A study of Virtual Reality and Short-range Wireless technologies on intrinsic motivation in exercise.

UNIVERSITY OF
LINCOLN

Matthew Atkins
ATK16657290

16657290@lincoln.ac.uk

School of Computer Science

College of Science

University of Lincoln

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Supervisor: Dr. Wayne Christian

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Abstract

This project aims to review the application of Virtual Reality (VR) Head-Mounted-Display (HMD) and Short-range Wireless Technologies through development of a mixed-reality (MR), portable exercise platform using Unity Game Engine, Bluetooth low energy (BLE) and the Arduino electronics platform to gather, process and analyse data to measure participants' enjoyment/fulfilment using Intrinsic Motivation Inventory (IMI), providing further research into intrinsic motivation and Exergame development.

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Chapter 1

Introduction

1.1 Notes

Studies suggest that almost five million people in the UK are forecast to become classified as morbidly obese by the year 2035, this consequently poses major health and financial implications for those living in the country and the National Healthcare System (NHS) (Keaver L, 2020)

Alongside this, the UK is suffering a job and housing crisis (Mulhern, 2019), crime has also seen an increase in urban areas across the UK (Elkin, 2022) making public spaces, services or businesses less accessible.

Therefore, I believe utilizing recent breakthroughs in virtual reality and micro-board technology to create an immersive, mixed-reality Virtual Exercise Environment (VEE) could provide significant physical and cognitive benefits to those suffering from poor physical fitness.

By studying intrinsic motivation and SDT (Self Determination Theory), I believe I can create a mechanism appropriate for fostering and reinforcing positive cognitive and social behaviors in participants, to which they will be able to transfer into other aspects of life.

The study will employ members of the general populace, consisting of varying (appropriate) levels of physical and mental fitness, to participate on both the VR environment, and analogue environment (without VR). Measuring their motivation levels using IMI (Intrinsic Motivation Inventory) before and after the experiment, comparatively between the two exercise mediums.

Chapter 2

Literature Review

2.1 Background

It has long been argued that motivation is the single most crucial mechanism in the cognitive development of humans, and perhaps the foremost-driving force of all progress attained by humanity.

It has been well-established that a wide diversity of motivation system exists in all levels of living organisms (Pierre-Yves Oudeyer, 2007). For example, there exists certain motivators in both humans and animals that "force" us to maintain homeostasis – such as hunger, thirst, exhaustion, or fear, which impel organisms to maintain chemical balances of energy. These are all evolutionary traits, acclimated over millennia to ensure our survival.
This makes motivation, at its core, a fundamentally inconsistent cognitive concept. As apart from the warnings our body gives us to live, where exists the necessity to push further than this? It must be understood that, although the pursuit of ideals such as happiness, comfort and fulfilment are perceived to have positive effects, they exist only to provide chemical balances in the brain. It is questionable to assume they are integral to survival of a species, or if they are necessary at all.

Biologically speaking, the betterment of man is of no concern to our being. The core and conclusive goal of every living organism can be defined as ensuring one's survival by eating, sleeping and exercising.

Some animals, however, are known to exhibit more general motivations that push them to explore, probe, or manipulate their environment (Pierre-Yves Oudeyer, 2007). This form of motivation known as "Intrinsic Motivation".

Coined by (Richard M. Ryan, 2000), intrinsic motivation can be defined as the "doing of an activity for its inherent satisfaction rather than for some separable consequence" (Pierre-Yves Oudeyer, 2007).
Intrinsic Motivation is based upon a framework known as SDT (Self-Determination Theory) and is aroused when a person or animal is pushed to enact on an objective for the fun or challenge of the task rather than because of external motivators, such as fear of punishment, pressures, or rewards.

Intrinsic Motivation Inventory is a multi-dimensional metric used to assess a participants experience related to a target activity (SDF.com, n.d.).

IMI assesses a participant's "interest/enjoyment, perceived competence, effort, value/usefulness, felt pressure and tension and perceived choice.

Using this instrument, we can yield six subscales and weigh their given scores to calculate a variable estimate of a persons projected intrinsic motivation.

IMI has already been used in several experiments within the scope of SDT and self-regulation.

A big constructor of motivation is interlinked with the ideology of hope. Dr. Curt Richter demonstrated that hope is a very powerful factor in perseverance (Pierre-Yves Oudeyer, 2007)

In 1985 Richter published a now-infamous paper titled "On the Phenomenon of Sudden Death in Animals and Man", this paper reviewed an experiment he had performed while working at Johns Hopkins university, Baltimore

Dr. Richter gathered 12 Domesticated rats, put them into jars half-filled with water, and recorded the time each rat took to swim before it gave up. Richter found that 2 of the 12 rats swam excitedly, drowning within 3 minutes, whereas as some managed to swim for days before finally giving up.

Next, Richter gathered 34 wild rats, renowned for their swimming ability (Hallinnan, 2014)After being dropped into the water one by one, each of the rats died within minutes.

Richter pondered as to why the behaviour in these rats was so unexpected. Why did the fierce, aggressive wild rats with seemingly better survival instincts drown so much faster that the domesticated rats, who had been lab bred and never been in a situation of danger.

"The situation of these rats scarcely seems one demanding fight or flight—it is rather one of hopelessness… The rats are in a situation against which they have no defence … they seem to literally 'give up' - (Richter, 1957)

Therefore, Richter revised his experiment, he took similar rats, put them in a jar – and just before they gave up, he picked them up, held them shortly, then placed them back in the water: this quickly taught the rats that the situation "was not hopeless". The difference in results was staggering. The rats that were given a brief rest managed to swim for much longer than the rats there were left alone, and they recovered almost immediately (Hallinnan, 2014)).

This change in behavior was because the rats realized that there was hope, a chance of rescue. If they continued to swim, a helping hand may finally come to save them.

"After elimination of hopelessness, the rats did not die" – (Richter, 1957)

Although the differences between Rats and Humans are obvious, the concept remains the same. While there is hope, motivation can be conjured.

Temporal Landmarks are defined as significant points in time that promote a break from the past and a sense of renewal moving forward (Hengchen Dai, 2018)

Much like Richter's study of rats and hope (Richter, 1957), Experiencing a temporal landmark may produce a 'fresh start effect', inducing motivation and making them more likely to achieve their goals.

Similarly, anticipation of a temporal landmark may also provide increase a person's current motivation if they are "reminded of an ideal future state" - (Hengchen Dai, 2018).

Dai and Li found that due to the way people perceive time, their goals and processes are often structured in a categorial manner. Their research suggests that temporal landmarks do influence motivation.

Dai and Li's research suggests that due to the way people perceive, organize and structure their goals in a categorical manner. Temporal landmarks do have an influence on intrinsic motivation.

Landmarks in both the past and future may increase motivation in circumstances where people have previously experienced but overcome failure, or when people are reminded of an ideal future state (Hengchen Dai, 2018). But may also produce adverse effects, such as when a landmark may cause another to feel further away.

Conclusively, more research must be done into this field of study before definitive results can be yielded. However, I wish to incorporate this cognitive concept into my exercise simulation, to measure the effects of temporal landmarks on participants intrinsic motivation.

Video games are a firmly established leisure pursuit which continue to grow in popularity (Reid, 2012). Typically yielding rewards of no tangible physical value, which incidentally fail to impact a person's career, physical health, or outward social life synonymous with a healthy lifestyle.

Although the benefits of playing video games have been heavily debated since their conception, there is exists no reason, unless in extreme cases, why mental and physical stimuli cannot be met elsewhere.

This poses the question, are video games necessary to motivation and SDT, and what motivates people to play video games.

Reid touches on the concept of 'flow experience' (the state of mind achieved when fully immersed in an activity (Cherry, 2022) and 'Attribution theory' (how a perceiver uses information to arrive at a casual explanation for events (McLeod, 2012) and attributes their characteristics to the formation of a safe 'medium' or environment in which "to learn about the consequences of actions through experience" (Reid, 2012). Through his research, he believes Computer games facilitate the fostering and development of many self-monitoring and coping mechanisms applicable to the real world, such as perseverance, hope, or critical reflection. And that the pursuit of challenge was a prevalent motivator.

Reid's research offers an insight into how video games can be used uniquely in their capacity to train, strengthen and reinforce positive motivators, self-determination and perseverance – of which could be transferrable applied to activities such as work, exercise or hardships, consequently.

From this, we can begin to conceive how exergames (games that focus on exercising the participant through the interpretation of motor movement to control an in-game object or character (Amanda E. Staiano, 2011) can be used to reinforce similar behaviours, such as intrinsic motivation, whilst producing noticeable health benefits.

Exergames suggest increased caloric expenditure, heart rate and coordination, whilst also reinforcing positive Psychosocial and cognitive impacts such as increased self-esteem, social interaction, motivation, attention span, and visual-spatial skills (Amanda E. Staiano, 2011).

(Amanda E. Staiano, 2011) suggested the skills acquired during the usage of exergames benefitted physical, social and cognitive development, which were transferrable into other activities, and with video games being played universally amongst 99% of boys and 94% of girls ages 12-17 – the potential and necessity for these mechanisms is becoming increasingly prevalent.

Exergames have been well-established and widely implemented as health tools in settings such as gyms and leisure centres – for instance, rowing machines or treadmills that increase motivation through competition, or virtual personal trainers that motivate players by encouraging them to proceed to the next level.

From this, I believe more research should be conducted into assessing intrinsic motivation and SDT using more immersive and modern technology at our disposal, such as Virtual Reality, and Mixed Reality inputs – to investigate and evaluate the nurturing and reinforcement of positive cognitive development characteristics.

For many, a world devoid of social and physical interaction is, unfortunately, commonplace. Hikikomori is a rising social issue affecting 541,000 Japanese citizens (Kyodo, 2016) especially young males. A study performed (Takahiro A. Kato, 2018) reported from a total of 247 across 8 countries, 239 (97%) of participants met the diagnoses requirements for analysis of Hikikomori syndrome: A" social phenomenon" described as total voluntary social withdrawal into long-term iso-lotion, retreating into the confines of their homes for" months or years".

Particularly prevalent in urban areas: This re-search suggests the number of individuals experiencing absolute long-term isolation is much higher than anticipated, and not represented solely by the number of cases related to medical vulnerabilities such as immunodeficiency. “There are few if any forms of imprisonment that appear to produce so much psychological trauma and in which so many symptoms of psychopathology are manifested” - (Haney, 2003). Haney’s research on extended periods of isolation, respectively, issues in Long-Term and” Supermax” Confinement offer an insight into the damage caused by social confinement inside and outside of incarceration. A study (Haney, 2003) assessing 100 randomly selected SHU (Security Housing Unit Prisoners) reported 91% of prisoners suffered from anxiety, 88%from headaches, 84% experienced lethargy and 68% reported Arrhythmia and Palpitations due to extended periods of isolation. Further studies revealed 41%of inmates reported Hallucinations, 63% talked to themselves regularly, 77%suffered from chronic depression and 88% experienced irrational anger. Haney argued exercise was critical to mitigation of these symptoms and vital to the psychological rehabilitation of prisoners. Regarding clinically accepted physical rehabilitation, virtual reality is quickly becoming a popular form of rehabilitative exercise. A study (Ali Pourmand, 2018) assessing” VR as a Clinical Tool for pain management” reported that “Current management techniques for acute and chronic pain, such as Opioids and physical therapy, are often incomplete or ineffective”. The study states that hold the potential to redefine approaches to treatment of acute and chronic pain caused by a variety of conditions or past injuries and illnesses. For this study, patients interacted with immersive VR environments which provided a noticeable distraction from painful stimuli leading to a potential decrease in” an individual’s perception of pain”. Overall, evidence for Virtual Psychology regarding rehabilitation is promising, but new. Therefore, more research must be conducted to validate the efficacy for VR as a rehabilitative medium.

Chapter 3

Methodology

This section discusses the tools and project management techniques, methodologies and techniques researched and implemented during the development course of the project in order to ensure its success.

3.1 Project Management

The appropriate project management methodologies should accommodate the aims and objectives identified within the project's scope and befit the demands of a project that qualifies it as a success.

The study aims to review the validity of Virtual Reality systems as a tool for aiding and benefiting Motivation, which in turn promotes the production of dopamine and endorphins, subsequently increasing levels of stamina, determination, perceived satisfaction, and *"greater clearance of lactic acid overtime"* (Forever Fit Science, n.d.).

Therefore, the main goal of the project was to create a Virtual Reality system which increased exercise effectiveness, while being enjoyable and engaging.

From this main goal, a series of objectives were produced, being:

1. Research intrinsic motivation theory, the effect of technology on motivation, and external effectors of motivation, and their manipulations.
2. To identify motivational effectors, and utilize them within a VR space
3. To gather qualitative and quantitative data using user-testing, surveys and questionnaires, alongside utilisation of calculable success metrics such as Intrinsic Motivation Inventory (IMI)

Risk	Likelihood (1-10)	Impact (1-10)	Mitigation
The artefact is incomplete, and therefore un-testable.	2	8	Showcase the existing artefact and gather IMI scores based on reactions to the demo.
The artefact does not work as intended and produces unsatisfactory results.	5	6	A pivot must me made, and new success criterion / metrics must be calculated to reflect the progress of the project.
Access to otherwise un-attainable lab equipment is denied.	1	6	Switch from Desktop VR to Mobile VR development, affordable and feasible, able to test at home.
There is not enough time to complete the project	3	8	Use the Gantt Chart as a guide to manage time, use Kanban to keep on track of tasks.

There is insufficient time to gather test data and review results.	3	6	Pivot project scope to reviewal of the system and its potential applications.

Fig.: A Project Risk Table.

In consideration of the mixed reality system, the base metric of qualification falls upon the numericized gradation of participant enjoyment/engagement data, produced by IMI (Intrinsic Motivation Inventory). Making a high overall score indicative of an enjoyable or engaging experience, and subsequently, the success metric of the project.

Risk Assessment

Risk analysis was carried out to assess how the outcomes or objectives of the project may change due to the number of risks threatening the project's completion, their likelihood, and impact to the project.

The purpose of risk assessment is to "ensure that the least number of surprises occur while your project is underway" (Lavanya, 2008). The successful development and maintenance of risk management and analysis processes helps to "predict the uncertainties in projects and minimize the occurrence or impact of those uncertainties". This improves the chance of successful project completion and "reduces consequences and risks" (Lavanya, 2008).

This, in turn, helps validate whether the product is viable inside the constraints of the project, as a high number of high likelihoods, high impact risks make a project too risky to undertake, and likely to fail.
On the other hand, a manageable number of risks, with either low likelihoods or low impacts, allow a mitigation plan to be made in the case of their occurrence.

Assessing and managing risks such as these allow us to take these potential challenges into account during the planning phase of the project, which means more time may be allocated or shifted from certain areas, sprints or phases of the project in preparation of these.

Using a numerically approached risk matrix, overall potential damage to the project could be calculated using the following formula for each identified risk in the project.

$$o = \frac{l}{i} * 100$$

Then, the "risk factor" of the project could be estimated using the mean of each identified risk.

$$m = \sum o_i \, / \, n$$

With the aims and objectives established, aggregated by a thorough assessment of potential risks to the products completion / success using a risk assessment table, a Gantt chart was created to manage the timescale of each "sprint" phase, task-time, and overall project timescale, in order to measure project throughput, and achievements of each cycle. This provided good representation of how the flow of work is expected/should go.

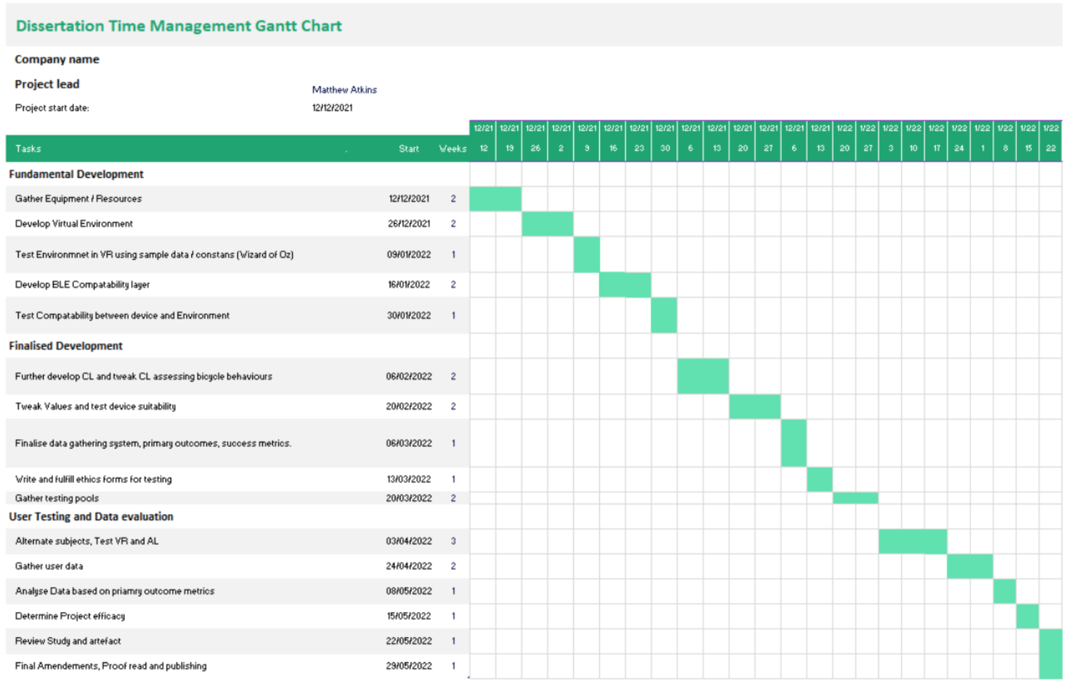


Fig.: A Gantt Chart Representing Project timescale and workload.

This was the original Gantt chart created to reflect overall time taken in each stage of the development cycle. However, it became clear the chart did not accurately represent the time taken to complete each sprint, or appropriately reflect development methodologies to be employed.

External effectors of the artefact production had been misjudged and therefore inhibited production of the artefact. For example, the sourcing and or funding of Virtual Reality equipment, such as HMD’s, Link cables or licenses, as commercial-grade HMD’s, such as the Oculus Quest or Quest 2 are extremely costly, not to mention in high demand.
Thusly, transportation arrangements for testing of the equipment had to be reconsidered, as borrowing equipment from the University stipulated it could not leave University grounds.
This meant the transportation and storage of the exercise bike, bicycle trainer and appropriate setup tools had to be arranged with the university.

University equipment could also only be borrowed for a certain amount of time, putting further time constraints on the project, and strict organisational policies had to be enforced.

Sourcing the equipment also required excess time due to supply-chain disruption challenges faced by logistics companies. This was exasperated by the recent semiconductor shortage (Ian King, 2021), set in motion by the Covid-19 pandemic.

This meant many items such as the Arduino board, VR Head-Mounted-Display (HMD) and bicycle trainer were either out of stock, delayed or both. This made efficiently re-allocating time and resources into completable project tasks challenging, as many relied on the use of or development with the appropriate equipment, such as the BLE integration.

External pressures from workloads outside of the project scope also affected the project timeline more than was considered, such as University Assessments, Revision and Studying, meetings and lectures.

