly, the penetration of the first design was arguably the most successful element with the attention and time it garnered as alluded to in the heatmaps. However, the notion of the penetration and what it offers were to be validated. Gaps between every chevron panel were implemented, saturating the idea of the glimpse into the future, validating whether the information a penetration or the novelty of the penetration in the original maze was the attracting factor.

Thirdly, objectives in form of collecting keys and matching them with the corresponding locks on the walls to open doors were introduced. The introduction of the door and lock system provokes deeper thought and consideration of the space. Navigating to and locating the unique keys scattered in the maze now utilises more of the limited space. Furthermore, the removal of the coloured panels were now replaced with plaques on the walls that acted as a lock that would remove the corresponding door when the correct key entered its collision field. The lock and it's unique shape now also acts as subtle internal landmarks. The addition of these objectives also allows for the testing of architectural importance with most participant's shown to be concerned with finding and matching all the keys, unconcerned with the maze's exit.
Lastly, the maze had been flipped so the original ending was now the starting. This was to retain a sense a sense of familiarity while causing initial confusion. Disorientating any returning participants while having the add bonus of testing how one navigates when the path is reversed.

*9 Month **Developments***

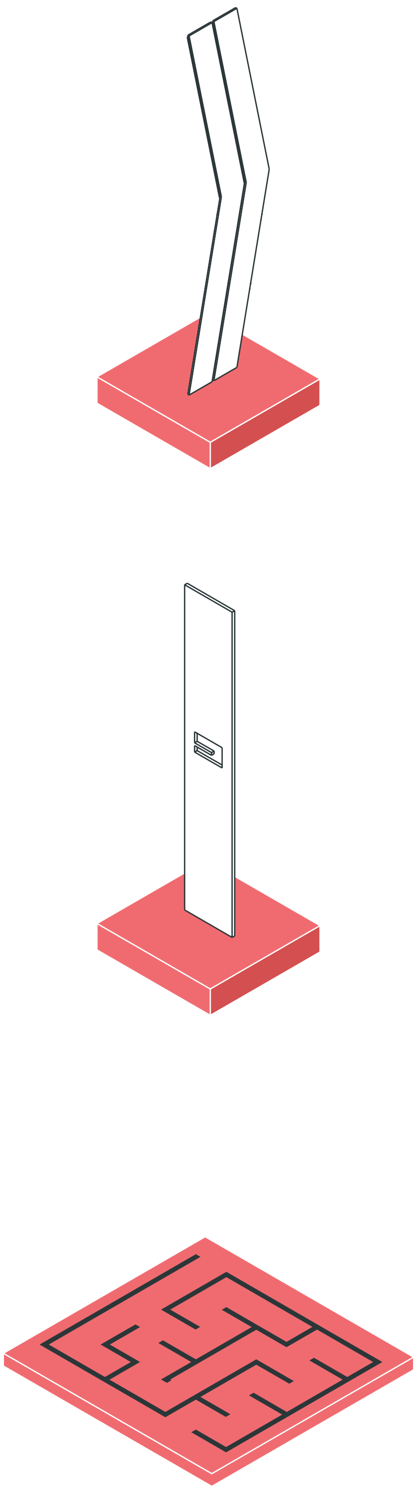


Fig 6.02 Individual changes and implementations to the iterated Maze.

