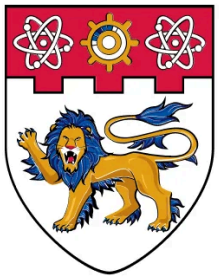

NANYANG TECHNOLOGICAL UNIVERSITY
SINGAPORE

# SC4060 - Virtual and Augmented Reality

## Final Project Report

| | |
|---|---|
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*Number of words: 4652*

*(excluding cover page, figures, and references)*

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# 1. Background

## 1.1 Motivation – Educational Challenges to Address

### (a) Importance of Red Blood Cells in the body

It is widely known that red blood cells perform integral roles in our bodies and their functions are essential to our daily life. Red blood cells transport oxygen from our lungs to our body's tissues where the tissues will use the oxygen to produce energy needed to sustain the body's functions (Cleveland Clinic Medical, 2025). Carbon dioxide is produced as waste and the red blood cells will transport it back to the lungs to be exhaled out of the body. This oxygen transportation process seems simple, but without red blood cells, a human body cannot survive.

While this may be readily taught, it can be difficult to visualise the exact processes red blood cells undertake in fulfilling their role as they are not visible to the naked eye.

Thus, many may overlook the importance of the red blood cells and neglect to take care of their body's ability to produce healthy red blood cells. An example of taking care of one's body's ability to produce healthy red blood cells is eating a nutritious diet that's full of vitamins and minerals like iron, B9, and B12, etc (Cleveland Clinic Medical, 2025).

### (b) Importance of Constant Blood Donation

Furthermore, if the human body experiences a deficiency in red blood cells, there would be detrimental effects on the individual's health as the body's ability to transport oxygen in the body is worsened. A medical condition that results in such deficiency is Anemia – a condition causing a gradual decrease in red blood cell levels in the body over time (Killeen & Tambe, 2025). This is why blood donations are crucial in saving peoples' lives as blood donations recover lost blood and red blood cells in one's body.

While most people are aware of the importance of blood donation to save peoples' lives in a medical emergency, they often overlook the constant need for blood donation due to shortages and limited storage period. For example, red blood cells last about 42 days in storage (American Red Cross, n.d.). Thus, constant blood donation is very important but most people are not aware of it as they don't experience the urgency in their own lives most of the time.

## 1.2 Educational Goals of the VR Application – LifeLine VR

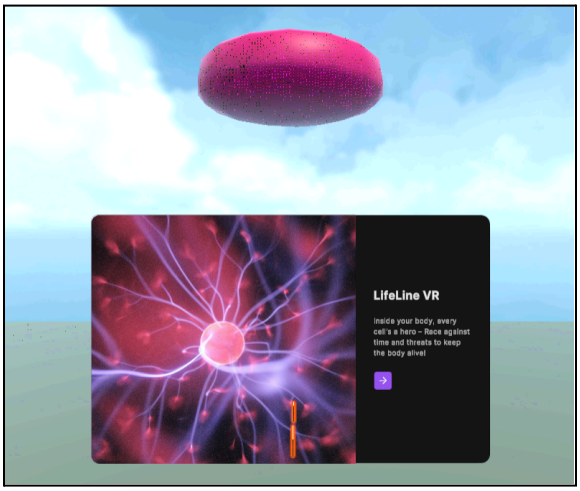
Therefore, our VR application aims to tackle the educational challenges of:

1. **Deepening the understanding of the importance of red blood cells** to a person's survival through immersive experiences and hands-on interactions of transporting oxygen from the lungs to body tissues.
2. **Raising awareness of the importance of constant blood donation** and potentially encouraging people to donate blood more frequently through immersive experiences of trying to ask for blood donations to survive as a player.

# 2. LifeLine VR

LifeLine VR application is a VR app that utilizes the immersive capabilities of VR to meet the educational goals as set out while providing a fun and immersive experience.

## 2.1 Storyline




Due to a twist of fate, you developed chronic "Anemia", a condition that results in the amount of Red Blood Cells in your body to decrease over time. This leads to reduced oxygen delivery to various parts of your body, causing you to feel fatigue, weakness, and shortness of breath. You have to forgo exercising and your body has started to deteriorate with this medical condition.