In reflection of this, an iterated Gantt chart timeline was created

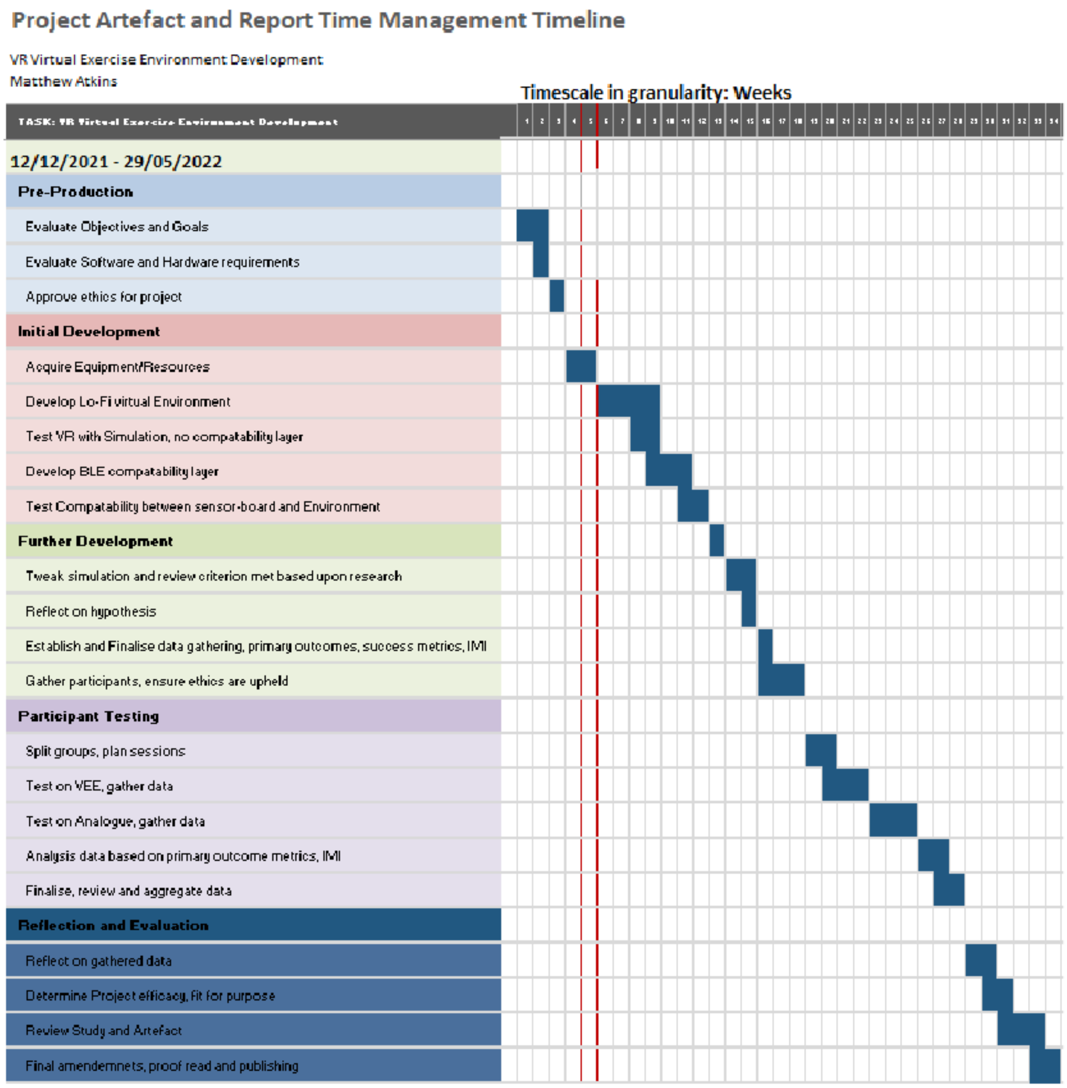


Fig.: Iterated Gantt Chart Representing Project timescale and workload.

The level of granularity produced in the chart only allowed for a rough estimation of time management provided over the entire project, which was befit for its purpose. However, many tasks required greater levels of granularity, containing subset phases. For this, additional tools such as Kanban boards were used.

Due to the nature of the nature of the project, the features and aims of the artefact were liable to change. To account for this, agile project management methodologies were employed to accommodate, in principle, the structure and allocation of project resources, time, and designation. The project's time management methodology followed the use task-focused methodologies such as "Scrum" and "Kanban".

Scrum

Scrum is a *"sprint-based project management system with the goal of delivering the highest value to stakeholders"* (Peek, 2021) agile productivity framework designed to aid the structuring and organization of teams, the segmentation and delegation of their tasks, definition of projects aim and objectives through utilization of various Agile tools, such as Kanban, and consistent iterative feedback overtime.

Scrum is designed with the expectation that it is "utilized on a project-specific basis" (Ashish Mundra, 2014), and is expected to be changed tweaked or flexed according to a project's needs or demands. Being mostly team-focused, Scrum methodology was tailored to suit development load balancing, time management and granularity of a sole-author.

Teams work collectively on a single development phase which are segmented into "sprints" (Ashish Mundra, 2014), typically two weeks in length. Then tasks are delegated to appropriate team members and placed in a work-management system in a "backlog", "in-progress" or "finish state", which is accessible by the entire team. Individual team members may also employ boards of their own for greater granularity. After each sprint, the results are shared with the team, and further tasks / decisions are made.

A key feature of Scrum is that workloads are transparent, meaning work between the team is clear and communicative, which ensures all team members understand which stage they should be at.

Kanban

Developed by Taiichi Ohno in the 1940s during his work at Toya, Kanban is a visual work management method or "tool" for management of workloads as they move through a development process, aimed at the "elimination of waste" and "doing more with less" (Santos, 2018), essentially focussing on "value for the customer and flow of work", Kanban was used to provide visualised granularization to each "sprint" of the development cycle, which made it easier to track and manage progress and throughput throughout the task-flow process.

"Scrumban"

"Scrum is a very simple framework within which the "game" of complex product development is played." (Reddy, 2015).

As a project grows in scale and complexity, the constraints and fallbacks of scrum are highlighted, requiring an evolution of the agile system in order to maintain development efficiency. In an interview Schwaber illustrates the fallbacks of over-reliance to the basic Scrum framework as *"many organizations change Scrum to accommodate the inadequacies or dysfunctions instead of solving them"* (Callanan, 2010). Schwaber goes on to state *"I estimate that 75% of those organizations using Scrum will not succeed in getting the benefits that they hope for from it"* (Callanan, 2010).

Scrumban is the combination of the two previously mentioned methodologies, it combines the most important characteristics of Scrum and Kanban and merges the development structure and routines of Scrum with the flexibility of Kanban to produce an agile, task-focused, visually representative tool that is both more efficient, and productive than either sole method.

Scrumban was utilized through the project management process as a simple combination of both “Scrum” and “Kanban” approaches, this flexibility of both methods produced an effective tool that allowed a fast, consistent, iterative approach to production.

Scrum was employed for the overall agile structure of the project, due to the often-mercurial nature of the artefact and project scope, whereas Kanban and the Kanban board were utilized to provide higher levels of granularity and structure to more in-depth tasks.

Both scrum and Kanban methodologies rely on a “pull system”, which control the flow of workloads, when one task is completed and is moved into the “finished” section of the board, the next appropriate task is ‘pulled’ into the in-progress section to be worked on.

Using this method ensures the end user or client receives a viable product in the shortest possible time. The pull system also helps to uncover bottlenecks in this process, which, in turn, also helps ensure a viable product is met within the constraints given.

Using Kanban, a project plan board was built and used as a pipeline to measure throughput over time and restructure where necessary. When developing the Kanban board, tasks were segmented into various sections.

Preparation: This entailed testing the theory and implementation of mathematical principles such as “sinusoidal acceleration” (JF O'Hanlon, 1973), application of gravitational force, or calculation of RPM on a single gyrometric axis.

Then, evaluation of technology to support these implementations: such as BLE and IMU sensory integration. The technology was researched and compared, then reviewed on whether they were possible to implement and feasible in consideration to time and resource constraints.

Frontend development: considered the implementation of features which did not rely upon external devices and were mostly Game-Engine specific. Such as the endless runner implementation, development of in-game assets, random tile generation and general movement and in-game physics management. As the results of user testing relied on characteristics such as visual feedback and response to external stimuli of temporal landmarks. For example, logs, buildings, noticeable trees etc. This meant more time was reserved to develop immersive but unique visual assets.

Backend Development: Essentially, this considered any development of API’s or scripts to help convert and utilise the IMU sensory DataStream being read over BLE, or data such as input from the VR headset (point-to-look interaction).

The artefact had to be tested in order to yield appropriate data and measure the effectiveness of the artefact. To do this, tasks were focused on demonstration and user testing, these contained testing the agile phases of initial development, backend development, post development and user testing.

A simple Kanban board was made using GitHub projects, and followed the structure show below.

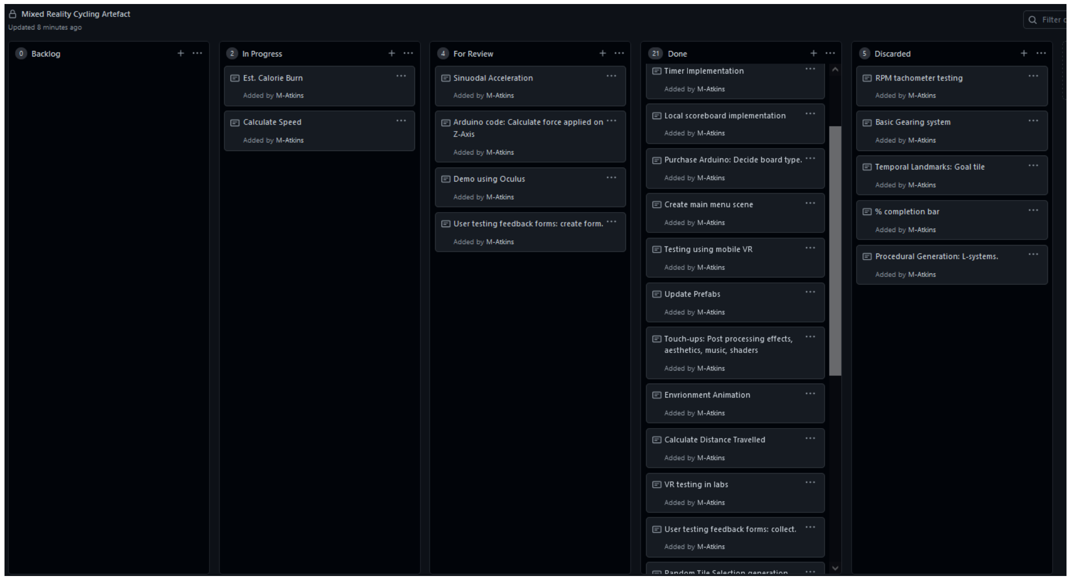


Fig.: An example of a Kanban board used for project development

3.2 Software Development

Typically, as the scale of a project increases, so do their aims and objectives, in turn, this increases the size of their workloads. To maintain efficiency, productivity and redundancy of a project development methodologies must be employed. Development methodologies are critical to the approach and application of project development and can incidentally result in the success or failure of a product. In this section, an explanation and justification of the software development methodologies used will be provided.

APM defines Agile project management as the "iterative approach… composed of several iteration or incremental steps towards the completion of a project." (APM, 2020)

Agile methodologies are *"widely implemented and used around the world"* (Rasnacis, 2016), The choice and adaptation of a software development methodology relies on the characteristics of the project type, goals, constraints and team members.

Due to the nature of the project, characteristics and features belonging to a variety of various software development methodologies were gathered, combined and utilized within the scope of the project.

Extreme Programming and Rapid Prototyping

Extreme programming (XP) is an agile based, test-driven software development methodology that "aims to produce higher quality software, and higher quality of life for the development team" (Alliance, n.d.). Which follows 5 core principles.

1. Communication
2. Simplicity
3. Courage
4. Feedback
5. Respect

The simplistic nature of the method is a straightforward, pragmatic approach of a rapid testing environment, in which goals are minimized, or broken into subsets. This increases manageability of the product while maintenance of a study workflow.

During the development of my artefact, a test-driven XP approach was taken to ensure everything worked. As the project scope grew, goals changed, and more features were eventually added, as was expected. Iterative code reviews and Rapid user-testing were implemented to ensure modules of the code ran as expected – For example, the BLE connection and DataStream API, or the remote gyroscope script.

After the reviewal of each module, integration testing began to ensure both frontend and backend development products ran as intended together. Because of this. Due to the XP and FDD development approaches, such as the *"Ten-Minute-Build"* method: in which the aim is to build and run the entire system at least every 10-minutes (Alliance, n.d.). Which simplified error fixing, as implementation of frequent iterative testing made it easy to understand why a module might fail under the given environment, as opposed to building a series of modules of modules together, then batch testing everything at once.

Although typically a team driven methodology, focused on fast software production towards a client. I was able to benefit from the rapid, test driven nature of XP due to the near-constant feedback I received and noted, which allowed me to pivot and focus my attention to appropriate areas of development, when and where it was required.

Feature Driven Development (FDD)

Scrumstudy

Feature driven development was implemented as a cohesive “amalgamation of industry acknowledged practices” orientated around “client-valued functionality” (SCRUMstudy, 2014). According to planview, FDD is *“customer-centric, iterative, and incremental”* software development methodology (planview, n.d.). FDD is designed to minimize management overhead, time, and money, which subsequently produces successful and satisfactory product delivery.
FDD is related to scrum, but as the name suggests, is a *“feature-focused method, as opposed to a delivery focused method”* (planview, n.d.). This means features are delivered on a much more frequent basis.

I utilized this approach when approaching the main development sprint of my artefact, in which the framework and background for the Exer-simulation had been created, and many assets or features needed to be implemented in a short period of time.

Because of this, some features may not have worked as intuitively as I may have hoped, or looked the most aesthetically pleasing, such as the countdown timer, main menu or scoreboard for example. However, the result was a feature-rich environment, which provided satisfactory functionality to a product that may be otherwise feature-sparse.

Kanban Boards

Due to the scale of the project, separate Kanban boards were developed and split, each representative of the workload to undertake throughout the various stages of artefact development and providing a higher level of task-granularity for each sprint in the development cycle. This also allowed for a greater degree of preparation, organisation and structure into which the project could be approached. The switch of boards allowed for the pivot from one section of the project to another interchangeably, without confusion or encumbrance.

The Kanban boards were divided appropriately, befitting the various development sprint cycles necessary for the project's completion. These consisted of Preparation & theory, Frontend development, Backend development, Demo and user testing stages of my artefact development.

Due to the Agile structure of the project's organisational framework, I was also able to implement a variety of case-appropriate development methodologies as and when they were needed, as expected from the flexible nature of agile frameworks.

A combination of the most appropriate development characteristics were used during the entire duration of the development process. However, there were times when aspects of certain methodologies were relied upon more heavily than most.

For example, Feature Driven Development (FDD) was mostly implemented during the backend and frontend development phases of the project being the two most feature rich stages of development, as a high volume of features were required in a short period of time. Whilst Extreme Programming XP was lightly relied upon to maintain feature redundancy and provide mitigative countermeasures to bugs in code, or engine errors.

This organisational structure and segmentation of stages allowed for the immediate resolution of bugs or challenges within development. This ensures *"high-quality software can be delivered faster with consistent, successive iterations"* (Weller, 2021). In respect to the project, an example of this would be the Oculus Quest camera not aligning properly when the game was launched, due to the agile methodology's iterative testing, this was immediately identified and resolved by reinstalling the Oculus and XR VR compatibility plugins using the Unity package manager, before the user testing stage commenced.

For instance, if this scenario were to occur under guidance of the waterfall methodology which is "sequential development process" that "emphasises a linear progression from beginning to end of a project" (Adobe, n.d.). A greater number of bugs would propose during the end of each testing phase, costing more time bug-fixing. Making the implementation of Agile methods exemplary.

Scrum, or more specifically "Scrumban" was implemented across the entirety of the project to provide an agile, iterative and flexible solution to the project's developmental concerns. For most, if not all stages of development Kanban boards were introduced to visualise and organise tasks and goals. While "sprints" were implemented to ensure consistent and satisfactory throughput was made over each iteration of development.

Capture Approaches

After the development phase of the artefact had concluded, user testing was considered, in order to appropriately test the Mixed Reality (MR) cycling simulation, the equipment had to be moved to the University so it could be used in conjunction with the Virtual Reality Headsets.

To create a testing pool representative of the general public, random people were asked a short questionnaire on their lifestyle and exercise habits. Once deemed appropriately healthy, not being at risk of specific illnesses or worsening injuries, the participants were asked if they would like to test the artefact.

Data capture approaches were strongly considered during testing of the artefact, as the capture data of the tests had to be reflective of and consolidate the aims and objectives of the Project scope

IMI had already been considered as an appropriate measurement of calculating user motivation and enjoyment, therefore a survey was created using Microsoft Forms, which inquired upon the reflection / reviewal of the Mixed Reality system.

During testing of the simulation, Each Participant was generated an anonymous 6-digit “Player Code” which they would use to compare their score against other participants on a leader-board (as a measure of motivation).

Using their player code, participants were able to enter their anonymous player code and score, then answer a series of questions over their enjoyment of the simulation, what they would change, what they didn’t like, whether they experienced any change in behaviour as a result of their surroundings. Accompanied by a short questionnaire to calculate their IMI score.

From this I was able to use cross-reference player scores with their feedback, and gain a more accurate insight into a participants performance in relation to their experience, which could be used as supporting evidence when calculating IMI scores.

Intrinsic Motivation Inventory (IMI) is defined as a "multidimensional measurement device intended to assess participants' subjective experience related to a target activity" (SDT, n.d.).

IMI has been used in several experiments in respect to intrinsic motivation and self-regulation. And assesses participants intrinsic motivation in a particular given activity using a subscale of 6 scores. These are defined as *"interest/enjoyment, perceived competence, effort, value/usefulness, felt pressure and tension, and perceived choice"* (SDT, n.d.) while performing a given activity.

After yielding these 6 subscale scores, an average is created across all subscales. These scores, in theory should correlate with the participants simulation score, providing an accurate result.

Overall, Agile methodologies have been identified as the most suitable software development methods for this project as the flexible nature of Agile methods provide a resilient and versatile management and development structure, appropriate for error handling, unforeseen challenges, and ever-changing constraints.

Agile methods, namely FDD and XP, have proven invaluable in their ability to yield feature-rich, satisfactory software within strict constraints (APM, 2020), while XP allowed the quick resolution of delays and other challenges within the project's development cycle.

3.3 Toolsets and Machine Environments

Unity Game Engine 2020.3.32f1

Unity Game Engine is a cross-platform *"real-time development platform"* (Unity, 2022) oriented around unrestrictive, production-focused, versatile game development using a *"robust ecosystem"* (Unity, 2022) without the difficulty of programming assembly, rendering, physics or other difficult and time-consuming challenges.

In conjunction with Unity hub, projects and games can be built accessed, saved, or uploaded to the cloud and distributed to a wide range of platforms with relative ease with satisfactory results.