9 Month Developments

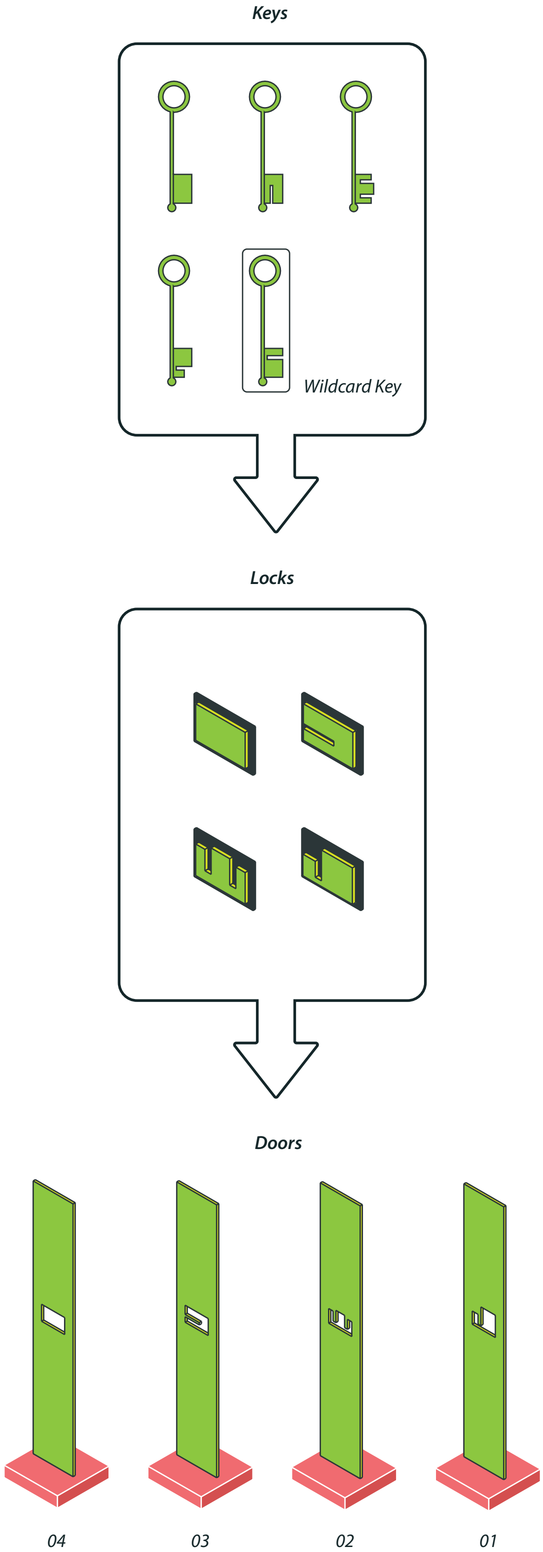


Fig 6.03 Key and Lock assets and systems.

Furthermore, a secondary Grasshopper script that accepts multiple Unity and pupil data sets respectively applies a Standard Deviation set to the sets of data in an attempt to generalise the experiences and lessen the time needed to analyse and interrogate multiple data sets individually for general trends. The mismatch of time and experiences of the data sets has been accepted and accounted with minor alterations to fit a chosen control from the sets.

Participants were then asked to navigate through with the pretense of making it to an exit. The discovery of the keys, lock and doors were left to their own discovery and discretion. The concept of misleading were also integrated into the objectives as there are 4 doors and locks in total. 2 of the doors were actually required to be opened to reach the end. However, 5 keys were scattered around the maze.

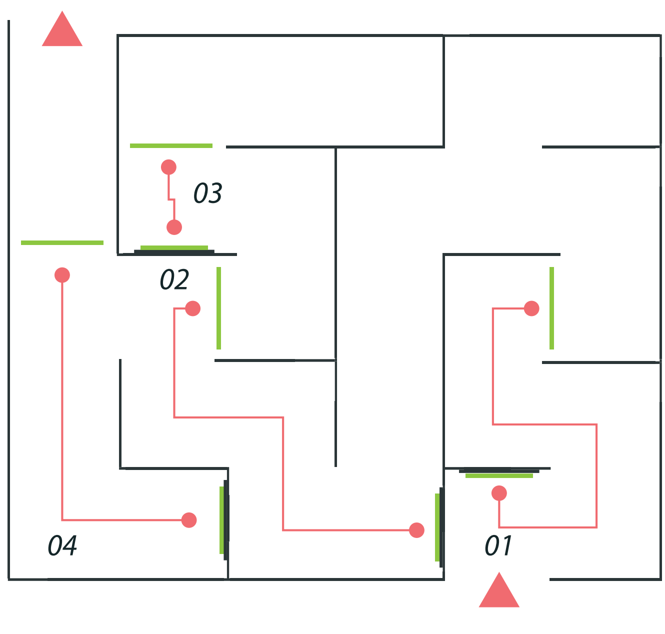


Fig 6.04 Placement of door and corrosponding locks in revised route through Maze.