As a determined person that leads an active lifestyle, you CANNOT forgo exercising and just let your body die! So, you prayed to the Red Blood Cells God, "Red Blood Cells God, please stop my Anemia condition... I will do anything in order to survive and keep exercising... Please... Pleas..."

Bzz... Bzzzzz.... Congratulations! The Red Blood Cell God has decided to grant you a special power – The power to transform from a "Human" into a "Red Blood Cell"!

With this special power, you can assist your body's Red Blood Cells (NPCs) in transporting oxygen from the lungs to various parts of the body to keep the body alive! As a special Red Blood Cell, you can transport more oxygen than Red Blood Cells NPCs and keep the body alive with your efforts!

Your Goal? Use your new powers to keep your body alive while engaging in various human physical exercises!

## 2.2 [Scaling Space] The 2 Game Modes – Human Mode & Red Blood Cell Mode

The LifeLine VR sets the scene in 2 different game modes – **Human mode**, and **Red Blood Cell mode**. Both modes are in first person perspective and have different scales – Human mode in the human world scale while the Red Blood Cell mode is in the microscopic scale. The player can

switch between the Human mode and the Red Blood Cell mode anytime they want as they play the game **(Spatial Element and Manipulation of Scale)**.

## 2.3 [Scaling Time] Decrease of Red Blood Cells Over Time

As the player plays the game in either game modes, the percentage of red blood cells in the body will decrease gradually, with major spikes in the amount decreased every 14 mins **(Temporal Element)**. Each playtime minute equals 10 real-world days. Players will need to source for blood packs to maintain a safe level of red blood cells in the body.

## 2.4 Player's Goal

The player's goal in the game is to survive while doing different activities in the Human mode that affects the body's oxygen demand, and switching to the Red Blood Cell mode to increase the oxygen levels in the various body parts by transporting oxygen themselves. Ultimately, the player should keep their red blood cells levels and oxygen levels above 0 throughout the game.

# 3. LifeLine VR Core Features and Implementation

## 3.1 Oxygen and Red Blood Cells Levels

### 3.1.1 Oxygen Level

Oxygen is a key commodity of the game as it is required by the player's virtual body parts to survive. The player's virtual body has 3 key parts that require Oxygen – Arms, Legs and Brain.

The Arms, Legs, and Brain has a default rate of oxygen demand of -1.0 per 5 gametime seconds.

### 3.1.2 Red Blood Cells Level

Red Blood Cells Level is an important aspect of the game as it controls the rate of increase of oxygen in the virtual body. Higher red blood cells level, capped at 100, is associated with a higher rate of oxygen increase in the 3 key body parts as shown in Table 3.1.2.1.

| **Red blood cells level** | 0 - 32 | 33 - 65 | 66 - 100 |
|---|---|---|---|
| **Rate of oxygen increase in Arms, Legs, and Brain** | +0.25 per 5s | +0.5 per 5s | +0.75 per 5s |

*Table 3.1.2.1: Red Blood Cells Level vs Rate of Oxygen Increase in Arms, Legs, and Brain*

The level of red blood cells decreases gradually over time (-0.5 per 5s), with major spikes in the amount decreased every 14 mins (between -15 to -30 per 14mins).

### 3.1.3 Tracking Oxygen and Red Blood Cells Levels

The player can track their oxygen and red blood cells levels via a User Interface (UI) panel (Figure 3.1.3.1) that follows the player around. The player can toggle the panel on or off.

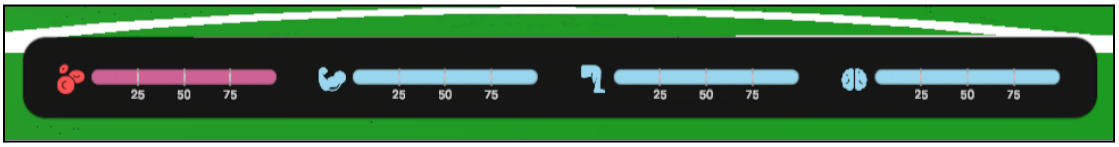



*Figure 3.1.3.1: Oxygen and Red Blood Cells Levels Panel*

### 3.1.4 Alert Notification Feature

Whenever the red blood cells levels or oxygen levels fall below half, an alert will be shown to the player to warn the player that appropriate actions need to be taken to restore the levels to a safe level (Figure 3.1.4.1).