Unity's 3D Game Engine (formerly known as Unity3D) has been chosen as the main development engine for this project. This is because Unity is free under creative license and available for use on nearly all platforms.

Unity provides solutions for nearly all aspects of game development, from texturing and modelling to animation and rigging, to physics and logic-based computing – Unity can provide in-engine platforms and services to their end-users free of charge.

Unity enables rapid and iterative development cycles, with real-time previews and testing of both frontend and backend development.

With a wide variety of free online resources, Unity was an appealing choice from first reviewal. Unity's strongest feature is its ability to switch and build projects to a variety of non-native platforms with the press of a button. This was especially helpful in my use-case, as when testing the Mixed-Reality simulation, I was forced to develop and test as a mobile VR user.

With Unity I was able to build my project to any Android or iOS application and test the project in-editor using the Unity Remote features and optional iOS and Android build support SDKs, which were easily accessible through the Unity Hub application.

The most time-productive point of Unity game engine however was their community-led asset store. This enabled me to access countless resources for free creative use in my simulation, saving me countless hours of ground-up modelling, texturing, rigging and animating.

Unity's community led forums also provided invaluable knowledge and advice, from which I could review old and similar questions or discussions in issues similar to my own, which aided in quicker bug-fixing and problem solving. And, as the Unity's code is based in C#, the Object-Oriented Programming (OOP) language provides a straightforward, familiar development style for developers to pick up.

Unity also offers a package manager to support the use of third-party non-native technology, the most important of which was the "Oculus XR plugin" and

“Windows XR plugin input management” packages. Without these, countless hours of development work would have had to go into creating a compatibility layer between standardized Virtual Reality headsets and my application. However, with the use of the package manager I was able to quickly and effectively implement Virtual Reality into my artefact.

Mobile VR headset (Iphone 8+)

A mobile VR headset was employed as a cost-effective solution for ‘in-house’ testing of the VR applications. Although development concepts differed slightly from desktop Head Mounted Displays such as the Oculus quest, the provided output was similar and helped me to reach a satisfactory quality of artefact.

Microsoft Visual Studio 2022

Microsoft Visual Studio is a widely popular and commercially *“IDE for creating modern applications for Android, iOS, Windows, as well as web applications and cloud services”* (VS, n.d.) use Integrated Development Environment (IDE). Visual Studio (VS) has been chosen as my designated IDE as it provides a number of useful, free tools and features.

Due to its “Lightweight and Modular Installation” (VS, n.d.)Visual Studio provides a code editor that contains support for most major development platforms, including support for Unity game-engine, it also supports Git integration, meaning useful code repositories can accessed, edited and pushed remotely, as and when they are needed.

More importantly, Visual Studio uses a built-in code debugger that shows the user syntactical, build or engine errors or warnings during development, this allows for quick and agile mitigation of bugs or errors in accordance with the practiced agile development methodologies, mistakes can also be isolated and identified using breakpoints with the program's editor.

Microsoft's "Intellisense" is a language-based service which provides *"intelligent code completions based on language semantics and analysis of source code"* (VS, 2022) and allows for auto completion of code or construction of functions and methods with easy to access, intuitive shortcuts functions.

Most notably, Unity has nearly full integration with Microsoft Visual Studio, which contains a lot of support for various tools or services on the IDE while using the Game Engine, this minimizes the risk of build errors, fatal crashes, or otherwise unsolvable compatibility issues between software builds.

Lightweight alternatives such as Sublime Text or VScode were also considered, however, for the scale of the project and design methodology. Built-in debugging and Microsoft's Intellisense made it an optimal choice for low-error, high productivity development.

Sublime text editor, however, was still used in part as a lightweight, portable alternative word-processing program to quickly take notes or reference code on the go.

Arduino electronics platform

The Arduino electronics platform is an *"open-source hardware and software development platform owned by Arduino"* (Arduino, n.d.), led by a user community that design and manufacture single board microcontrollers, kits, schematics and information exchanges online.

The Arduino platform was chosen due to, in part, the open-source nature of the platform. This meant things like guides, videos information exchange or advice were free, and community led. Through these forums, guides and videos I was able to integrate my Arduino with Unity game engine at a much more efficient time cost than if I had attempted the development manually.

A large reason the Arduino platform was chosen is due to the intuitively simple and versatile range of microcontrollers the company provides.

At the cost of around £25 GBP (Ble Nano 33, 2022), I was able to purchase a fully manufactured Arduino Nano 33 BLE: a portable, wearable microcontroller, consisting of a *"9-Axis Internal Measurement Unit, and Accelerometer, Gyroscope and Magnetometer"* (Ble Nano 33, 2022), with the addition of built in BLE, and a micro-USB connection for both power and serial debugging. This meant no tools were required to assemble a board to meet the required criterion, saving assembly time, equipment cost, time taken to learn electronic assembly techniques and my own user safety.

Developing and debugging on Arduino's is straightforward and fast due to Arduino code, a programming language designed for the Arduino platform based on C and C++, of which I have prior experience in. This made developing in the language easy to pick up.

The Arduino cloud-based IDE *"allows you to write code and upload sketches to any official Arduino board from your web browser (Chrome, Firefox, Safari and Edge)"* (Arduino, n.d.) *and* makes development of Arduino boards and Arduino code portable, fast and ergonomic. The library contains a wide variety of examples to use and load straight onto your board to check board sensor readings, inputs, outputs and processing of data. Both of Arduinos native and cloud-based IDE's are straightforward, intuitive and easy to use, making them a great choice for quick and easy development.

Using the Arduino online IDE, Arduino forums and other various open-source resources, I was able to read the gravitational force applied to the Arduino's IMU, connect my device to the Unity game Engine, and send information for use with the game.

Oculus Quest 1st Generation

The Oculus Quest 1st Generation was used, in part, due to limited availability and access to Virtual Reality HMDs. However, the quest was considered favourably due to the portable nature of the device, Oculus describe the device as an "all-in-one VR System" (Oculus, n.d.) . This consideration meant it could be used wirelessly, therefore minimising risk when during the demo and testing phases of the product, such as while cycling.

This made it an appropriate choice over other, heavier, wired headsets such as the Oculus Rift.

This, paired with the newer safety-oriented “Pass-through” technology made possible by two “front-facing cameras mounted on the front of the device”, make it a much safer alternative to many other headsets, as users may need to see their surroundings if they feel an obstruction, or start to become disoriented. This was a feature other competitors could not provide.

GitHub and git cli

Github was utilized as a version control and redundancy management service from my project. As I was often moving workstations, especially to test Virtual Reality HMD’s in the University computer labs, git was an essential tool in maintaining up-to-date code, accessible from anywhere remotely. With the use of a Private Access Token (PAT). Secure and reliable access to my code was essential.

Google Drive was considered for this purpose but did not have the same Version Control tools and services that Git and Github provided.

Github boards

GitHub boards were used a straightforward, free, online project management tool. This met the requirements of my project well, as the simple nature of the boards made them light-weight, scalable and versatile—overload of information was not an issue.

Other Kanban service websites were researched online, such as Kanbanize and Trello. However, many of these services were unnecessarily feature rich for the scope or plan of my project, and required the payment of a subscription free to use.

Microsoft Excel

After the testing and data capture development stages have concluded, data analysis must be performed on the dataset to validate and review the results to help conclude whether they support the hypothesis of the project.

Microsoft excel is described as “industry-leading standardised proprietary data processing software” (Microsoft, n.d.), and is offered for free under the University license. Enabling the re-structure and re-organisation of data to be used with visualisation and management tools to provide insights into datasets more efficiently.

Due to the nature of the project, the majority of data gathered will most likely be quantitative, meaning statistical analysis is important, this makes excel a necessary tool. Google sheets also offer a competitive, cloud-based alternative. However, it is not as feature rich as the Microsoft Excel. Where in-depth analysis is necessary, a feature rich environment will be desirable.

3.4 Research Methods

The University of Newcastle, Australia, define research methods as *"strategies, processes or techniques utilized in the collection of data or evidence for analysis in order to uncover new information or create better understanding of a topic"* (University of Newcastle, n.d.)

Data collections tools can be:

Quantitative Measures

- Surveys / Questionnaires
- Observation
- Document Screening
- Experiments

Qualitative Measures

- Interviews
- Focus Groups
- Observations

(University of Newcastle, n.d.)

Qualitative data is described as *"non-numeric information, such as in-depth interview transcripts, diaries, anthropological field notes… survey questions, audio-visual recordings and images"* (Uk Data Service, n.d.)

Research gathered on Intrinsic Motivation and external effectors of motivation such as pressure, emotion or tension mainly consisted of Qualitative research. This is because perceived emotions are subjective, and difficult to quantify or numericize, each individual participant’s severity, range or perceived impact of an emotion changes completely based on many outstanding factors.

Quantitative research has been sourced, such as performance statistics – these are statistics reports that *“help you identify and analyse bottlenecks in your processes and the time taken for the completion of each activity.”* (IBM, 2022). Using performance statistics, A representation of effectiveness of Intrinsic motivation and its subsequent effect on performance can be illustrated.

Quantitative research is defined as the *“process of collecting and analysing numerical data”* (Bhandari, 2022). Using this research, I decided to gather and present my data using a combination of qualitative and quantitative results. This was achieved using Intrinsic Motivation Index (IMI) to provide a numerical results of participants enjoyment, competence, effort, felt usefulness, pressure, tension and perceived choice, alongside user scores and travel metrics, and qualitative information, such as open-ended questions or open discussions as to the feedback of the experience.

This numerical data will be used to *“find patterns and averages, make predictions, test casual relationships and generalise results”* (Bhandari, 2022). The data will be validated by the qualitative data given by users in the report, such as written responses in reflection of the experience of the simulation.

The project aims to review the simulation using both Qualitative and Quantitative data types, representing an accurate review of the Mixed Reality simulation through statistical analysis and non-statistical analysis.

Chapter 4
Design, Development and Evaluation

4.1 Software Development

Requirements

This project aims to develop a Virtual Reality simulation capable of subconsciously increasing exercise efficiency and duration by means of intrinsic motivation.
To achieve this, an "endless runner" simulation is created and populated with randomly generated scenery and landmarks, an Endless runner is a *"game where a main protagonist runs forward into the game which never ends"* (Chong, 2015). Although the simulation can run indefinitely, the brain is tricked through the user of temporal landmarks (fallen logs, rocks, fences, large trees) (Hengchen Dai, 2018) into thinking they will reach an end goal, this gives the user hope and subconsciously encourages them to work for harder or longer.
To further increase intrinsic motivation, external stressors such as competitive scoreboards or countdown timers will be implemented, this also subconsciously triggers the brain and body to work harder or faster to meet a perceived goal state.
Once the simulation is over, the user will fill out a participant feedback survey, reflecting their personal thoughts and grading their experience based on the six subscale of Intrinsic Motivation Inventory. This would provide both quantitative and qualitative data for use in statistical model analysis.

Fig. 0: An example of an Endless Runner: Jetpack Joyride (Halfbrick Studios, n.d.).

Using the data gathered I will befit the IMI subscale scores to various models to produce a visualisation of their effectiveness.

Publicly available datasets were researched, however, insufficient data existed online, or was inaccessible. Regardless of this, the approach of my testing relies of project specific data.

Therefore, the artefact is being tested on its effectiveness to increase Intrinsic Motivation in order to produce more effective results in an exercise setting.

Thusly, the long-term goal for this body of research is to evaluate and validate VR platforms and technologies using a Virtual Reality system in their efficacy to increase motivation and exercise effectiveness.

Personas

Personas were utilized to help define the project's aims and goals and provide elicitation or validation to the project scope.

Personas are defined as *"fictional characters, which you create based upon your research to represent the different user types that might use your service, product, site or brand*" (Interaction Design, n.d.).

My design phase focused mainly on the use of Goal-Directed Personas, this focusses on the process and workflow the average user would prefer to utilize to achieve their goals.

Peter | 35 Years Old | Product Manager

- Works for a large company
- Has technological experience
- Lives in a dangerous area

Kate | 20 Years Old | Sales Assistant

- Works at a franchise
- Enjoys exercise
- Works all day, most days of the week

James | 55 Years Old | Retired

- Sedentary lifestyle
- Cannot be away from the house for long periods of time
- Likes to relax

From these basic personas, we can elicit why the exercise system would be useful for people who work a lot, live in dangerous areas, find it difficult to travel or exercise, have busy lifestyles, or become easily stressed.

Design

Designs of the both the hardware and software iterated overtime. Initially, the cyclical design for integrating and translating bicycle movements into the game engine wirelessly relied upon IoT development, and the use of lasers.

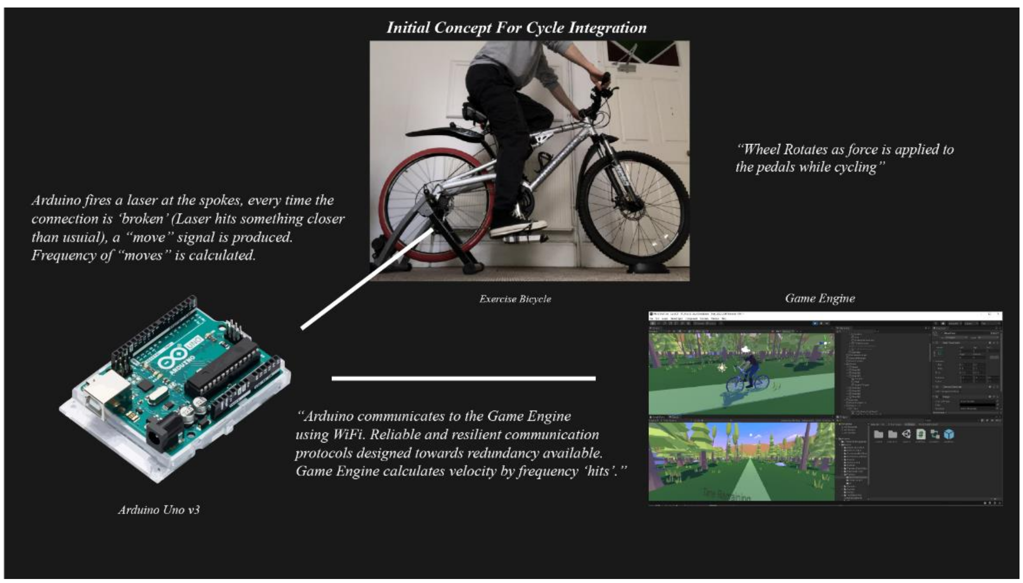


Fig. 1: Initial Design Concept for Cycle integration.

In this example, the Arduino would fire a laser at the back wheel's spokes. As the wheel turned, the laser would bounce of either the spokes or a foreign object. Every time this happened, a logical TRUE was returned to the device. The frequency of these laser interruptions would be used to calculate the velocity of the bicycle based alongside participant weight, height and bicycle weight.

The main benefits to this solution were that they allowed for a more accurate acceleration measurement, and enabled the use of gears in the simulation, which would, in turn, provide a greater degree of immersion during use of the simulation.

Regardless, this solution contained certain drawbacks, which when evaluated could not be mitigated appropriately to achieve the degree level of project success.

Firstly, the Arduino boards required for this capability where far outside of budget restrictions for the project. As the project was conceptualized with affordability in mind, this was an undesirable characteristic.

Secondly, the device had to stay static, and could either the board of bicycle could not "shift" or move too far away or the results would start to become erroneous, power consumptions were also a major concern for the board type. Therefore, iterations to the design were made.

Arduino Nano

After redevelopment of the bicycle-system, a lightweight, portable and affordable energy efficient design was made. This design relied upon the more cost-effective, smaller 'Arduino Nano' designed for wearable devices. This Arduino board consisted of a 9-Axis internal Measurement Unit sensor, making use of an accelerometer, gravitometer, and gyroscope. The board also came with built in short-range wireless communication technology in the form of Bluetooth Low Energy (BLE), this type of Bluetooth allowed for the short range, constant stream of small bytes of data from one device to another whilst being able to run on a single AA battery.

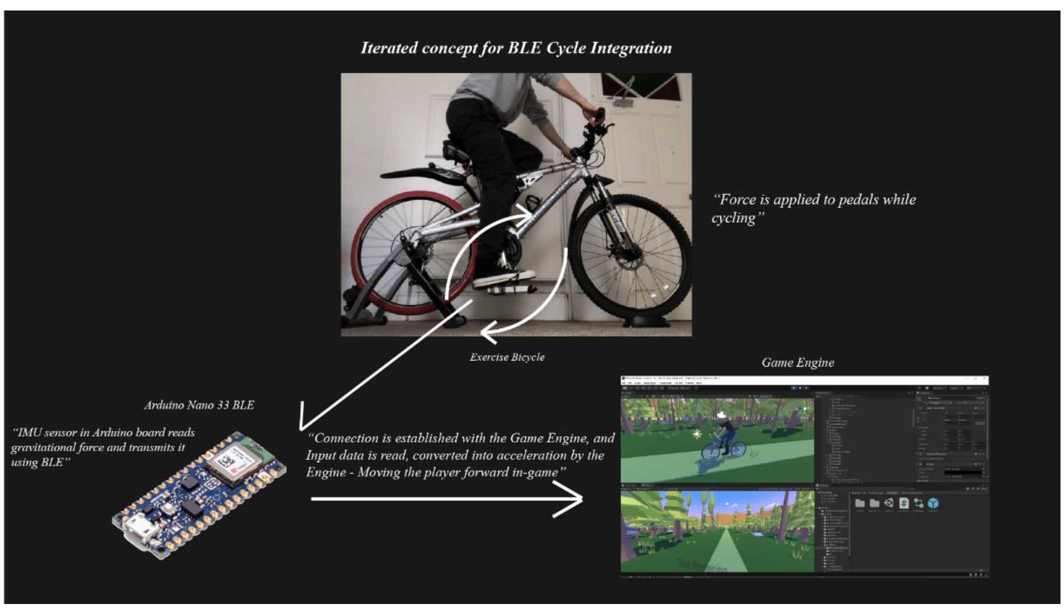


Fig. 2: Iterated Design Concept for Cycle integration.

The Arduino board and auxiliary power source were affixed to the bicycle using a secure housing to allow for easy access and security against knocks or scrapes, due to the fragile nature of the small board.

When downwards gravitational force on the Z-axis is applied to the Arduino, this data is captured by the IMU sensor and sent to the game engine host (Either a PC, phone, or Standalone VR device), where the degree of force is used, alongside the weight of the participant and of the bicycle, to calculate acceleration.

Flowchart

A flowchart was created to appropriately visualize the project's sequence of activities and processes to help appropriately orient development approaches.

Flowcharts represent the *"separate steps of a process in sequential order"* (ASQ, n.d.) flowcharts encourage visual clarity, "instant communication, and effective coordination" (Lynch, 2021). This tool helps to increase efficiency and analysis of processes more effectively.