*9 Month **Evaluation***

Firstly, testing and running the preliminary data sets through the Standard Deviation model proved to largely ineffective. Without major alterations to the data set in forcing major events to line up timeline-wise, the causes of irregular deviations as the rate, directional, focus and perception of each participant and their subsequent data is unique major events will very rarely coincide with other experiences, creating false trends with colliding contexts. However, major alterations then created unreliable trends and the aforementioned importance of considering the events preceding and succeeding were disregarded and skewed. However, this is the a limitation of allow free roaming within a space therefore, another standardisation model will need to be considered in future developments as multiple individual data sets will be very difficult and time consuming to analyse individually.

9 Month Evaluation

Furthermore, the relationship of the abstracted model and the overview of positioning and sightlines, although provided an excellent understanding of the relationship between element and person. This did little to relate the element and architecture to an experience. Therefore an extra view module was added that attached a first person camera and provided the users experiential view.

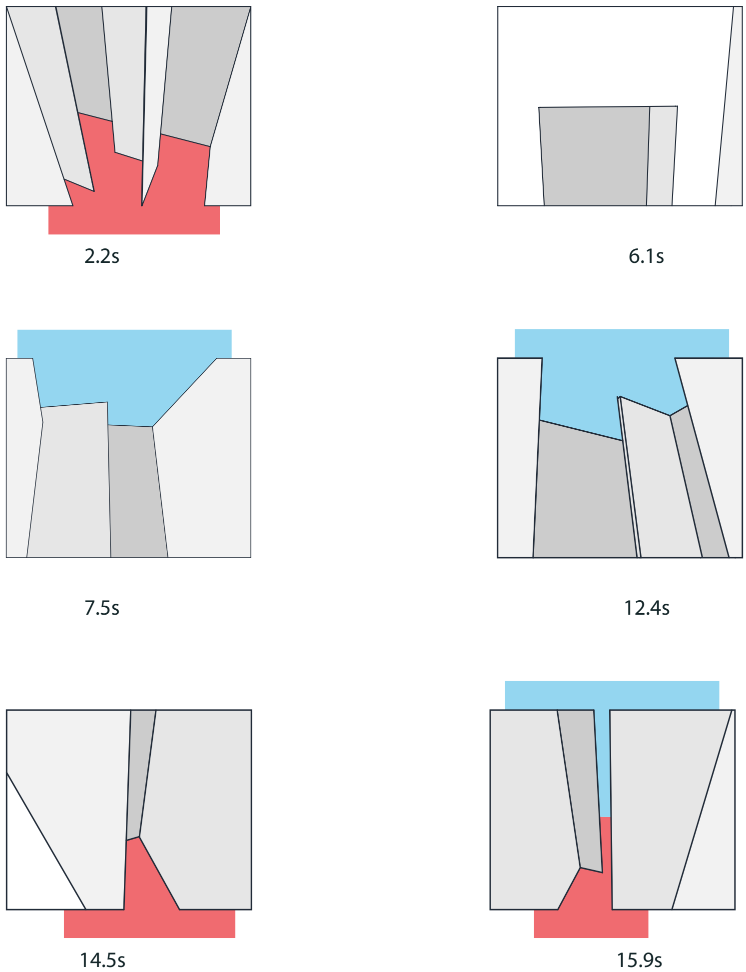
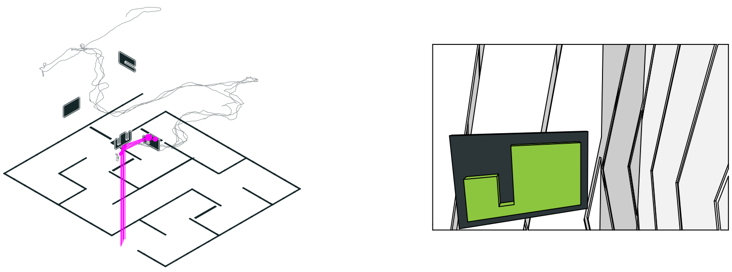