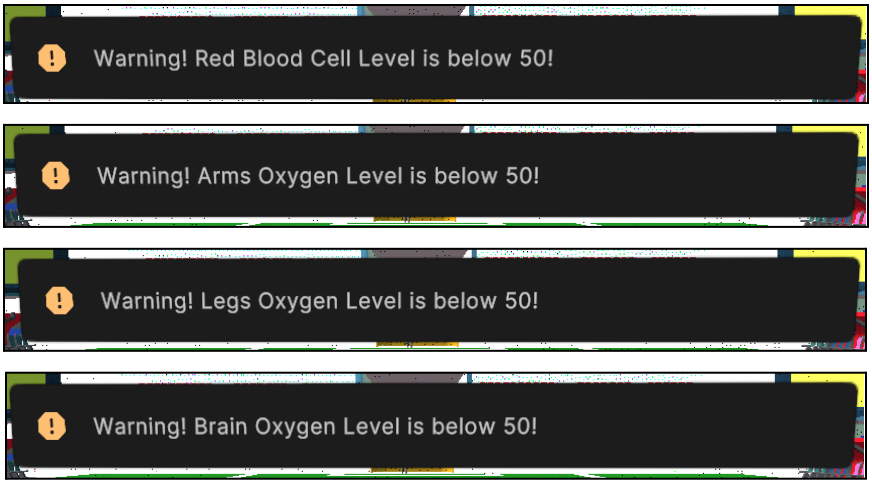



*Figure 3.1.4.1: Alert Notification to warn player of dangerous red blood cells / oxygen levels*

### 3.1.5 Game Over

The game is over if any of the 3 key body parts' oxygen level reaches 0 or if the red blood cell level reaches 0. Figure 3.1.5.1 shows the game over screen. The player can play the game again if they choose to by clicking on the "Back to Main Menu" button.

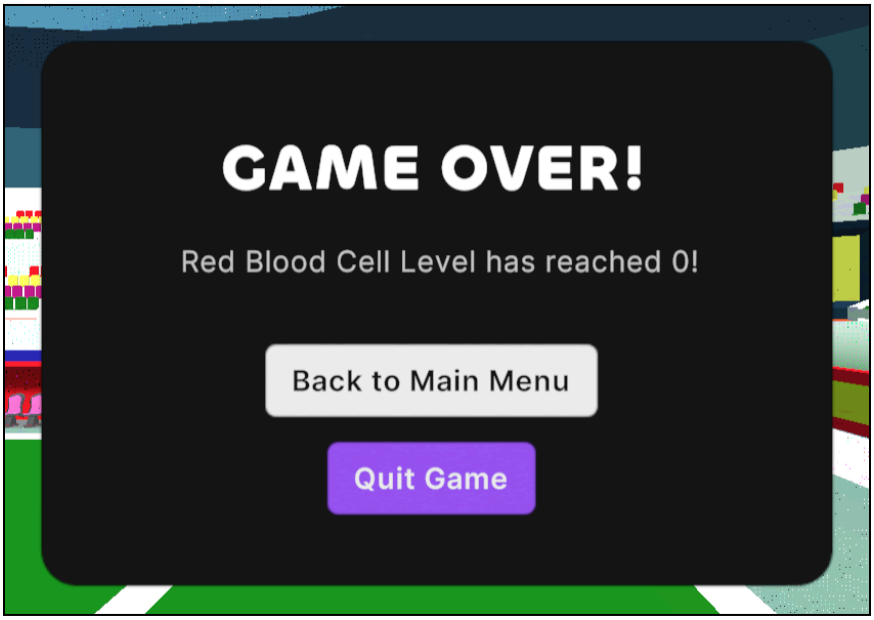



*Figure 3.1.5.1: Game Over Screen*

## 3.2 Human Mode

### 3.2.1 Performing Human Activities in Virtual Football Stadium Environment

In the Human mode scene, the player can move around and interact with the virtual football stadium environment in a first-person perspective as shown in Figure 3.2.1.1.