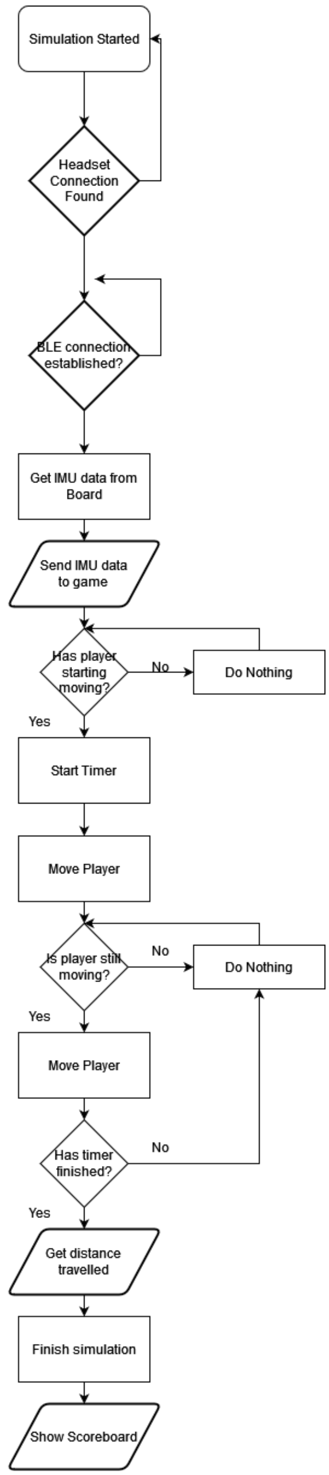


Fig. 2: Flowchart for the software processes of the simulation.

Safety Considerations

Before development of the game engine began, a user risk-assessment table was made, this concerned all the potential typical and project specific dangers participants may face while participating in the simulation, their likelihood and severity, and how they can be mitigated.

User Risk	Likelihood (1-10)	Impact (1-10)	Mitigation
The user becomes disoriented and falls off of the bike.	3	7	Speed of the bicycle should be limited to prevent disorientation, and time spent using the simulation should be limited.
The user trips or gets caught on a cable while using the simulation	3	7	Cable use should be kept at an absolute minimum, wireless technology should always be preferred if possible.
The user becomes too immersed and leans off the bicycle	2	4	Movement should be kept on a single axis / track, and move in a straight line on a flat plane to discourage

			'leaning' during use of the simulation
The user panics while using the mixed-reality system.	4	5	A "panic-button" should be implemented, or utilized in the Virtual Reality headset, which stops or terminates the simulation

Fig. 3: A user Risk Table.

It was concluded that users should not have the freedom to turn or move along the x-axis of the game world. Doing so could result in the urge to 'lean' while cycling, potentially causing them to fall off the bike.

Secondly, it was important the technology involved was as wireless as possible. A bicycle has many moving parts, using wires while immersed in VR while operating a machine could cause wires to get tangled and snag, knot or snap. These wires could potentially hit the participant, throw them off the bicycle if connected to a wearable device such as the HMD, or cause damage to expensive electronics.

Finally, change in elevation or terrain while immersed in VR could cause sickness or disorientation, which could also lead the leaning or falling during participation. Therefore, the terrain should remain consistent and flat.

In consideration of this, the optimal solution was to create a single-axis, endless runner with an unobstructed path that only allowed the participant to travel along a straight, flat plane.

This removed the concern for leaning, moving or disorientation. As they would be taken care of by the game engine, this left less things for the brain to focus on.

The endless runner formula followed this simple concept:

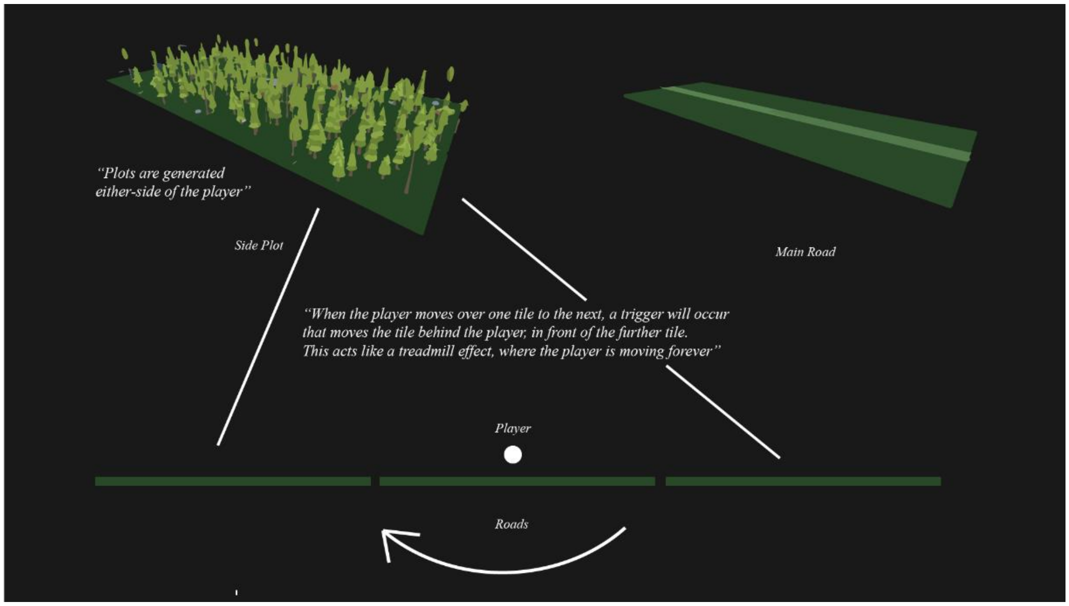


Fig. 3: Endless runner Concept design.

The participant will begin on a flat 'road' tile that are identical to each other. As the participant reaches the end of one tile, the game will move the tile behind them in front of the furthest tile away from the player, which will incidentally be out of sight lines.

This will give the illusion of a never-ending plane. As each new tile spawns, a randomly selected "plot" tile will be instantiated, some including temporal landmarks (rocks, fences, fallen logs, signposts etc.).

Doing so will provide the illusion of a naturally generated, never-ending forest, in which the player will learn to recognize unique landmarks within the scenery and associate them with progress.

Development of the art style used also followed various iterations of research. Originally, the game was conceptually high-fidelity, with realistic looking scenery and post-processing effects.

However, due to the cross-platform nature of the artefact, having to be built and ran on both Mobile and Desktop VR platforms, realistic graphics were deemed too performance intensive.

Instead, design pivoted towards a cartoon-like “low-poly” design style.

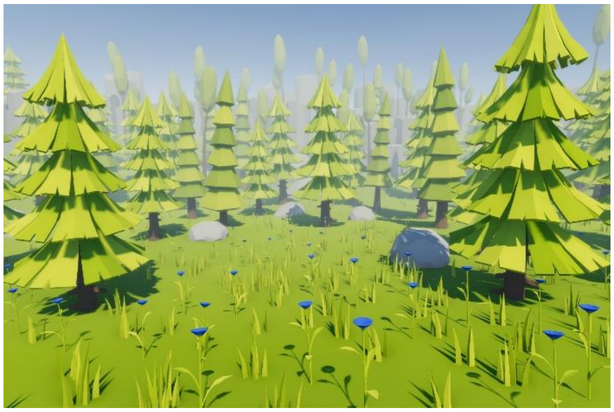


Fig. 4: An example of a low-poly art style. (Nicrom, 2021)

This design style is very popular amongst small project-development teams, requiring cheap, time-effective assets that don’t impact the gameplay performance or experience of said game.

Additionally, low poly assets are reported to have a positive psychometric effect on participants, due to their vibrant, colourful, but simple nature – this is known to have a calming effect, due, in part, to the low-processing demand for the brain on its environment. (Kiefl, 2019)

Kiefl touches on this in the paper “*effects of graphical styles on Emotional States for VR-Supported Psychotherapy”*. Based upon the theory that the human mind is *“designed as a computational system that consists of a series of information-processing programs”* (Putnam, 1967). Kiefl concludes audio-visual cues can “represent user emotion”, and how shapes using “sharp” containing a “higher valence” arouse more stimulus and are perceived as more “attractive than straight or angular lines”.

Due to the quick-to-produce, popular nature of the assets. Many free low-poly 3D assets are available for use in the unity asset store, which is both optimal, and time effective.

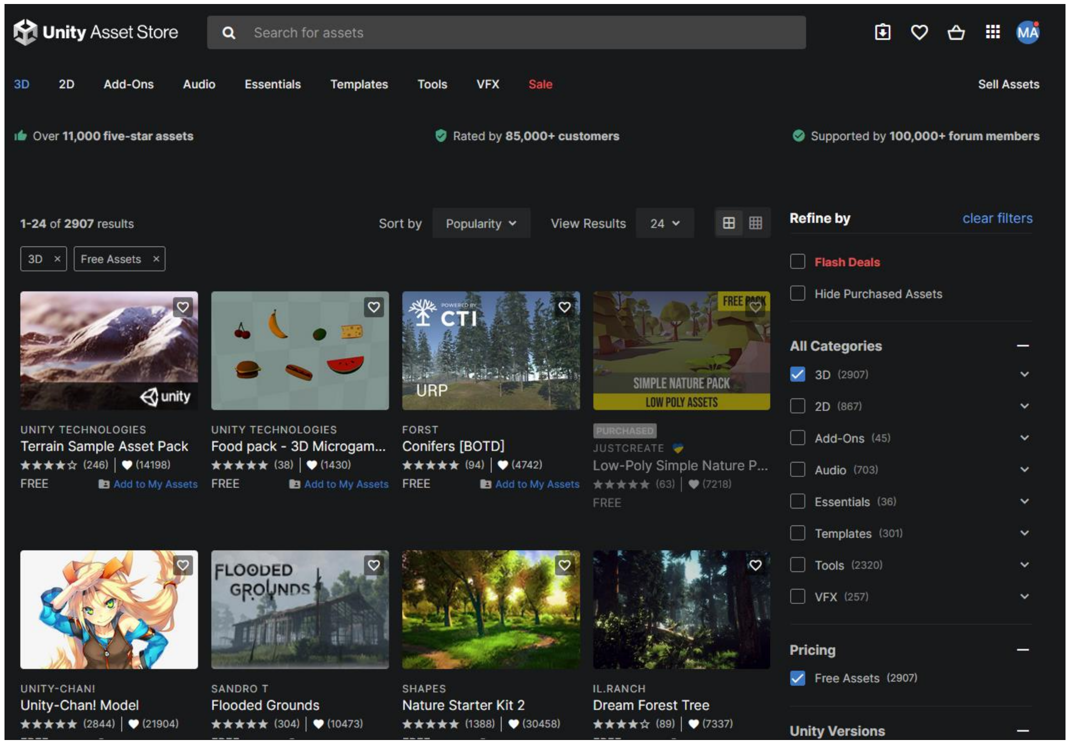
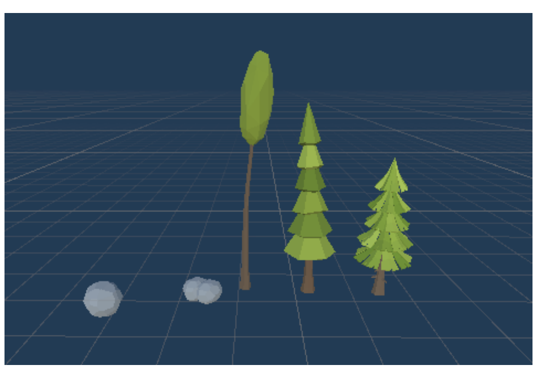
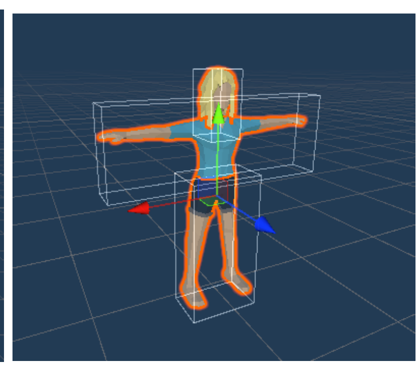


Fig. 5: Unity Asset Store

After the design style of the project was decided, appropriate, free to use packages were selected which reflected the low-poly, cartoonish design style and production methodology discussed previously.

From the packages, the most suitable assets were chosen, this included models, textures, prefabs, lighting and shaders pertinent to the project aims.





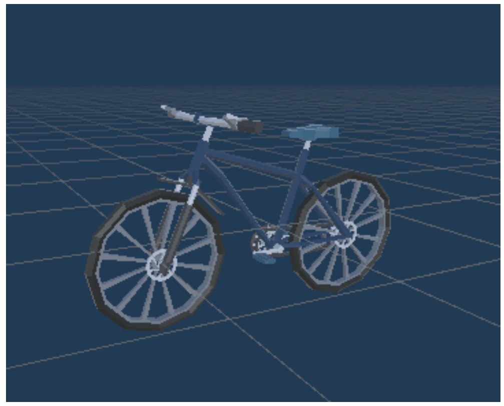


Fig. 6,7,8: Example Assets chosen for use in development.

Building and programming

The software development phases of the artefact were built using Unity Game Engine, Visual Studio, and C#.

Unity game development relies on an object-focused method of development. In this sense, every script, function or process is attached to, in-some-shape or form, a physical, in-engine Game Object.

The design of the endless runner simulation experienced multiple iterations over time. In the beginning stages of development, procedurally generated tiles were implemented, creating a truly unique and randomized experience.

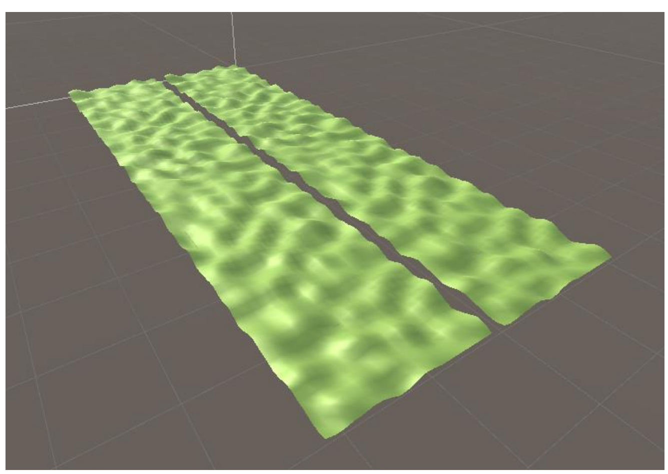


Fig. 9: Initial proof-of-concept for procedural generation

However, these were performance costly, and not fit for purpose within the style or scope of the project.

L-Systems

Another generation system considered were “l-systems”. L-systems are a dictionary of symbols or strings, which follow a set of production rules which aid in the seemingly random expansion as the L-system grows larger.

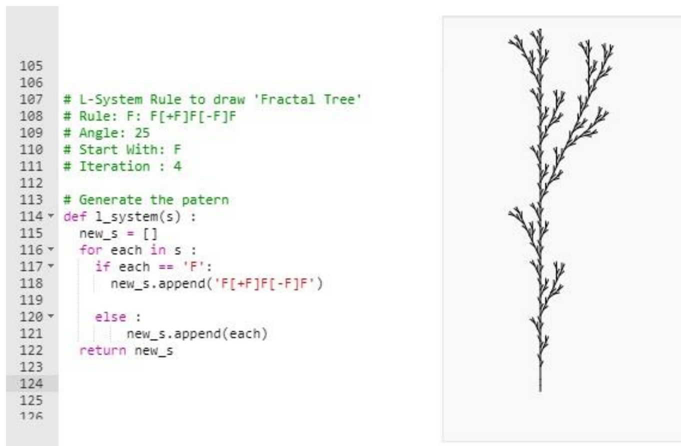
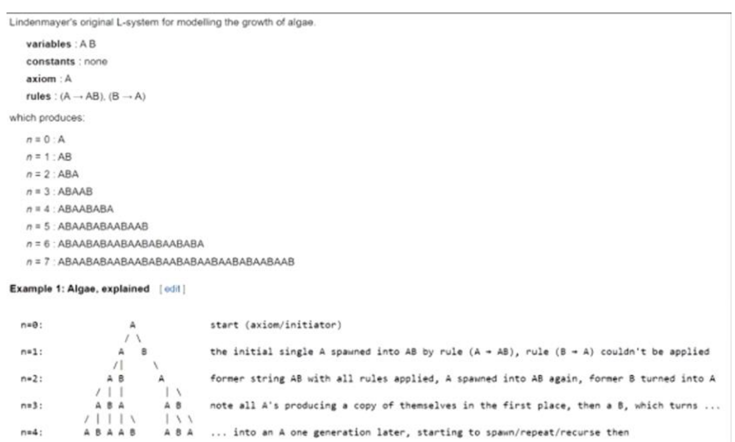


Fig. 10: Example and Pseudocode of an l-system (Studio, 2016)



Lindenmayer's original L-system for modelling the growth of algae.

variables : A B
constants : none
axiom : A
rules : (A → AB), (B → A)

which produces:

n = 0 : A
n = 1 : AB
n = 2 : ABA
n = 3 : ABAAB
n = 4 : ABAABABA
n = 5 : ABAABABAABAAB
n = 6 : ABAABABAABAABABAABABA
n = 7 : ABAABABAABAABABAABABAABAABABAABAAB

Example 1: Algae, explained [edit]

```
n=0:            A             start (axiom/initiator)
               / \
n=1:          A   B           the initial single A spawned into AB by rule (A → AB), rule (B → A) couldn't be applied
             /|    \
n=2:        A B     A         former string AB with all rules applied, A spawned into AB again, former B turned into A
           / | |    | \
n=3:      A B A     A B       note all A's producing a copy of themselves in the first place, then a B, which turns ...
         / | | | \  | \ \
n=4:    A B A A B   A B A     ... into an A one generation later, starting to spawn/repeat/recurse then
```

Fig. 41: Theory of an l-system – (Studio, 2016)

The concept behind this creates a seemingly endless, randomized structure, or in respect to this project, paths.

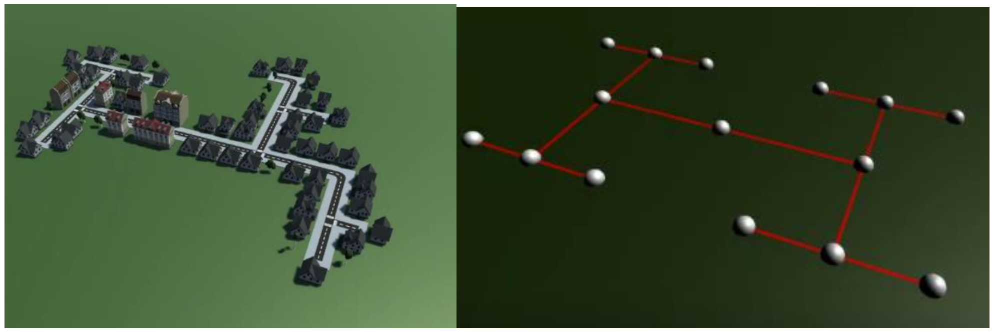


Fig. 52: l-system implementation in Unity – (Sunny Vale Studios, 2016)

This idea was also eventually scrapped, however, as multiple navigation paths were not needed.

Instead, flat plane prefabs were developed, making use of the models and textures gathered from the package manager.