Fig 6.05 First person snippets (Preliminary Tests) taken from Rhino and post-processed in Adobe Illustrator.

9 Month Evaluation

Results from the same participants being run through this newest iteration of the maze showed considerable increase in 'Flow' and overall enjoyment. This was mainly due to the fact that a challenge that the architecture facilitates was introduced. The chevron design was successful in the way that it visually disorientated participants with the consistent and intensive visual complexity. However, this disorientation was only present initially and under certain circumstances within the journey. When adjusted to the visual overload that this panel design created, there were a greater focus on elements such as the locks, keys, doors and tops and bottom of the wall.



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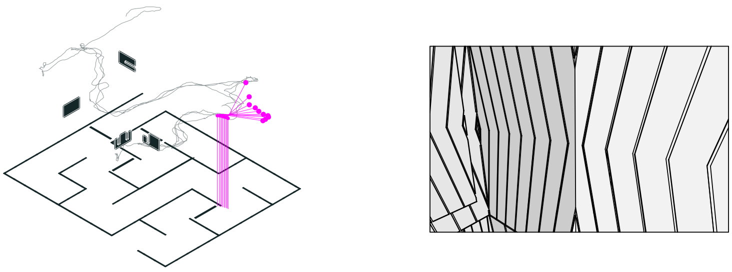

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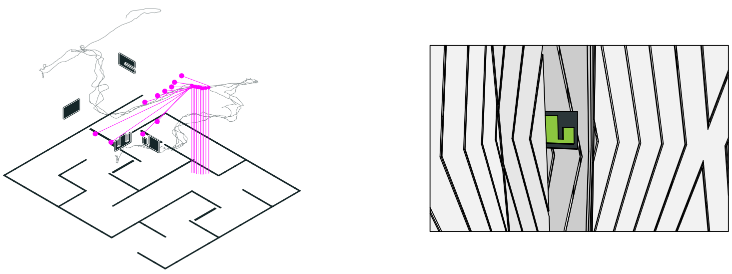

03

Fig 6.06 Final outputs from a data source captured in the iterated Maze.