*Figure 3.2.1.1: Virtual Football Stadium Environment (Human Mode)*

#### (a) Impact of Human Activities on Rate of Oxygen Demand

The player can choose to perform different activities, such as walking, running, lifting dumbbells, and etc. As shown in Table 3.2.1.2, different activities will affect the rate of oxygen demand for different body parts (Arms, Legs, and Brain), replicating how human bodies work in real life.

| **Activity** | **Arms** | **Legs** | **Brain** |
|---|---|---|---|
| Walking | -1.0 per 5s | -1.0 per 5s | -1.0 per 5s |
| Running | -1.0 per 5s | **-5.0 per 5s** | -1.0 per 5s |
| Lifting Dumbbells | **-5.0 per 5s** | -1.0 per 5s | -1.0 per 5s |
| Others | -1.0 per 5s | -1.0 per 5s | -1.0 per 5s |

*Table 3.2.1.2: Rate of oxygen demand of various body parts depending on the activity performed by the player*

With a rate of oxygen increase of +0.75 per 5s (with reference to Table 3.1.2.1), there will be a net decrease of -4.25 per 5s in the oxygen levels in the Arms and Legs when the player is lifting dumbbells or running respectively.

### (b) Updates to Oxygen Levels Panel UI

Visual feedback in terms of an update to the Oxygen Levels Panel UI (Figure 3.2.1.3) is introduced to let the player know that the rate of oxygen demand for the Arms / Legs has increased. For example, when running, the legs icon and bar will turn yellow to indicate that the rate of oxygen demand for the legs has increased. This enhances the game experience.


*Figure 3.2.1.3: Visual feedback for when the rate of oxygen has increased for a particular body part*

### (c) Walking vs Running

The player movement is in one of two states, walking or running. Running will increase the rate of oxygen demand for the legs.

The walking motion can simply be performed with the left controller's joystick (Figure 3.2.1.4), while the running motion must be performed by the player physically swinging their arms (with the controllers) up and down continuously while pointing the left controller's joystick forward (Figure 3.2.1.6). Instructions for running are added into the Human mode scene as a station as shown in Figure 3.2.1.5.

For the player to be considered running, the player must continuously swing their arms for at least 1.5 seconds. And similarly when the player is in the running state, the player must stop swinging their arms for at least 1.5 seconds to be considered not running anymore. This method of implementation is to buffer for short periods of non-swinging motions, as well as to mimic the real-world where it takes a while for a human to start/stop running.

To minimize motion sickness, a Tunneling Vignette is applied when the player is running as shown in Figure 3.2.1.6.