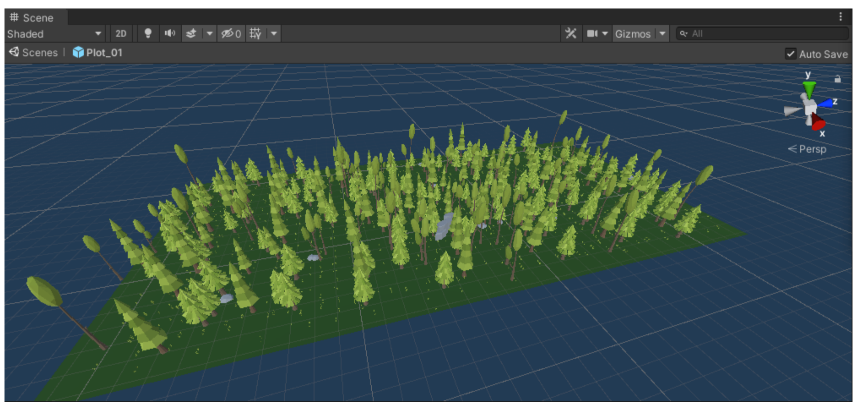


Fig. 63: Developed prefab using the model editor and pre-made assets.

Using this tile system, creating prefab models which provided rich, high-fidelity, aesthetically pleasing content was simple and straightforward.

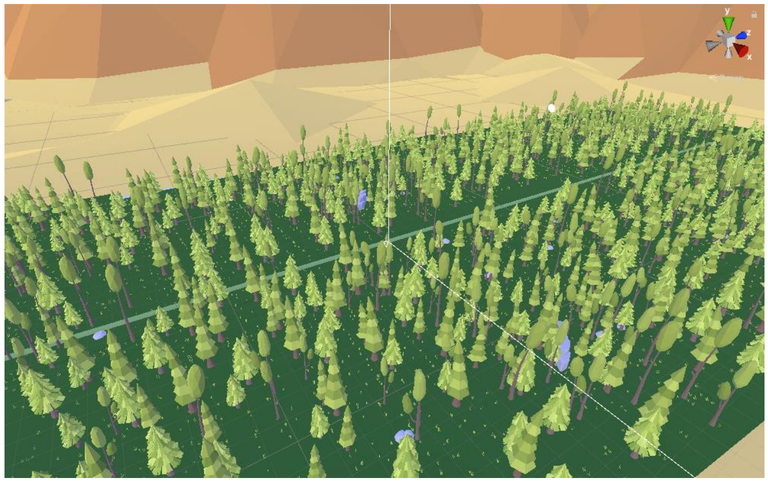


Fig. 74: Random Generation and Placement of Plot tiles.

Using this system, random generation of prefabs in the endless runner provided optimal results, while maintaining low-performance costs. The same tile system was used for the ‘roads.

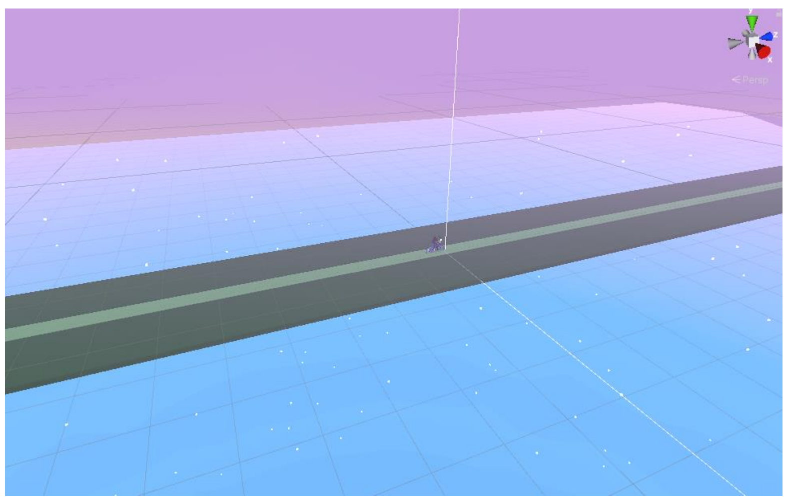


Fig. 85: Endless runner proof-of-concept for road tiles.

These processes were also used for the development of the player model, bicycle, and environment surrounding the endless runner and tile system.

Fig. 96: Finalised player model.

After the frontend development phase concluded, development focus pivoted towards backend development, this considered all ‘inner-workings’ of the simulation, such as player movement, goal states, tile generation, game optimisation etc.

Spawn Manager

An empty game object was created which managed the instantiation and placement of both roads and tiles, inside it contained two scripts, which, when called upon a trigger, would both move road tiles from behind the player, and spawn more randomly selected prefabs for the game world.

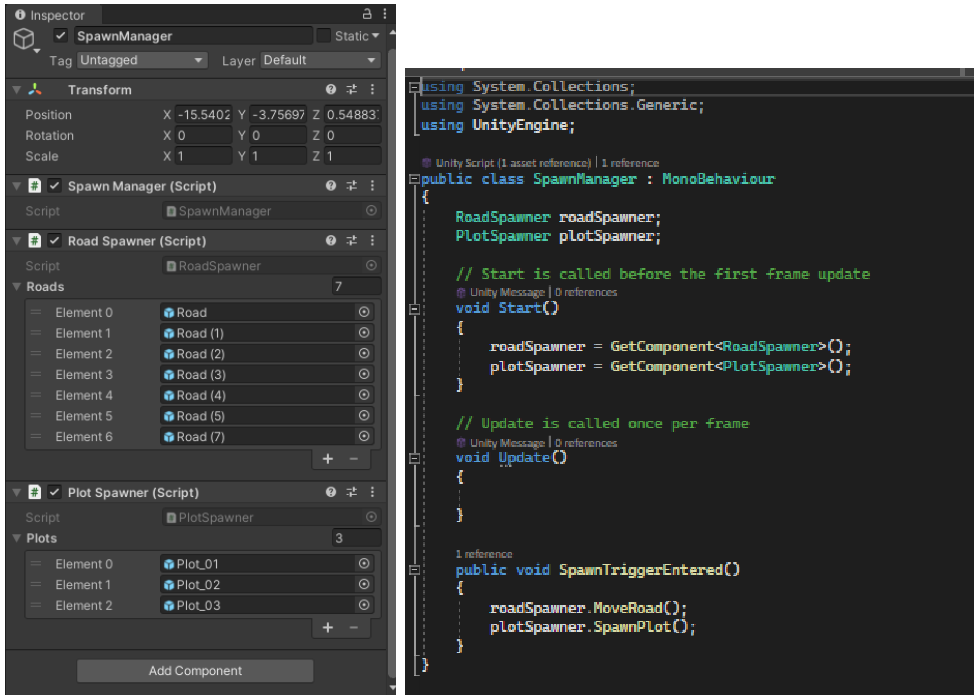


Fig. 107, 18: Unity spawn manager code and inspector view.

```
using System.Collections;
using System.Collections.Generic;
using UnityEngine;
using System.Linq;

public class RoadSpawner : MonoBehaviour
{
    public List<GameObject> roads;
    private float offset = 98f;

    // Start is called before the first frame update
    void Start()
    {
        if(roads != null && roads.Count > 0)
        {
            roads = roads.OrderBy(r => r.transform.position.z).ToList();
        }
    }

    // Update is called once per frame
    void Update()
    {

    }

    1 reference
    public void MoveRoad()
    {
        GameObject movedRoad = roads[0];
        roads.Remove(movedRoad);
        float newZ = roads[roads.Count - 1].transform.position.z + offset;
        movedRoad.transform.position = new Vector3(0, 0, newZ);
        roads.Add(movedRoad);
    }
}
```

Fig. 119: Road Spawner Script.

```
Unity Script (1 asset reference) | 2 references
public class PlotSpawner : MonoBehaviour
{
    private int initAmount = 1;
    //private float initStartZ;
    private float plotSize = 350;
    private float xPosLeft = -88;
    private float xPosRight = 90;
    private float lastZPos = 0;


    public List<GameObject> plots;
    // Start is called before the first frame update
    Unity Message | 0 references
    void Start()
    {
        for (int i = 0; i < initAmount; i++)
        {
            SpawnPlot();
        }
    }

    // Update is called once per frame
    Unity Message | 0 references
    void Update()
    {

    }

    2 references
    public void SpawnPlot()
    {
        //Debug.Log("SPAWNED");
        GameObject plotLeft = plots[Random.Range(0, plots.Count)];
        GameObject plotRight = plots[Random.Range(0, plots.Count)];

        float zPos = lastZPos + plotSize;

        GameObject clone1 = Instantiate(plotLeft, new Vector3(xPosLeft, 0.35f, zPos), plotLeft.transform.rotation);
        //Instantiate(plotLeft, new Vector3(xPosLeft*2.8f, 0.35f, zPos), plotLeft.transform.rotation);

        GameObject clone2 = Instantiate(plotRight, new Vector3(xPosRight, 0.35f, zPos), new Quaternion(0, 0, 0, 0));
        //Instantiate(plotRight, new Vector3(xPosRight*2.8f, 0.35f, zPos), new Quaternion(0, 0, 0, 0));

        if (Vector3.Distance(transform.position, plotLeft.transform.position) > 20)
            Destroy(plotLeft);

        //if (clone1.transform.position.z > moveCube.rb.transform.position.z+50)
            //Destroy(clone1);
        lastZPos += plotSize;
    }
}
```

Fig. 20: Plot Spawner Script.

Movement Manager

Using the data stream being read from the Arduino board IMU, a script was created to push the participant through the level using in-engine gravity. This was a much more reliable and accurate approach, as acceleration and deceleration would be automatically calculated by Unity, and require less processing time.

Here a max speed value is set, checks on the velocity of the bicycle will ensure it is not going dangerously fast for the purposes of user testing and demonstration.

```
using System.Collections;
using System.Collections.Generic;
using UnityEngine;

Unity Script (2 asset references) | 2 references
public class MoveCube : MonoBehaviour
{
    // Start is called before the first frame update
    //private BleTest script;
    public BleTest script;
    //public float movementSpeed = 10f;



    float MaxSpeed = 50f;
    public float movementSpeed = 0;
    public Rigidbody rb;
    public bool isTurning = false;
    public bool hasMoved = false;


    List<float> Forces = new List<float>();

    Unity Message | 0 references
    void Start()
    {
        rb = GetComponent<Rigidbody>();
        movementSpeed = 0;
    }


```

Fig. 212: Movement Manager Script.

Logic operators for “isTurning” and “hasMoved” ensure that, on each frame the update function is called, it is not applying the same force value last sent by the Arduino, in the scenario that the user is no longer pedalling, or has stopped.

```
void Update()
{
    if(Input.GetKey(KeyCode.UpArrow))
    {
        isTurning = true;
        Debug.Log("NO MATCH");
        movementSpeed = script.remoteAngle;
        GetComponent<Rigidbody>().AddForce(new Vector3(0, 0, +20));
        //they dont match, so the bicycle is moving
    }

    if (rb.velocity.z > 1)
    {
        Debug.Log("HASMOVED TRUE");
        hasMoved = true;
    }


    Debug.Log(rb.velocity);
    float spd = script.remoteAngle;
    if (movementSpeed == script.remoteAngle || movementSpeed == script.remoteAngle +1 || movementSpeed == script.remoteAngle - 1)
    {
        isTurning = false;
        Debug.Log("MATCH");


    }
    else
    {
        isTurning = true;
        Debug.Log("NO MATCH");
        movementSpeed = script.remoteAngle;
        GetComponent<Rigidbody>().AddForce(new Vector3(0, 0, +50));
        //they dont match, so the bicycle is moving
    }



    if (rb.velocity.z > 50)
    {
        Debug.Log("TOOFAST");
        GetComponent<Rigidbody>().AddForce(new Vector3(0, 0, -50));
    }




}
```

Fig. 22: Main Section of the Movement Manager Script.

If statements were employed to mitigate minor changes in force applied. And velocity checks were implemented to stop dangerous cycling.

Raycasting

Raycasting was implemented as a Virtual Reality interaction measure when a participant did not have access to joystick controllers while they were cycling, or using mobile VR.

The code below determines whether the user is looking at a button, if they look at the button for longer than 3 seconds, this confirms their selection.

```
//public GameObject gameObject;

[SerializeField] LayerMask layer1;
[SerializeField] LayerMask layer2;

bool isCounting = false;
float countdown;
public float time = 3;
public LevelChanger changer;


// Start is called before the first frame update

// Update is called once per frame
Unity Message | 0 references
void Update()
{
    //selector(layer2);
    //selector(layer1);

    selector();
}

1 reference
public void selector()
{
    if (Physics.Raycast(transform.position, transform.TransformDirection(Vector3.forward), out RaycastHit hit, 500f))
    {
        /*
        if (hit.transform.CompareTag(tag))
        {
            Debug.Log(tag + " selected");
            isCounting = true;
        }
        */
        //Debug.Log(" selected");
        isCounting = true;
    }
    else
    {
        isCounting = false;
        countdown = time;
        //Debug.Log("notselected");
    }
    if (countdown <= 0)
    {
        Debug.Log("selected 3 seconds");
        hit.transform.gameObject.SetActive(false);
        //Destroy(hit.transform.gameObject);

    }

    if (isCounting) countdown -= Time.deltaTime;

    }
}
```

Fig. 23: Raycasting script.

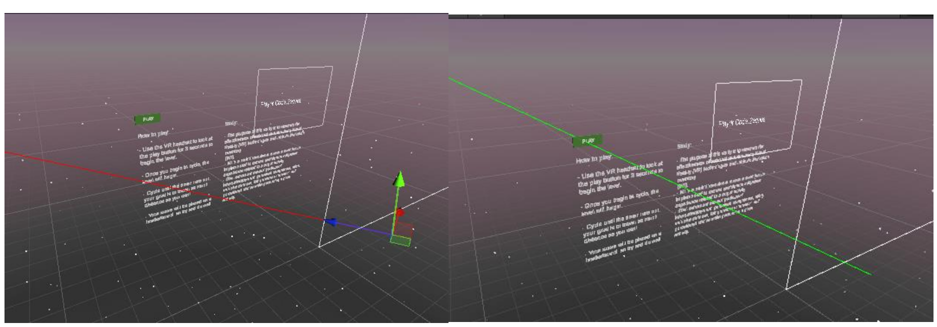


Fig. 24,25: Proof-of-concept raycasting when interacting with a button.

As you can see, when the user is not making direct contact with the button, the ray is red, when the ray is green, a countdown is started. Once the conditions of the countdown are met (it reaches 0), the game object is triggered.

Timer

A timer was implemented to increase pressure and motivation on participants during the test.

Once the participant starts moving, the timer begins, the update function is called once per Unity frame, which is equivalent to a single second, and decrements the counter by one on each pass, and the total distance travelled is update.

Once the timer stops, the score is recorded and sent to the score manager.

```
Unity Message | 0 references
void Update()
{
    if(moveCube.hasMoved == true)
    {
        if (timeValue > 0)
        {
            timeValue -= Time.deltaTime;
            recordScore = false;
        }
        else if (timeValue < 1)
        {

            timeValue = 0;
            finaldistance = distance.totalDistance;
            Debug.Log(finaldistance);

            //watch for sudden stop, maybe change to an addforce op
            //moveCube.rb.velocity = new Vector3(0, 0, 0);

            if (recordScore == false)
            {
                scoreboard.gameObject.SetActive(true);
                scoreManager.AddScore(new Score(GlyphGen.code, finaldistance));//change readinput to code

                scoreUi.getScores();
                recordScore = true;
            }
            //scoreboard.gameObject.SetActive(true);
            //scoreUi.getScores();

        }
    }
    DisplayTime(timeValue);

}

1 reference
void DisplayTime(float timeToDisplay)
{
    if(timeToDisplay < 0)
    {
        timeToDisplay = 0;
    }


    float minutes = Mathf.FloorToInt(timeToDisplay / 60);
    float seconds = Mathf.FloorToInt(timeToDisplay % 60);

    timerText.text = string.Format("{0:00}:{1:00}",minutes,seconds);
}
}
```

Fig. 26: Timer Script.

A displayTime function was also created to visualise and convert the countdown timer into a human-readable format.

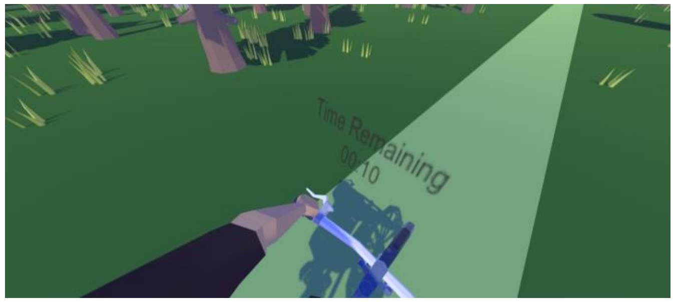


Fig. 13: Timer used in the Unity Simulation

Distance Travelled

Total distance travelled was recorded by adding the sum of the player location with their previous location on each physics based update using the FixedUpdate() method.

```
using System.Collections;
using System.Collections.Generic;
using UnityEngine;

Unity Script (1 asset reference) | 1 reference
public class DistanceTravelled : MonoBehaviour
{
    public GameObject player;
    public float totalDistance = 0;
    public bool record = true;
    private Vector3 previousLoc;

    Unity Message | 0 references
    private void Start()
    {
        totalDistance = totalDistance - player.transform.position.z;
    }
    Unity Message | 0 references
    void FixedUpdate()
    {
        if (record)
            RecordDistance();
    }
    1 reference
    void RecordDistance()
    {
        totalDistance += Vector3.Distance(transform.position, previousLoc);
        previousLoc = transform.position;
    }
    0 references
    void ToggleRecord() => record = !record;
}
```

Fig. 27: Distance Travelled script.

Leader board

A simple local leader board was implemented to provide competitiveness between participants.

A score manager script was created to take input data, namely the participant player code and score, and store them in an encrypted json format for use between sessions. This meant even when the program was used between systems, the score board would remain.

```
using System;
using System.Collections;
using System.Collections.Generic;
using System.Linq;
using UnityEngine;

Unity Script (2 asset references) | 2 references
public class ScoreManager : MonoBehaviour
{
    private ScoreData sd;
    Unity Message | 0 references
    void Awake()
    {
        var json = PlayerPrefs.GetString("scores", "{}");
        sd = JsonUtility.FromJson<ScoreData>(json);
        //sd = new ScoreData();
    }

    1 reference
    public IEnumerable<Score> GetHighScores()
    {
        return sd.scores.OrderByDescending(x => x.score);
    }

    1 reference
    public void AddScore(Score score)
    {
        sd.scores.Add(score);
    }

    Unity Message | 0 references
    private void OnDestroy()
    {
        SaveScore();
    }

    1 reference
    public void SaveScore()
    {
        var json = JsonUtility.ToJson(sd);
        Debug.Log(json);
        PlayerPrefs.SetString("scores", json);
    }

}
```

Fig. 28: ScoreManager script.

After scores were appended and stored in a .json format. The physical score UI board was updated using the ScoreUI script.