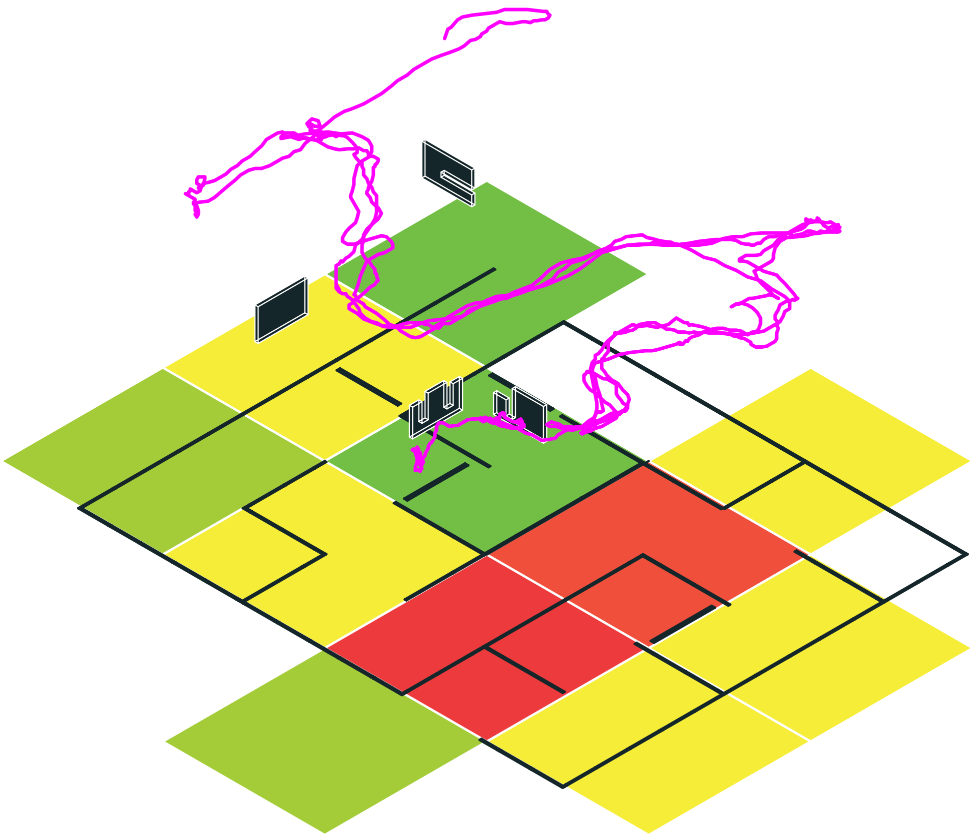

Fig 6.07 Final path and movement heatmap from a data source captured in the iterated Maze.

*9 Month **Evaluation***

When the key and lock system was understood, the architectural elements such as the chevron panelisation design was overshadowed by the task of matching the key pattern design to the lock plaques and subsequently finding the corresponding door that it opened. The objective of the doors then overshadowed the navigational aspect of the architecture as 78% of all participants ignoring the exit to the maze in favour of matching the remaining keys to the locks which were unnecessary to open. This would suggest that the purpose within the architecture became more important and enjoyable than the initial goal of pathfinding thus in many immediate cases such as the of the chevron panel, gaps penetrating between panels and the layout or familiarity of the maze became fairly obsolete and obscure.

However, when comparing the cognitive responses from both the mazes, the iterated maze induced a generally higher cognitive load from participants throughout the experience. Partially due to the larger visual stimulation. However, when this was adjusted to, the act of concentrating on finding and matching keys as sub-objectives within the architecture generally required more thought.

9 Month Evaluation

Time Taken; 18.7992			
Flow States;	Flow(Pos)	25.57947%	
	Flow(Neg)	37.003311%	
	Stress	23.013245%	
	Boredom	14.403974%	
Pupil Diameter; (Left / Right)	30.7%<d< MAX	2.150538%	2.150538%
	23.1% <d< 30.7	0.082713%	0.082713%
	0<d<23.1%	44.003309%	47.394541%
	MIN<d<0	53.763441%	51.861042%
Hippus MAX MIN (Left/ Right)		0.481604 To 0.978131 0.449297 To 0.907993	
Stress Timestamps Pupil; 23.1%<d<MAX Flow State; Stress & Boredom		0.8 0.9 1.2 1.3 1.4 1.5 2.1 4.4 8.4 12.8 24.9 24.9 25.0 26.8 27.0 27.7 28.1 28.4 30.6 58.1 63.1 65.1 65.3 65.5 68.6 69.4 69.5 70.0 70.1 70.3 70.4 72.1 72.4	

Fig 6.08 General trends and cognitively recognised timestamps from data source.

9 Month Discussion

The thought of a higher cognitive load within an architecture may seem negative and indeed it would be within the right context. However, considering the general purpose of the maze which is navigating and requires recollection of memory when backtracking is needed or deduction when deciding on a path, it is a structure that entertains and amuses through higher cognitive loads. Therefore, the higher cognitive loads experienced within the maze within reason is positive to the experiences as opposed to a more relaxed architectural environment such as a spa or meditation space. The criteria for the cognitive science within architecture then needs to be defined with respect to both the design intent and purpose that the architecture becomes a vehicle for.