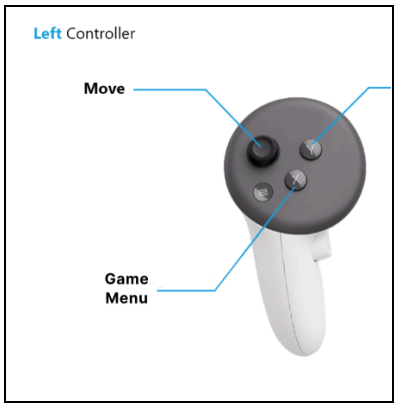



*Figure 3.2.1.4: Meta Quest 3 Left Controller*

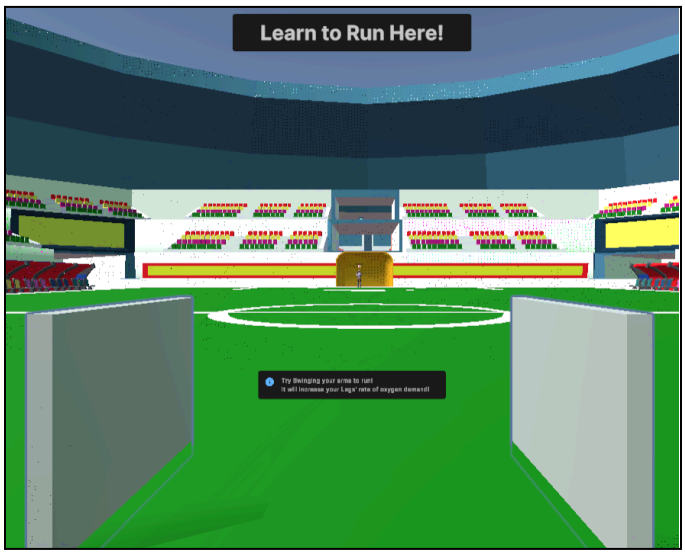



*Figure 3.2.1.5: Instructions on how to trigger running in Human Mode*

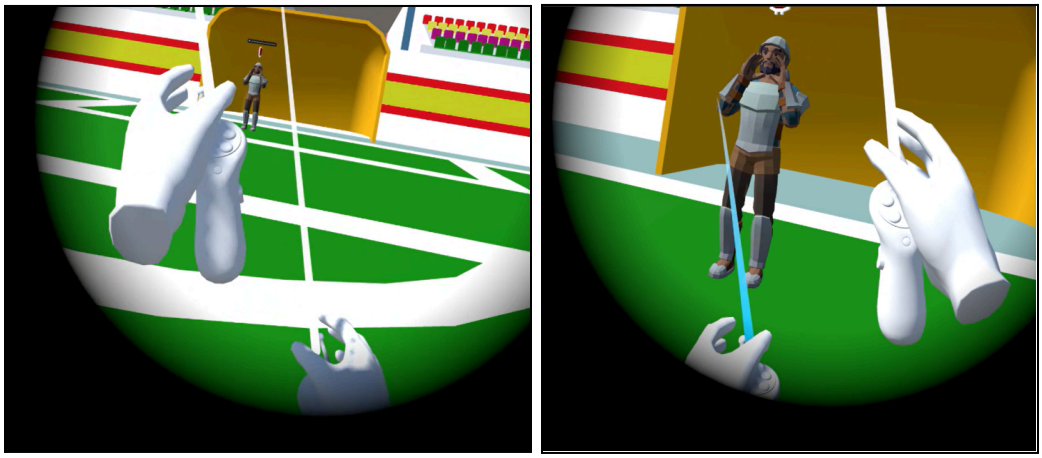


*Figure 3.2.1.6: Human Mode Running Motion with Tunneling Vignette after the Player swings their arms physically for more than 1.5s*

### (d) Lifting Dumbbells

To lift the dumbbells, the player needs to point the directional rays at the dumbbell and press the Right Controller's trigger button as shown in Figure 3.2.1.7.