This looped over every element in the json file, and assigned the appropriate score characteristics to the UI elements of the game world.

```
using System.Collections;
using System.Collections.Generic;
using System.Linq;
using UnityEngine;

Unity Script (2 asset references) | 1 reference
public class ScoreUi : MonoBehaviour
{
    public RowUi rowUi;
    public ScoreManager scoreManager;

    Unity Message | 0 references
    void Start()
    {
        //getScores();
        //scoreManager.AddScore(new Score("Eran", 6));


    }

    1 reference
    public void getScores()
    {
        var scores = scoreManager.GetHighScores().ToArray();
        for (int i = 0; i < scores.Length; i++)
        {
            var row = Instantiate(rowUi, transform).GetComponent<RowUi>();
            row.rank.text = (i + 1).ToString();
            row.name.text = scores[i].name;
            row.score.text = scores[i].score.ToString();
        }
    }
}
```

Fig. 29: ScoreUI script.

The result produced a scoreboard that would appear at the end of every participation session.

Fig. 30: Score Board proof-of-concept.

BLE

To save weeks of development and time, an open-source BLE API was utilized and modified from a repo created by Adabru.

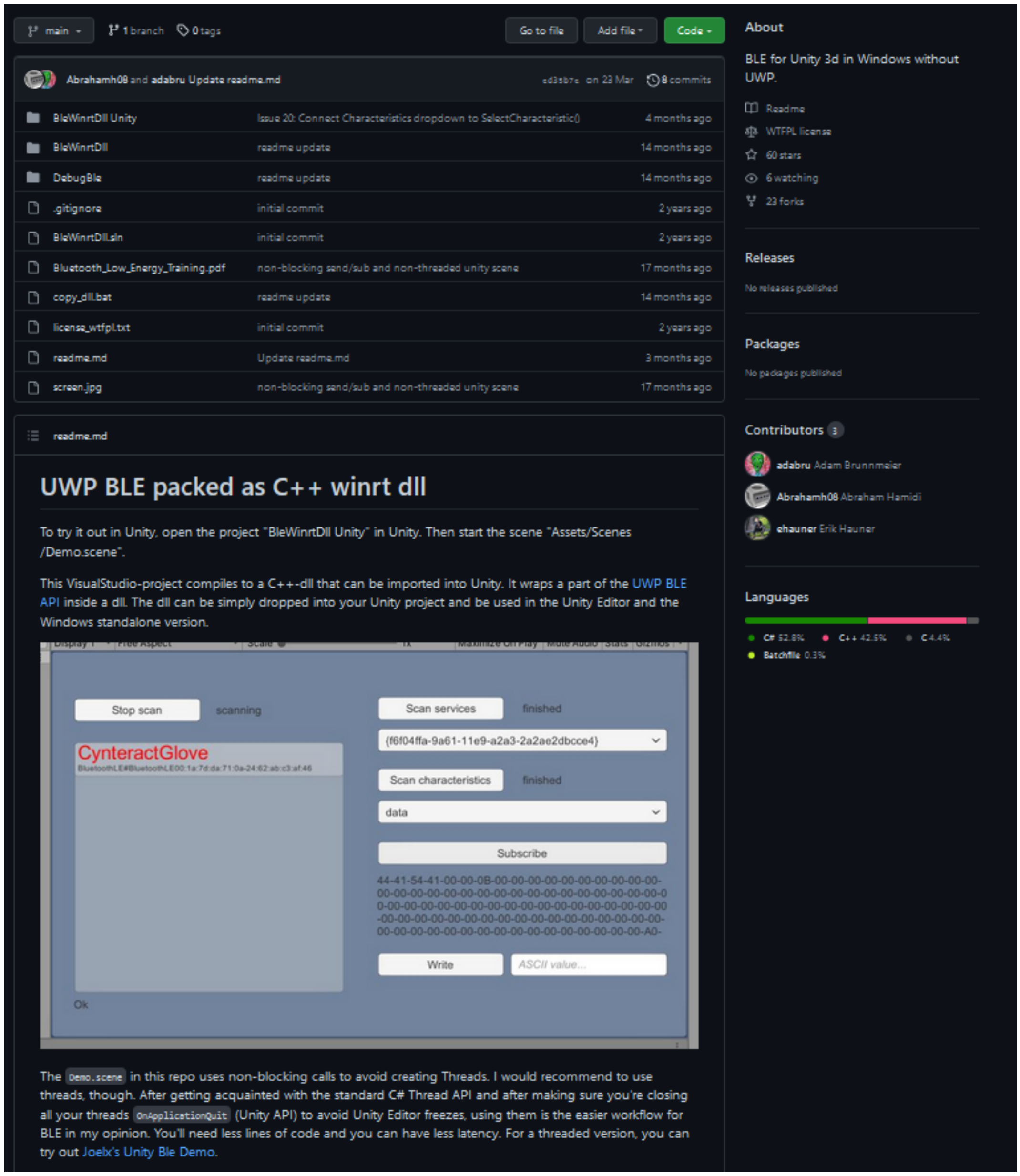


Fig. 314: BleWinrtDll repo – (Adabru, 2020).

This simplified API allowed for the advertisement and connection of BLE devices within Unity Engine.

Modifications were made to the example code to create a Unity BLE service that operated on the principles of 'Threads'. Thread is a low-power mesh networking technology for IoT devices (ref). It is reliable, secure and enables the fast response of input/output data between BLE devices, which was required for the nature of the project.

Firstly the device name and characteristics were assigned to the script, so the game new which specific device to look for during startup.

```
using System;
using System.Collections;
using System.Collections.Generic;
using System.Threading;
using UnityEngine;
using UnityEngine.UI;

Unity Script (1 asset reference) | 3 references
public class BleTest : MonoBehaviour
{
    // Change this to match your device.
    string targetDeviceName = "Arduino Nano 33 BLE";
    string serviceUuid = "{9A48ECBA-2E92-082F-C079-9E75AAE428B1}";
    string[] characteristicUuids = {
         "{00002713-0000-1000-8000-00805f9b34fb}"      // CUUID 1

    };

    BLE ble;
    BLE.BLEScan scan;
    bool isScanning = false, isConnected = false;
    string deviceId = null;
    IDictionary<string, string> discoveredDevices = new Dictionary<string, string>();
    int devicesCount = 0;

    // BLE Threads
    Thread scanningThread, connectionThread, readingThread;

    // GUI elements
    public Text TextDiscoveredDevices, TextIsScanning, TextTargetDeviceConnection, TextTargetDeviceData;
    public Button ButtonEstablishConnection, ButtonStartScan;
    public int remoteAngle, lastRemoteAngle;


    // Start is called before the first frame update
    Unity Message | 0 references
    void Start()
    {
        ble = new BLE();
        ButtonEstablishConnection.enabled = false;
        TextTargetDeviceConnection.text = targetDeviceName + " not found.";
        readingThread = new Thread(ReadBleData);

        //Call Scan Handler
        StartScanHandler();
```

Fig. 32: Modified BLEtest script.

Then, a new BLE thread was created on script initialization, which would read data coming in from a device.

The ScanHandler() function was called, which began the service of looking for devices.

```
1 reference
void ScanBleDevices()
{
    scan = BLE.ScanDevices();
    Debug.Log("BLE.ScanDevices() started.");
    scan.Found = (_deviceId, deviceName) =>
    {
        Debug.Log("found device with name: " + deviceName);
        discoveredDevices.Add(_deviceId, deviceName);

        if (deviceId == null && deviceName == targetDeviceName)
            deviceId = _deviceId;

    };

    scan.Finished = () =>
    {
        isScanning = false;
        Debug.Log("scan finished");
        if (deviceId == null)
            deviceId = "-1";


    };
    while (deviceId == null)
        Thread.Sleep(500);
    scan.Cancel();
    scanningThread = null;
    isScanning = false;

    if (deviceId == "-1")
    {
        Debug.Log("no device found!");
        return;
    }
    StartConHandler();
}

// Start establish BLE connection with
// target device in dedicated thread.
2 references
public void StartConHandler()
{
    Debug.Log("STARTCONHANDLERWASCALLED!!!!!!");
    connectionThread = new Thread(ConnectBleDevice);
    connectionThread.Start();

}
```

Fig. 33: BleTest script scanhandler() function.

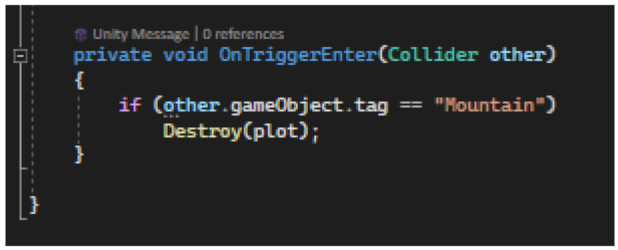
This created a new thread and called the ScanBleDevices() function, on the condition that the scan had finished, and a device had been found – the connection handler StartConHandler() function was called to establish a connection and read BLE device data from the Arduino.

This device data was declared as a public static variable, which meant it could be called amongst any script within the scope of the MonoBehaviour namespace, this meant it could be used for the player move scripts or other pertinent features.

Optimisation

A simple solution to optimisation was created to stop the instantiation of too many game objects in once session, which could cause system instability.

A game object was created which followed far behind the player as they moved throughout the level and removed everything it touched. This was a straightforward approach to optimization of the game world



```
Unity Message | 0 references
private void OnTriggerEnter(Collider other)
{
    if (other.gameObject.tag == "Mountain")
        Destroy(plot);
}

}
```

Fig. 34: Destroyer script.

Most optimisation came from the low-poly design approach of the simulation.

Player Code generation

Player codes were generated using a dictionary of symbols titled ‘glyps’, when the glyphgen function was called, a range of characters were set, and a random alphanumeric symbol was taken from the dictionary over each pass.

This provided each participant with a secure, anonymized player code that could be used to track progress during participation.

```
public class GlyphGen : MonoBehaviour
{
    const string glyphs = "abcdefghijklmnopqrstuvwxyz0123456789";
    public static string code;
    //add the characters you w
    // Start is called before the first frame update
    //int charAmount = Random.Range(5, 5);
    public Text text;
    void Start()
    {
        glyphgen();
    }

    // Update is called once per frame
    void Update()
    {

    }

    void glyphgen()
    {
        int charAmount = Random.Range(6, 6); //set those to the minimum and maximum length of your string
        for (int i = 0; i < charAmount; i++)
        {
            code += glyphs[Random.Range(0, glyphs.Length)];
        }
        Debug.Log(code);
        text.text = code;
    }
}
```

Fig.35: Player code generator 'glyphgen' script.

Gyroscope

Manual Gyroscope functionality was added for use and testing between mobile VR applications, this sets the correct initial rotation and position of the player camera, rather than the relative location of the phone.

Then the script checks for the presence of a gyroscope, and uses the offset to provide accurate visual feedback.

```
using UnityEngine;

Unity Script (2 asset references) | 0 references
public class Gyroscope : MonoBehaviour
{
    private Quaternion offset;

    Unity Message | 0 references
    private void Start()
    {
        if (SystemInfo.supportsGyroscope)
        {
            Input.gyro.enabled = true;
        }
        offset = transform.rotation * Quaternion.Inverse(GyroToUnity(Input.gyro.attitude));
    }

    // Update is called once per frame
    Unity Message | 0 references
    void Update()
    {
        if (SystemInfo.supportsGyroscope)
            GyroModifyCamera();

    }

    2 references
    private Quaternion GyroToUnity(Quaternion q)
    {
        //difference of x y z??

        return new Quaternion(q.x, q.y, -q.z, -q.w);
    }

    1 reference
    void GyroModifyCamera()
    {
        //Apply offset
        transform.rotation = offset * GyroToUnity(Input.gyro.attitude);
    }
}
```

Fig. 36: Gyroscope control script.

Animation

Physics-based animation was also implemented to the wheels and pedals of the Player Bicycle model. The rotational force of the object relied upon the velocity of the player game object, this resulted in simplistic, but very accurate moving animations.

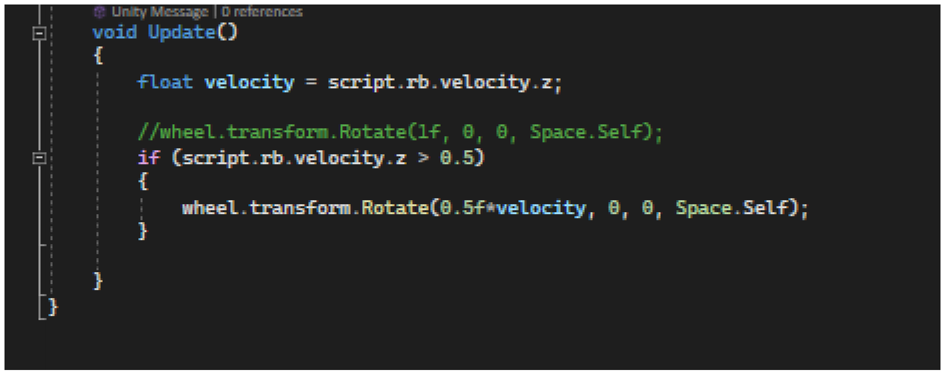


Fig. 37: Animation script.

Arduino

A major feature of the project is the Arduino, this portable device enables the gathering and transmittal of gyroscopic data over short-ranges using power-efficient wireless technologies.

Thankfully, due to the open source nature of the Arduino Electronics Platform, examples provided by the Arduino company, and a well-established long term community, resources and guidance for development was plentiful.

Firstly, the appropriate packages were loaded to the Arduino, these were the ArduinoBLE header, which controlled and Bluetooth connections, characteristics or input/output of data over the device.

And the LSM9DS1 header, which was a package containing functionality for the 9-Axis Internal Measurement Unit belonging to the Arduino Nano board, allowing for the utilization of the board's sensors.

```
#include <ArduinoBLE.h>
#include <Arduino_LSM9DS1.h>


//----------------------------------------------------------------------------------------------------------
// BLE UUIDs
//----------------------------------------------------------------------------------------------------------

#define BLE_UUID_TEST_SERVICE              "9A48ECBA-2E92-082F-C079-9E75AAE428B1"
#define BLE_UUID_ACCELERATION              "2713"
//#define BLE_UUID_ACCELERATION              "00002713-0000-1000-8000-00805f9b34fb"
#define BLE_UUID_COUNTER                   "1A3AC130-31EE-758A-BC50-54A61958EF81"
#define BLE_UUID_RESET_COUNTER             "FE4E19FF-B132-0099-5E94-3FFB2CF07940"

//----------------------------------------------------------------------------------------------------------
// BLE
//----------------------------------------------------------------------------------------------------------

BLEService testService( BLE_UUID_TEST_SERVICE );
BLEByteCharacteristic accelerationCharacteristic( BLE_UUID_ACCELERATION, BLERead | BLENotify );
BLEUnsignedLongCharacteristic counterCharacteristic( BLE_UUID_COUNTER, BLERead | BLENotify );
BLEBoolCharacteristic resetCounterCharacteristic( BLE_UUID_RESET_COUNTER, BLEWriteWithoutResponse );
```

Fig. 38: Arduino BLE and IMU script.

The BLE service, test and input/output characteristics were defined, these would be used to identify and connect the Arduino to other devices over Bluetooth.

```
bool setupBleMode()
{
  if ( !BLE.begin() )
  {
    return false;
  }

  // set advertised local name and service UUID:
  BLE.setDeviceName( "Arduino Nano 33 BLE" );
  BLE.setLocalName( "Arduino Nano 33 BLE" );
  BLE.setAdvertisedService( testService );

  // BLE add characteristics
  testService.addCharacteristic( accelerationCharacteristic );
  testService.addCharacteristic( counterCharacteristic );
  testService.addCharacteristic( resetCounterCharacteristic );

  // add service
  BLE.addService( testService );

  // set the initial value for the characteristic:
  accelerationCharacteristic.writeValue( 0.0 );
  counterCharacteristic.writeValue( 0 );

  // start advertising
  BLE.advertise();

  return true;
}
```

Fig. 39: Arduino BLE and IMU script.

The BLE device name and broadcast service was assigned, and characteristics were added for broadcasting, the initial characteristic values of the device were set and the BLE module begin broadcasting or “advertising” the device.

```
void loop()
{
  static unsigned long counter = 0;
  static long previousMillis = 0;

  // listen for BLE peripherals to connect:
  BLEDevice central = BLE.central();

  if ( central )
  {
    Serial.print( "Connected to central: " );
    Serial.println( central.address() );

    while ( central.connected() )
    {
      if( resetCounterCharacteristic.written() )
      {
        counter = 0;
      }

      long interval = 20;
      unsigned long currentMillis = millis();
      if( currentMillis - previousMillis > interval )
      {
        previousMillis = currentMillis;

        //Serial.print( "Central RSSI: " );
        //Serial.println( central.rssi() );

        if( central.rssi() != 0 )
        {
          digitalWrite( RSSI_LED_PIN, LOW );
          //float accelerationX, accelerationY, accelerationZ;

          if ( IMU.accelerationAvailable() )
          {

            //HERE

            IMU.readAcceleration( x, y, z );

            if (x < -0.1) {
              x = 100 * x;
```

Fig. 40: Arduino BLE and IMU script.

The main loop function looked for BLE devices to connect, and when connected, read the acceleration values of the IMU sensor

```
        if( central.rssi() != 0 )
        {
          digitalWrite( RSSI_LED_PIN, LOW );
          //float accelerationX, accelerationY, accelerationZ;

          if ( IMU.accelerationAvailable() )
          {

            //HERE

            IMU.readAcceleration( x, y, z );

            if (x < -0.1) {
              x = 100 * x;
              degreesX = map(x, 0, -100, 0, 90);
              //Serial.print("Tilting down");
              Serial.print(degreesX);
              Serial.println("  d Down");
           }
            delay(50);

            accelerationCharacteristic.writeValue(degreesX);


          }

          counter++;
          counterCharacteristic.writeValue( counter );
        }
        else
        {
          digitalWrite( RSSI_LED_PIN, HIGH );
        }
      } // intervall
    } // while connected

    Serial.print( F( "Disconnected from central: " ) );
    Serial.println( central.address() );
  } // if central
} // loop
```

Fig. 41: Arduino BLE and IMU script.

After reading accelerometer data of the device, downwards force on the x axis of the device was calculated and assigned to the accelerationCharacteristic of the BLE module, this was then written and broadcast wirelessly to any device that connected to the Arduino.

Operation

To use the system, An Arduino board loaded with the IMU reader and BLE transmittal code is attached to an external power source and powered on automatically.

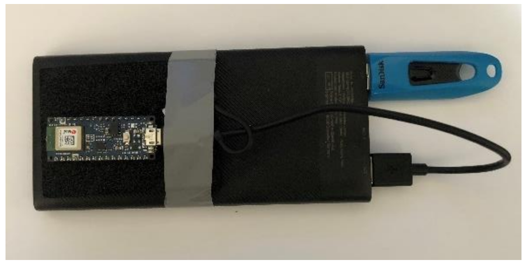


Fig. 42: Arduino Device attached to power bank.

A static or exercise bicycle is required for operation of the device, and the Arduino's housing is attached to the underside of either pedal.

Foot loops are a common feature of most exercise bicycles, which prevent the slipping of feet during exercise, as I am using a mountain bicycle with a bicycle trainer and tire, a foot loop was improvised using zip-ties and tape.