The use of cognitive and behavior data proved effective within the first iteration as the dominant areas such as the bare, white walls and attributing the type of influence from certain architectural elements were easily identified and altered to fit a design goal in the context of path finding. However, with the introduction of the internal objectives and tasks, the architectural elements were no longer the sole focus and was completely foreshadowed by the tasks at hand, only once again having an effect when participants had completely an objective and was moving to start another which was supported by the first person views provided.
The pupil data supported this as there was a notable shift in the cognitive states of when a key was matched, opening a door and when the participant was traversing the architecture; searching for the next key. In hindsight, these sub-objectives should have been implemented first and foremost and the architectural elements would then be developed to provide a more profound effect as supporting elements for the users purpose within the architecture.

As for the effectiveness and usability with the tool within the design context; it provided detailed recounts of live recordings that then allowed for deeper analysis of the experiences and targeting of elements which has led to design choices that has in one way or another improved the general experiences of the maze when noticed.

However, drawbacks and faults noted when use in a design context were:

Lack of guidance, this is an inoffensive fault as the nature of the tool and research was based around the sandbox environment. However, extra time was used to interpret and relate the data and events to the architecture.

Individual analysis, the larger issue with the failure of the standard deviation model was the restriction of analysing one data set at a time. Comparing two data sets was time consuming and challenging in attempts to identify general trends.

Final validity of data outputs, the lack of testing and small testing samples without an objective rubric to critique against requires some speculation to fit the design context. However, this is a fault created by the time restraint and requires time to mitigate.

7 CONCLUSION & REFLECTIONS

Final Thesis Conclusion and Reflections

To reiterate, this thesis seeked to explore other potential, more influential applications of virtual reality technologies. The research addresses how VAMR can be incorporated into the design process and establishes a number of confirmations in the use of VMAR for Architecture and Design.
The work undertaken in this study informs how powerful a tool it could be and defines how it could be incorporated more frequently into the workflow of the conceptual and development stages of architectural design. Presently, the sandbox itself requires a level of automation that is applied throughout each test of any design and can interpret the data and help visualize it quickly.
Taking advantage of the spatial isolation and disconnection from architects that Virtual Reality headsets provide and embracing this as a first step in true, instinctual and sub-conscious client feedback that unintrusive, autonomous tools such as this can further delineate.

The use of pupillary response technology provides an insight into the cognitive and stress loads triggered and studying these alongside the movement and head behaviors allows for a detailed image of the potential issues and identifying the contributing elements to these issues. However, underlying issues still remained as discussed, largely in due to the time restraints and limited ability devoted to quite a broad and well spread research involving computational design and automation, software development, game design and general coding and psychological studies centred and grounded within the architectural sciences and CAD.

However, with further reflections upon this body of research, it is clear to see the merits and failures of its outcome. The developed tool itself has been able to aid in efficiently identifying elements and directing design shifts and solutions which has created desired effects when one is inhabiting the virtual environment. However, the lack of ability to standardise large data sets and when a task is introduced such as the one within the iterated maze, clear

Final Thesis Conclusion and Reflections

distinctions between tasked invoked psychological states and architectural invoked psychological states can be seen but not recognised via automation.

So to readdress the initial question:

How can we as Architects and designers better understand what our clients perceive in our design solutions?

The solution goes deeper than understanding what our client see and look at. Rather, it is understanding that the architectural motions and intents that we as architects and designers strive to make the centrepiece and forefront of our designs is second to the purpose. It is the purpose of the architecture, space and mainly the actor that we can better understand how a tool like this can be fully utilised.

This research has provided another step into the "what do we look at?" question with further data sets and evaluations into cognitive and mental stress states. This then begs the question: "what do people do with architecture?", only then, can this tool be further developed and evolve into one that not only guides experiences, but purpose with architecture.

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