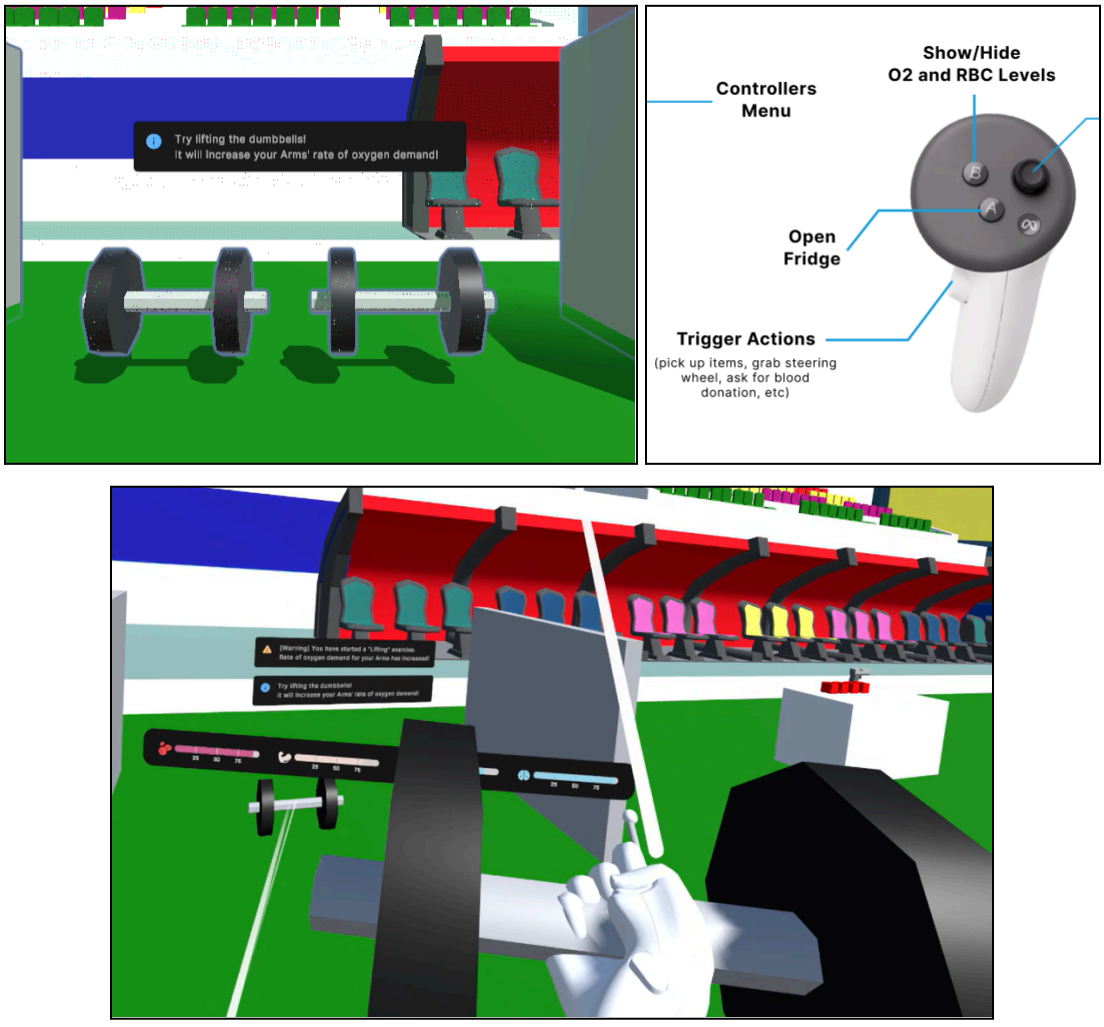



Figure 3.2.1.7: Lifting Dumbbells

## 3.2.2 Asking for Blood Donation

### (a) Human NPCs

As the red blood cells level decreases overtime, in order to maintain a safe level of red blood cells in the body, the player will need to find blood packs by encouraging Human NPCs (Non-Player Characters) to donate their blood (Figure 3.2.2.1) by clicking on the Right Controller's trigger button.

*Figure 3.2.2.1: The 5 Human NPCs in different outfits and poses*

There are 5 NPCs in the game scattered around the stadium, and each NPC has different outfits and poses as shown in Figure 3.2.2.1 to add variation.

### (b) Blood Donation Success Probability

Each NPC will donate their blood with a different random chance (0.2, 0.4, 0.5, 0.6, 0.8). Each NPC's successful or failed attempt will result in a corresponding notification (Figure 3.2.2.2) and there is a cooldown of 3s before the player can ask for blood donation from the same NPC again.


*Figure 3.2.2.2: Success (Left) and Failure (Right) Blood Donation Request Notifications*

### (c) Blood Packs

A successful blood donation request will add 1x blood pack to the player's fridge inventory, and it can only last for 4.2 minutes before it becomes unusable. Each blood pack can be used to restore 50 red blood cell levels.

As shown in Table 3.2.2.3, to simulate the perishable nature of blood in blood packs, blood packs are categorized into one of five different states according to the time left before that blood pack becomes unusable. Spoilt blood packs cannot be used.

| Blood Pack Type | Time Left | Amount of Red Blood Cells Level Replenished |
|---|---|---|
| Super Fresh | 3mins to 4.2mins | 50 |
| Fresh | 2mins to 3mins | 50 |
| Slightly Stale | 1min to 2mins | 50 |
| Stale | Less than 1 min | 50 |
| Spoilt | 0min | 0 |

*Table 3.2.2.3: Blood Pack Types and their corresponding information*

Each blood pack obtained from a Human NPC will start off in the "Super Fresh" state. As time goes on, the blood pack's "time left" will decrease through the use of Unity's Update method, and the quality will change accordingly.

(d) Fridge Inventory

All the blood packs obtained by the player can be accessed in their fridge inventory as shown in Figure 3.2.2.4. Blood packs can be used by clicking on the "Cup" icon and Spoilt blood packs can be discarded by clicking on the "-" icon. Consuming a blood pack will notify the player that the blood pack has been consumed and 50 red blood cells levels have been restored as shown in Figure 3.2.2.5.

The player will start the game with 2 SuperFresh Blood Packs in their fridge.