This is a safety measure to A) ensure the ensure does not lose footing and fall of of the bicycle, and B) to ensure the user does not stand on and damage the device attached to the pedals during use.

A video containing a demonstration on how the Mixed Reality system works is attached to the link below.

https://youtu.be/23eWtzB5Yhc

Fig. 43: Bicycle with Bicycle trainer attached.

The board is stored in a housing affixed to the bottom of the bicycle pedal, where it lays face-down and secured using the re-usable zip-tie located at the end of the housing.

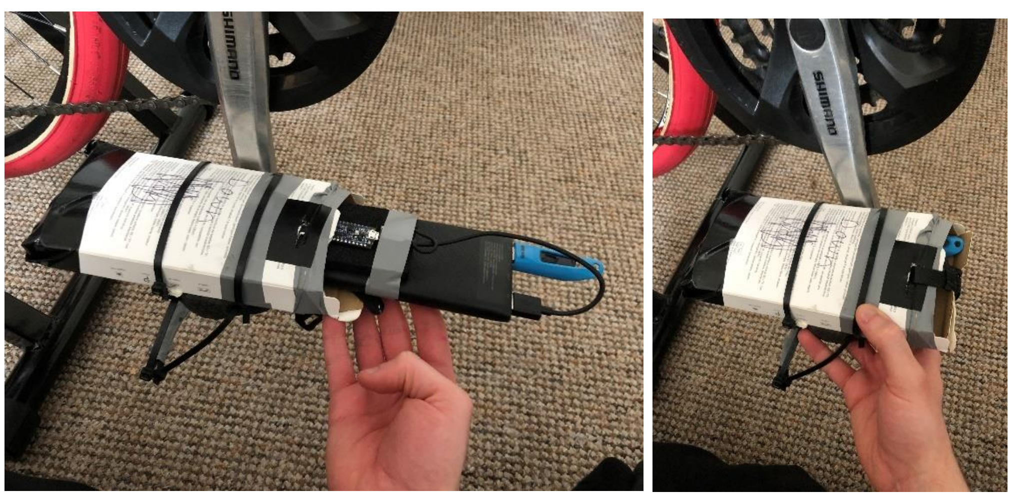


Fig. 44: Securing the Arduino to the bicycle using the housing.

The participant places their foot through the foot-loop, and sits atop the bicycle

Fig. 45: Operation of the bicycle.

The Virtual Reality Head-Mounted Display is placed on the user's head and loaded up with the endless runner software. This can be performed by user the participant or help from another person.

Depending on the type of headset used. Such as a wired headset, it is recommended that a third-party help you with this if possible. The experience designed for using wireless, mobile or remote Virtual Reality devices such as Phone-mounted displays, or the Oculus quest.

Fig. 46: Mobile VR headset used.

When the simulation loads, the user placed into a main menu, containing instructions on how to play and start the game, and a short rationale as to the purpose of the study.

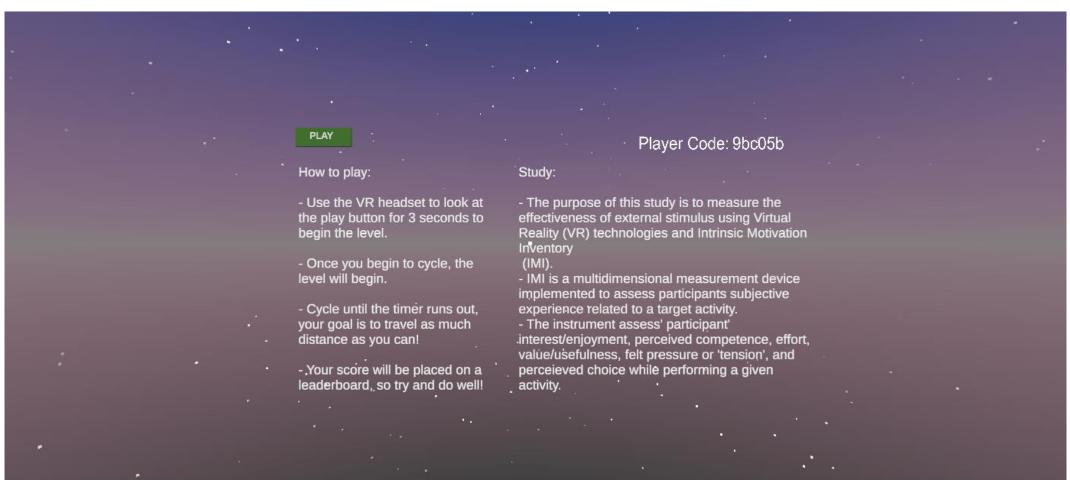


Fig. 47: Unity Main Menu.

The user begins the game by looking at the ‘play’ button for 3 seconds, once the simulation starts, the user will be transported to the endless runner level.

Once transported to the first level, BLE is connected automatically using the BLE API integration.

Fig. 48: In-game level.

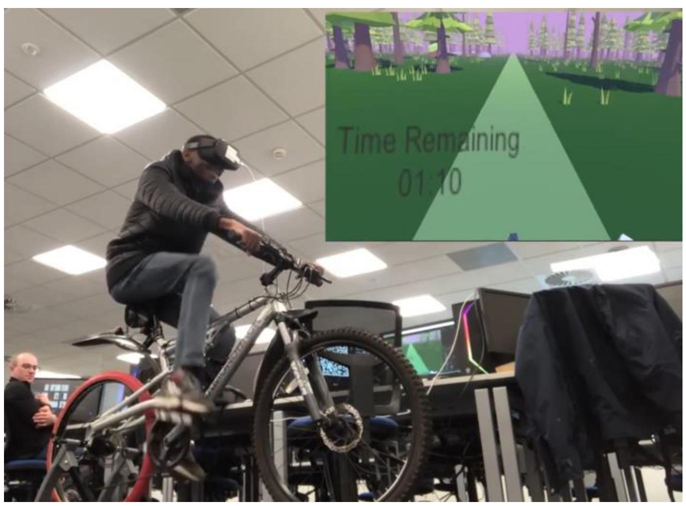


Fig. 49: Initial testing of the in-game level.

The simulation begins once the user begins pedalling, which activates a countdown timer located on the bottom left side of the bike.

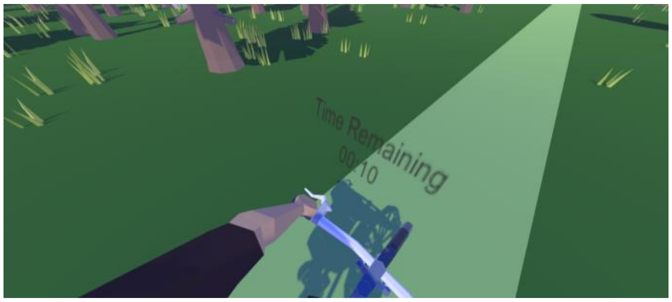


Fig. 50: Timer functionality in-game.

The goal of the participant is to travel as much distance as they can in the given time, once the timer runs out, the participant's score is recorded and placed upon a leader board.

Fig. 51: Scoreboard showing player scores and ranking.

4.2 Research

Participant recruitment

As the study aimed to represent the motivational effects of Virtual Reality devices on the general population, participant recruitment was performed in an “ad-hoc” nature. Meaning willing participants were found by asking, face to face in person. Those who were willing to participate in the study answered a few, straightforward questions on their overall health, fitness, and diet to ensure they were healthy enough to participate in the study without resulting illness or injury.

Ethics

To remain ethical integrity, participants were appropriately briefed on the scope and aims of the project study beforehand, and again during participation.

Before participation of the study began, participants were required to read a user consent form which clearly defined the criterion for participation in the study, what the study was about and how their data would be used and processed.

If participants met any of the exclusory criteria of the study, they were denied participation.

Results

Once the development phase had concluded, testing was conducted by participants using an Oculus Quest HMD borrowed from the University. Testing of the simulation was performed to determine the appropriateness of the artefact to deliver a satisfactory testing result to either support or deny the hypothesis raised in the study, and reach the goals, aims or objectives defined in the projects scoped (mentioned in the methodology section).

Participants will test the Endless runner scene of the simulation, and each will cycle to reach the highest possible score within the time given. Each participant will have the same time and approximate knowledge of the system in order to produce fair and un-biased results.

Afterwards Participants completed a participant feedback form, in which they gave qualitative feedback on the artefact as well as scoring of the 6 IMI subscales defined in the methodology sections.

Due to changes across platforms and editor versions, the simulation had to be changed slightly on the main menu scene. In which the user would be given 30 seconds to read the rules and rationale of the simulation before starting automatically.

This was because the artefact had been designed for use in mobile VR, and due to package differences, ray casting was causing unresolvable issues.

Regardless, nothing was altered over the endless runner portion of the simulation, which was the focus of the project.

Once results were gathered and submitted, the anonymised IMI results were loaded into a spreadsheet document, and tables were made with Microsoft excel to visualise and analyse the artefacts effectiveness.

Player Code	Player Score	Interest/Enjoyment	Percieved Confidence	Effort	Value/Usefulness	Felt Pressure / Tension	Perceived Choice	IMI Score
Q56jg1	4167	7	10	7	4	1	3	5.333333333
nrmtao	3900	8	6	5	7	3	5	5.666666667
29mrnr	4007	7	9	6	6	3	1	5.333333333
f9rz1w	4106	6	7	4	6	4	8	5.833333333
dyi4rg	4183	9	8	9	8	4	7	7.5

Fig. 52: IMI scores collected from participant feedback.

Qualitative Analysis of User Experience feedback

Distribution of VR experience was varied, but more participants with heavy experience using Virtual Reality devices would have been beneficial to the study.

However due to the cost, time and space requirements for the regular use of Virtual Reality, most people do not own a headset.

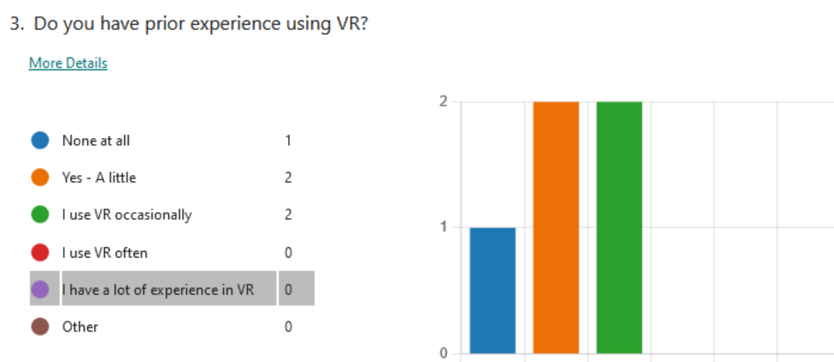


Fig. 53: Participant Feedback.

A varied distribution of cycling proficiency / experience was held by participants. This was beneficial to the study as we were able to see how much the simulation motivated experience users in contrasted in inexperienced users.

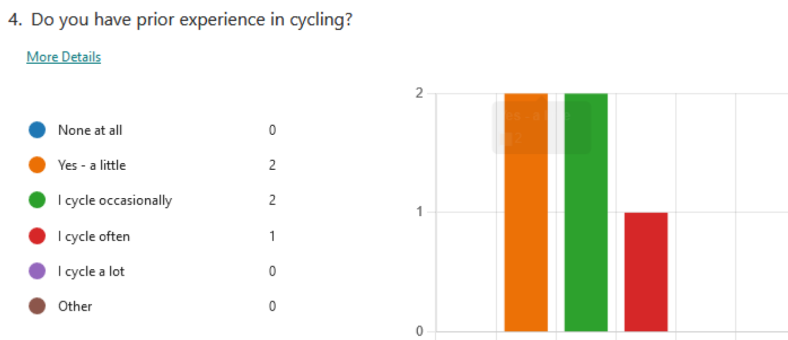


Fig. 54: Participant Feedback.

Enjoyment of the Mixed Reality simulation was unanimous, users felt calmed and immersed by the surrounding scenery, music and effects. This, in turn allowed them to focus on cycling, instead of reasoning between reality and virtual-reality.

6. What did you enjoy about the experience?

5 Responses

ID ↑	Name	Responses
1	anonymous	Immersive, nice surroundings
2	anonymous	Music and scenery was nice
3	anonymous	Going cycling through the forest was cool
4	anonymous	Felt realistic
5	anonymous	Creative vr interface

Fig. 55: Participant Feedback.

This positive feedback supports the goal of creating an immersive Virtual Reality scene to provide a basis of the study. As, if the simulation was not immersive, it would be hard to measure the effects of the external stimulus within the level.

Participants also provided critical feedback on the experience, suggesting the incorporation of hills, turns and breaking into the simulation.

All of these are both valid and feasible points, which, given appropriate time could be researched, considered, and potentially implemented into newer versions of the simulation.

7. What didn't you enjoy about the experience?

5 Responses

ID ↑	Name	Responses
1	anonymous	Road was like 5 degrees off centre so I felt as though I was ordering forward but was traveling slightly forward right in the game
2	anonymous	Could incorporate turns and hills to the video
3	anonymous	no breaking or distance measurement
4	anonymous	Took a couple of tries to work Weren't any dogs near me
5	anonymous	Nil

Fig.56: Participant Feedback.

Some potential changes / amendments reported by the participants already exist within the game's functionality and could be easily implemented given appropriate time.

Others, however, such as turns, hills and the ability to change direction arise safety concerns, which was the rationale behind the single axis-movement to begin with.

8. Is there anything you would change or add to the experience?

5 Responses

ID ↑	Name	Responses
1	anonymous	Ability to change direction
2	anonymous	Adding turns and hills, maybe a silly-ish scene that isn't a typical cycling route
3	anonymous	add a distance measurement, or change the environment as you move
4	anonymous	No
5	anonymous	Nil

Fig. 57: Participant Feedback.

This qualitative data provided structure and support for the following quantitative feedback reported from the survey. And allowed for a more in-depth analysis of the reasoning or rationale behind participant answers.

Quantitative Analysis of User Experience feedback

An initial average rating of 7.6 was given to the experience of the simulation, which further supports the hypothesis that this is an enjoyable framework for the boosting of motivation.

5. How would you rate the experience out of 10?

5 Responses

ID ↑	Name	Responses
1	anonymous	7
2	anonymous	8
3	anonymous	7
4	anonymous	7
5	anonymous	9

Fig. 58: Participant Feedback.

80% of users preferred the system over the user of a regular exercise bicycle, which provides a basis of support for validating the benefit.

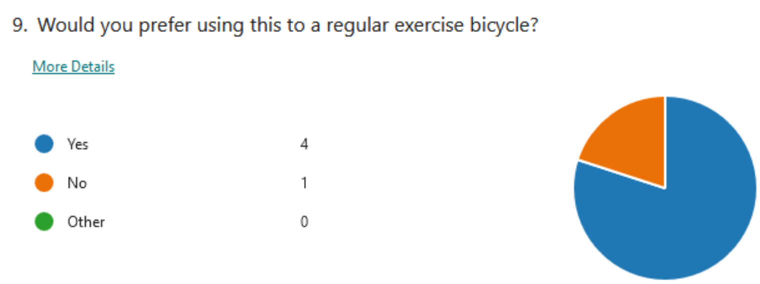


Fig. 59: Participant Feedback.

Participants also reported their thoughts on the future application of this technology for commercial or recreational use. As such, results were overwhelmingly positive.

This section of feedback supported the overreaching narrative and main goal of the study, which was to validate the use of VR technologies and their effect on motivation to progress development and research into the field of Intrinsic Motivation and exerGames.

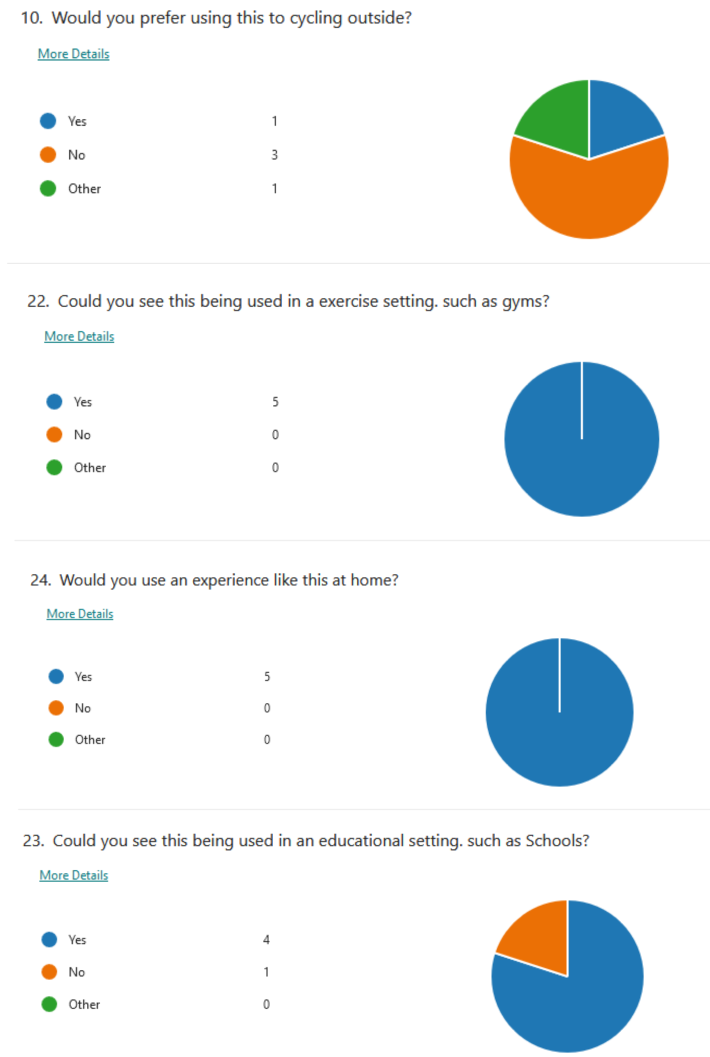


Fig. 60: Participant Feedback.

After reviewal of initial feedback of the simulation, minor amendments were made and some qualitative questions were added.

Users also reported that external stimulus such as the music, trees and timer increased their perceived motivation and performance during participation.

11. Did the external stimulus such as music, trees, or timer increase or decrease your performance or motivation, if so, why?

2 Responses

ID ↑	Name	Responses
4	anonymous	Yes
5	anonymous	Increased

Fig. 61: Participant Feedback.

However, not all participants were aware of the temporal landmarks placed within the simulation. This suggests they were not completely noticeable or ‘eye-catching’.

12. Were the landmarks such as rocks, tall trees, fallen logs and flowers noticeable, did they give you a reference point as to how far / fast you were traveling?

2 Responses

ID ↑	Name	Responses
4	anonymous	Yes
5	anonymous	No

Fig. 62: Participant Feedback.

Discussion

Simulation validation using IMI

Ultimately, the main success metric (as discussed in the methodology section), was determined by the six subscales of Intrinsic Motivation Inventory. These 6 subscales reported on the Enjoyment, Confident, Effort level, Value, Pressure and Choice perceived during participation of the study.

These 6 subscales could be used to calculate the overall Intrinsic Motivation effectiveness of a system, device or platform.