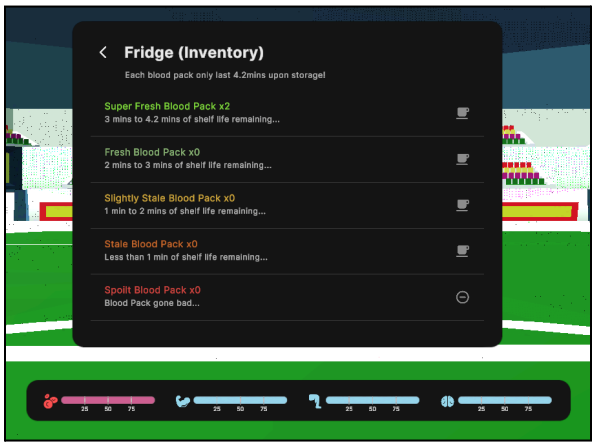



*Figure 3.2.2.4: Fridge Inventory containing Blood Packs*

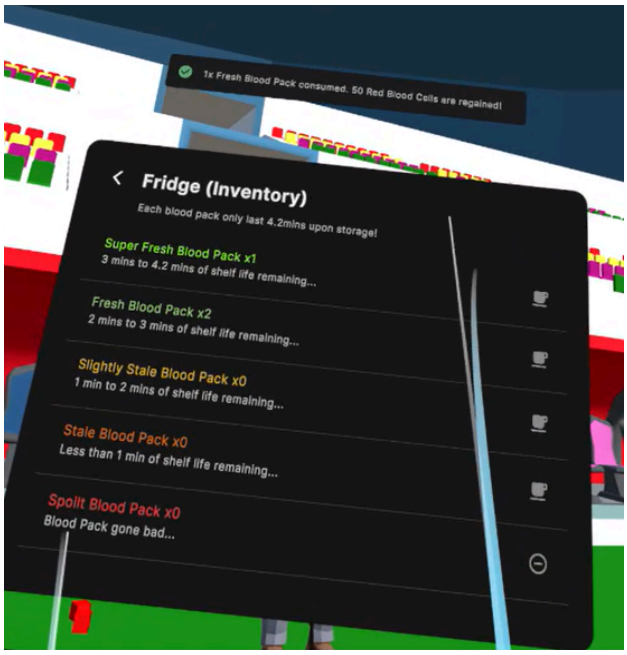



*Figure 3.2.2.5: Blood pack consumption notification*

## 3.3 Red Blood Cell Mode

### 3.3.1 Bloodstream Environment

#### (a) The Environment Map – Bloodstream

In the red blood cell mode, the scene is set in the bloodstream environment, with 4 major body tissues – Arms, Legs, Brain, and Lungs. Each body tissue is linked together via a set of blood vessels that forms the environment map for the red blood cell mode. Figure 3.3.1.1 shows the sketch and the Unity implementation of this bloodstream environment. To enhance gameplay interaction and immersiveness through movement potential, we made the bloodstream layout such that there are different paths that the player can take to move from one point to another, and that the paths can go in any direction in three-dimensional space.

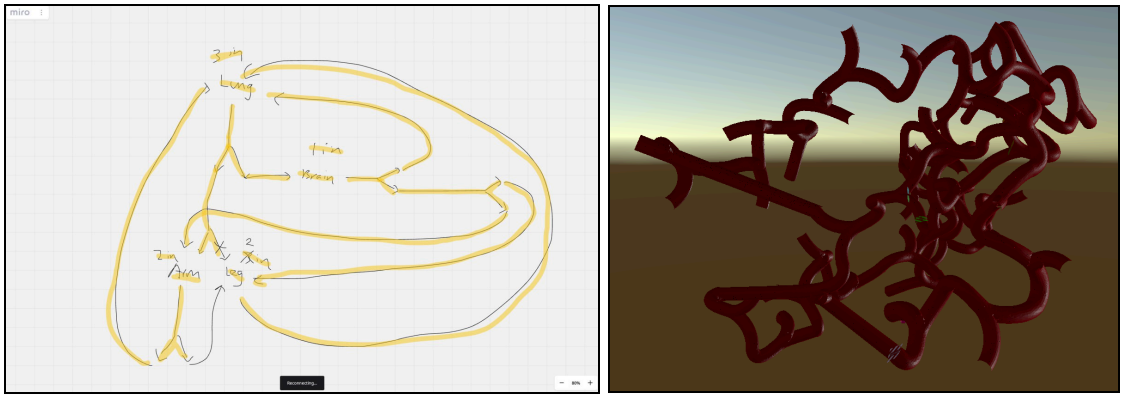



*Figure 3.3.1.1: Full Blood Stream Environment (Left: Sketch; Right: Implementation in Unity)*