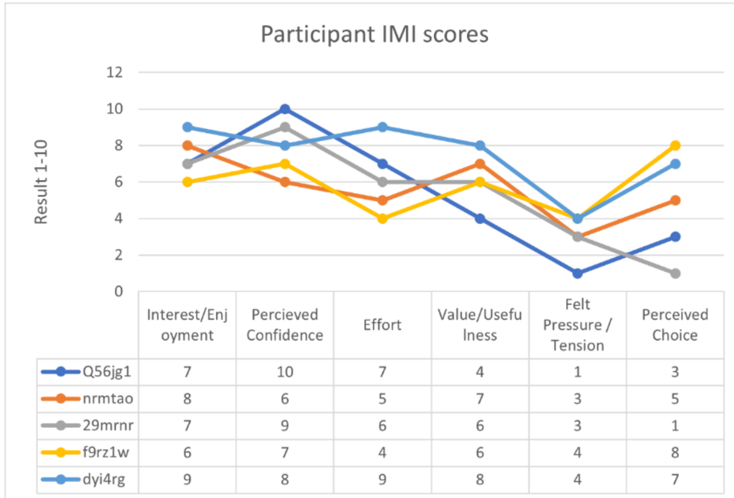


Fig. 63: Participant IMI subscale scores.

As illustrated by the scatter chart, results were positive across all participants. Each participant felt the experience was enjoyable, they felt confident using the system, effort levels were high, and many thought the system was valuable to the improvement of their health and fitness.

However, felt pressure / tension scores were low – indicating that external stressors such as the timer / scoreboard perhaps did not have the intended effect on participants' motivation.

Perceived choice received mixed results, this scale is used to determine how much freedom one feels they experience during an activity or exercise, regardless of the level of input they possess.

More perceived freedom is expected to produce an increase of endorphins, and thusly, dopamine / serotonin in the brain. This in turn, would see the increase of motivation overtime.

The average of each subscale score for every participant was calculated to receive an overall Intrinsic Motivation Inventory rating. Which represented the level of intrinsic motivation an activity, process or device produces during use.

As we can see, overall, IMI scores remain high across all participants, this tells us that most, if not all participants felt an increase in their motivation and performance during use of the Mixed Reality Platform.

Consequently, this is a strong supporter for the validity of the system.

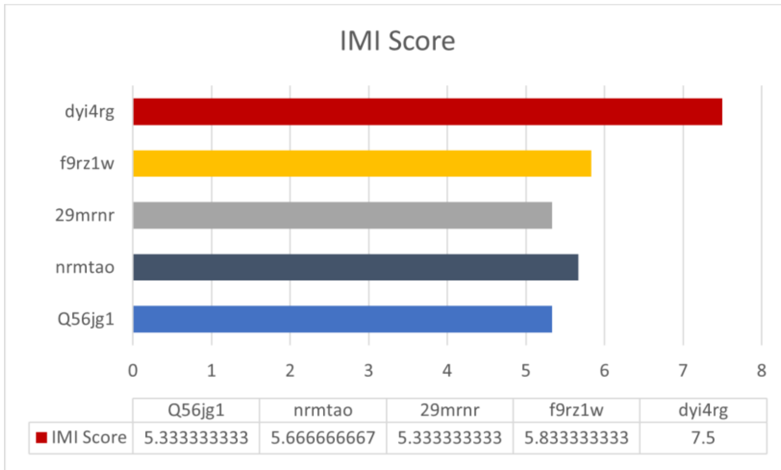


Fig. 64: Participant Overall IMI scores.

After comparing overall IMI / motivation scores with the in-simulation player score results we can see that irrespective of participant distance covered, overall performance was similar.

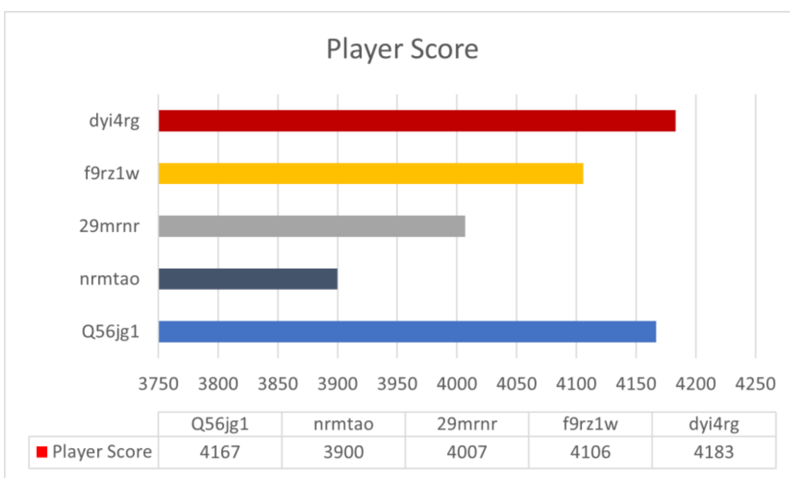


Fig. 65: Participant Player Scores.

When considering the potential range of age, physique, sex, fitness level and overall health of each individual, we can see that the participants who enjoyed the simulation more, outperformed the people who felt less encouragement of motivation.

Chapter 5

Conclusions & future application

This aim of this project focused on the theory and application behind intrinsic motivation, how it could be used, and how it could be invoked using modern immersive technologies amongst the general populace.

A Mixed Reality exercise simulation was created using a virtual reality head-mounted display, and Bluetooth capable Arduino sensory board, Unity game engine and a static bicycle.

Subsequently, I also aimed to create an adaptable, cost-effective Virtual Reality exercise experience to enable users to exercise within the safety of their home, this would allow individuals living in ‘dangerous’ areas, or those who are unable to leave their homes to exercise safely and effectively,

The purpose of this simulation was to validate the effectiveness of Virtual Reality technologies or systems in their application to increase exercise performance, through terms of intrinsic motivation.

This refers to the invocation of motivation through means of exposure to external stimulus, such as temporal landmarks, music, or visually pleasing scenery to induce a flow-like state of exercise. Or the utilization of stressors such as countdown timers, or competitive scoreboards, which subconsciously encourage individuals to work harder in order to meet seemingly arbitrary goals.

Validation of the system would be received using IMI or Intrinsic Motivation Index, to measure levels of self-determination and Intrinsic Motivation based upon six subscales of motivation (enjoyment, pressure, value, freedom of choice etc.).

The system was tested on its ability to improve overall exercise performance of participant’s during use of the system.

Results from this project indicate that during use of the system, those who reported high overall IMI scores tended to exercise more effectively, reaching higher scores.

This supports the hypothesis of increasing Intrinsic Motivation using VR technologies. As when participants completed the participant feedback survey, participants were unaware they were reporting on IMI levels and were simply asked to rate the experience from one to ten, using the six subscales of IMI.

This means pre-conceived bias should not have been an issue, had participants been aware of the fact they were specifically being graded on their level of motivation, this may have influenced study data and lead to bias or skewed results.

Irrespective of this, the main goal of the project was to research, develop and test a Virtual Reality System's effectiveness in increasing motivation in participants.

Statistical Analysis of the project results indicated that at least 80% of participants saw an increase of motivation during use of the simulation, and 20% saw large increases in motivation, which subsequently correlated to an increase of overall performance.

It could be deduced that, participants who reported higher subscale scores, such as high enjoyment, low pressure, high perceived confidence and high perceived choice, outperformed other participants who report mid-to-high levels of Intrinsic Motivation.

This supports the notion that intrinsic motivation has a quantifiable impact on the performance of both our minds and bodies during exercise.

Dataset

Overall, the research undertaken by the study was conducive in collecting and analysing results to reach an appropriate answer to the hypothesis proposed in the study.

This was made possible by the careful consideration and implementation of project management and software development methodologies and techniques employed over the course of the research, development and testing stages of the project.

Risk analysis of the projects likelihood to fail, potential challenges to arise, and mitigation of such challenges aided in the smooth production of the artefact. This, alongside time organisational and visual techniques such as Gantt charts, allowed for proper management of tasks, phases and sprints of the development lifecycle.

The implementation of agile production methodologies and tools such as scrum and Kanban allowed for a higher level of granularity, structure and organisation for each task, section of sprint of the software / hardware development phases, without these tools, development would have been slowed due to bottlenecks or issues without appropriate research or mitigation.

Due to the time constraints of the study, testing a large pool of participants was made challenging

Participant recruitment could have been more meticulously planned and structured, as not enough time or consideration was given to the selection of participants in the study.

Although the aim of the study was respective of the general population, variable such as variation in age, physique, sex, fitness, lifestyle and overall health were not considered. This ultimately made comparing the performance of participants to their IMI scores difficult.

A greater pool of participants could have been collected, furthermore, demographic groups should have been implemented, so results would represent the comparative motivational increase of those with similar conditions, such as younger people, or people who exercise regularly.

An even male to female ratio should also have been considered, as biological difference between the sexes resulted in overall different performance data, even if effort level was the same.

Due to the anonymised nature of the study, there was no way of telling which of the participant results belonged to male or female participants, this caused a bias of results.

Metrics

The goal of the study was to verify effectiveness of VR technologies in increasing intrinsic motivation and exercise performance.

Because of this, there could have been a greater focus on measuring the usability of the Mixed Reality system developed using well-establish or well-researched system usability metrics such as ISO 9241011, which provides a clear definition and standard of system usability based on Effectiveness, Efficiency, and Satisfaction.

Irrespective of the plethora of system usability metrics available, a quantifiable standard of usability would have provided supporting evidence for the validity of the system developed.

Subsequently, a greater focus on qualitative data would have been made.

Given more time, funding and equipment, the performance of each participant could have been measured overtime using performance assessments (PAR-Q – physical readiness questionnaire), biometric measures, and anthropometrical measures.

Participants would have been split into two study groups, one using just the exercise bicycle, the other using a virtual reality bicycle.

The participants would be evenly split and distributed based on age, physique, physical fitness and overall health. Then, performance increase overtime would be measured to determine motivational levels.

Performance metrics may have been beneficial to favour over intrinsic motivation as the basis of the study, as motivation is hard to measure due to its subjective nature. Individuals are motivated by many different things, some of which are unpredictable and irrational at times, therefore the invocation of motivation is difficult to trigger consistently.

If given more time, I would have created different levels or scenes, participants would then cycle through each, and their performance in relation to the external stimulus would be measured.

This would give a good indication of how external stimulus influences motivation, such as cold or noisy environments, would they decrease overall performance?

Regardless of this, IMI still provided an effective measurement of user enjoyment and motivation while using the system to provide satisfactory results during use of the MR system.

Overall, the simulation was generally well-received, and participant performance, satisfaction and levels of motivation remained positively high over the course of testing.

This data provides irrefutable evidence on the validity of using Mixed Reality systems as a means of increasing motivation and performance. By this standard, I believe the solution developed and delivered in the aim of investigating the hypothesis of the study validates the use of VR and Short-range technologies as means of increasing motivation.

In future, I hope this research will help the introduction or implementation of Mixed Reality systems in the use of places such as gyms, hospitals or schools to help improve exercise efficiency amongst individuals having difficult exercising or finding motivation to exercise.

Chapter 6

Reflective Analysis

Overall progress made considering the development of the artefact and results achieved through participant testing and statistical analysis could be considered successful with the scope of the study.

The testing phase was semi-successful, as a pool of 6 participants was smaller than expected, but still satisfactory for gathering data in support of validating the Mixed Reality system in terms of increasing intrinsic motivation.

However, minor external factors were not considered, such as sex, lifestyle, fitness and overall health. Which potentially led to a small bias of results. Anonymity of data made it difficult to mitigate this, and a paired t-test could have been used to spot variations within the dataset.

Version control between the Unity game engine and package management caused development issues while trying to implement certain features that had either not yet been updated for use with newer versions of unity, or broke while being re-imported to older versions.

Thankfully, the Unity Hub and Unity development community helped me to conclude that a rollback to a later, more stable version of Unity would be more appropriate for development.

This meant that not all new features were available, but plenty of resources for development and bug fixing existed for my Unity version, which helped development run smoothly.

Although Unity's built-in tools for cross-platform development were well-used and greatly appreciated. Some aspects of gameplay did not work when moving from mobile VR development to desktop VR development. Namely ray-casting, this prevented some minor functionality to project, and changes had to be made to mitigate this. However, this did not greatly affect the user-experience of the artefact.

BLE also became an unforeseen challenge during testing. As, in high traffic areas were many wireless connections between devices existed – such as the

University Buildings, meant range on the Bluetooth device was often interrupted and became increasingly low. This issue had never been raised before as during home development, in a low-traffic area, BLE connectivity had never been an issue.

To mitigate this an extension cable was used to position the Bluetooth receiver closer to the computer board, which preserved its wireless functionality and kept the user safe from wire-related incidents.

Furthermore, once testing began using the Oculus quest HMD, the quest seemed to randomly reset its orientation in relation to the scene. This was a very frustrating error as the headset had to be re-oriented to match the bicycle between each participant.

Due to the game being unlicensed and in development, running the Unity game on the Oculus quest wirelessly was not permitted by the device, this meant the Oculus link cable had to be used in development mode, which was something I wanted to avoid, due to safety concerns.

Despite challenges faced during the development and testing of the artefact, the project was successfully completed, all aims, objectives or goals were of the study were met and a conclusion that the system could be appropriately utilized to increase levels of motivation during exercise was made.

If the study could be performed again, more focus would have gone into optimization of the simulation, which would have provided a more immersive experience, and allowed for additional layers of functionality.

More levels would have been made to perform a more in-depth analysis on the types of motivators and their effectiveness.

In terms of data transfer, the technology used would be changed from BLE to wireless IoT, as it is more versatile and resilient than BLE and has a longer range of communication, which in theory should cause issues during development and testing.

A more in-depth screening process using a greater pool of participants would be performed to get a represent better diversity within the study and provide more accurate study data.

More data would have been collected, and there would be a greater focus on quantitative data, more success metrics and system usability scales would have been implemented to get a more accurate, well-rounded picture of the testing phase and validity of the system.

Overall, the project was challenging, but enjoyable. Mixed Reality systems are a new concept in the scope of VR technology, and I’m glad I had the opportunity to contribute towards the research of the field.

The opportunity to develop and test Virtual Reality equipment, learn game development and work on electrical software engineering has been exciting, and watching participants who were keen to use enjoy the artefact was a very fulfilling experience.

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Appendix

UNIVERSITY OF LINCOLN

Participant Information Sheet/Information about the research

Title of Study: A study of Virtual Reality and Short-range Wireless technologies on intrinsic motivation in exercise.

We are inviting you to take part in a research study. Before you decide, it is important that you know why we are doing the study and what is involved. Please read the following information carefully.

What is the purpose of the study?

This study investigates the potential validity of Virtual Reality technology for use in increasing motivation during exercise. If results support the thesis made, it is possible Virtual Reality technologies could be employed in commercial or clinical settings to increase exercise efficiency amongst users subconsciously.

Testing phases of the study will be performed on University grounds.

Am I eligible to take part?

You are being invited to take part because you have displayed appropriate interest and willing into a study which requires satisfactory levels of motivation / interest in order to provide a satisfactory result.

If suffer from any illness, injury or condition that may impede your ability / make participation in the study dangerous, you will not eligible for the study.

Do I have to take part?

Participation is completely voluntary. You should only take part if you want to and choosing not to take part will not disadvantage you in anyway.

What will I be asked to do?

You will be asked to participate in a Mixed Reality cycling exercise simulation. In which, you will use a static bicycle while wearing a Virtual Reality Head Mounted Display, and cycle through a virtual scene.

Afterwards, you will complete participant feedback results, in which, by completing, you consent to the anonymised and private use of your data for statistical analysis.

You can expect the study to last 5-10 minutes or less.

You may be asked whether you meet the exclusory criteria for the project, in which case, you will have to disclose, for a matter of participant and ethical safety.

However, you are not required to specify why you meet the exclusory criteria, which is sensitive information.

The study may contain video/audio recording or photography, in which, user's will be asked for their permission before hand.

All data will be anonymised, including participation and survey results.

You should try to describe involvement from a potential participant's perspective – what should they expect to happen if they agree to take part?

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Title of Study Participant Information Sheet Draft xx Version 1.0 date Ethics reference:

Will I be paid expenses for taking part?

You will not be paid for participation in this study.

What are the possible benefits / risks of taking part?

By participating in this study you will be given access to Virtual Reality equipment, you will be given the opportunity to exercise using a brand-new, Mixed Reality system.

There are risks involved. However, all measures are taken to minimize and mitigate the occurrence of these risks. Injury should only occur if equipment is abused, or misused during participation.

Will anyone know I have taken part?

The information we collect will be handled in confidence. No one will know you have taken part. As your responses are anonymous.

Where will my data be stored?

The data obtained from the study will be stored securely on an encrypted hardrive in password protected files. Only the researcher/researchers will have access to it. Paper copies will be stored in a secure cabinet/office at the University. The data from this study *may* be put in an Open Access repository for other researchers to use in future research.

What will happen if I don't want to carry on with the study?

As you have completed the study anonymously it will not be possible to remove the data provided, as I will not be able to identify you in any way.

What will happen to the results of the research study?

Results of the project will be used solely for the purposes of statistical analysis, and reflective analysis to help validate the hypothesis proposed in the study.

Who is organising and funding the research?

This research is being organised by Matthew Atkins at the University of Lincoln.

Who has reviewed the study?

All research conducted by the University of Lincoln is looked at by an independent group of people, called a Research Ethics Committee, to protect your interests. This study has been reviewed and given favourable opinion by a University of Lincoln Research Ethics Committee.

What if there is a problem?

It is very unlikely that this study would cause you any harm. If you have a concern or a complaint about any aspect of this study, you should ask to speak to the researchers who will do their best to answer your questions. The researchers contact details are given at the end of this information sheet.

If you remain unhappy and wish to complain formally, you can make a formal complaint through the University complaints procedure or by contacting ethics@lincoln.ac.uk.

Further information and contact details

Contact details

Matthew Atkins: 16657290@students.lincoln.ac.uk

Salah-Al Majeed: SALMajeed@lincoln.ac.uk

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Title of Study Participant Information Sheet Draft xx Version 1.0 date Ethics reference:

User Experience feedback survery

https://forms.office.com/r/KZb8aFam3F

Questions

Responses 5

User Experience Form

The survey will take approximately 5 minutes to complete.

Section 1

...

User Consent And Project Briefing

By completion of this form you are agreeing to anoynimized use of your performance data, results and questionnaire answers for statistical analysis and reviewal for the corresponding Undergraduate thesis project.

How will my data be used:
Your data will be completely anonymized, encrypted using randomized "player-codes" to maintain anonimity. Data can or may be used for statistical analysis and production of graphs or diagrams using said data.
Video footage may also be used for the purposes of demonstration during the project, before participation, you will be asked whether permission to record the performance is consented to.

What is this study about:
This study concerns the effect of Virtual Reality technologies and their impact on Intrinsic motivation. Essentially, the aim of the study is to see whether VR technology can be used to improve the perceived enjoyment/engagement and therefore effectiveness of exercise - thusly improving motivation.

1. Player Code
*

Enter your answer

2. Score *

The value must be a number