Figure 3.3.1.2 shows the player's perspective when playing the game in red blood cell mode where the player is located inside the bloodstream environment.

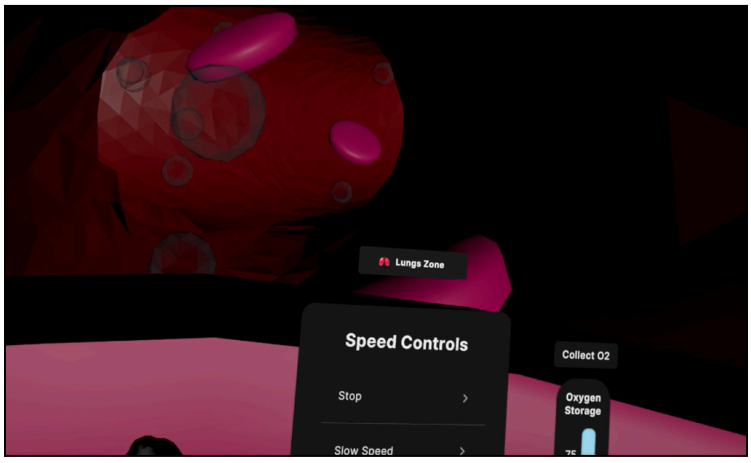



*Figure 3.3.1.2: Player's View in Red Blood Cell Mode*

(b) Major Body Tissue Zones

The 4 major body tissue zones are marked in the environment as shown in Figure 3.3.1.3. Oxygen can only be collected in the Lungs, and can only be deposited in the Arms, Legs, and Brain.


*Figure 3.3.1.3: Zones Signs*

The player's current zone is tracked and implemented via Unity Collider events.

(c) Direction Signs

To let the player know where they are going, direction signs (Figure 3.3.1.4) are added to the bloodstream.

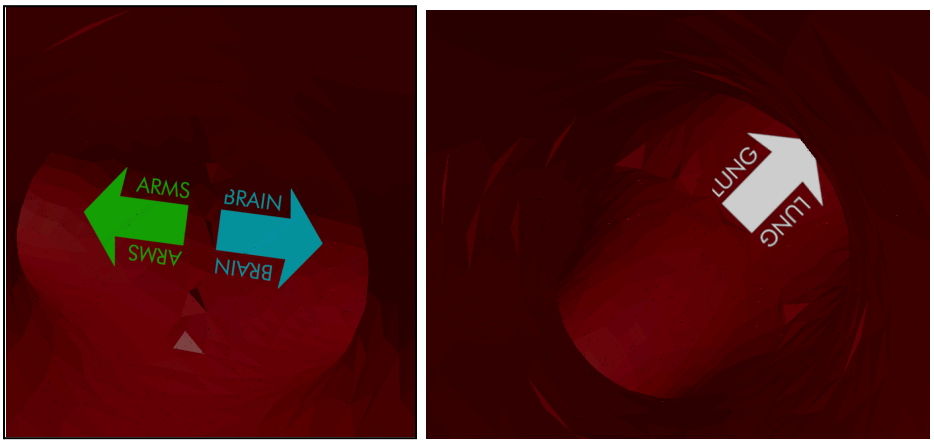



*Figure 3.3.1.4: Fork direction signs*

(d) NPC Entities Generation

NPC Entities, including Red Blood Cells, White Blood Cells, Virus Cells, and Oxygen, are automatically generated and populated into the scene (Figure 3.3.1.5) via our custom NPC Spawner script. Spawned NPCs will flow in the bloodstream in a **forward direction**, following a **Brownian** motion to make it more realistic. Oxygen NPCs will only be spawned in the Lungs zone and they will stay in that zone, ignoring forward motion.

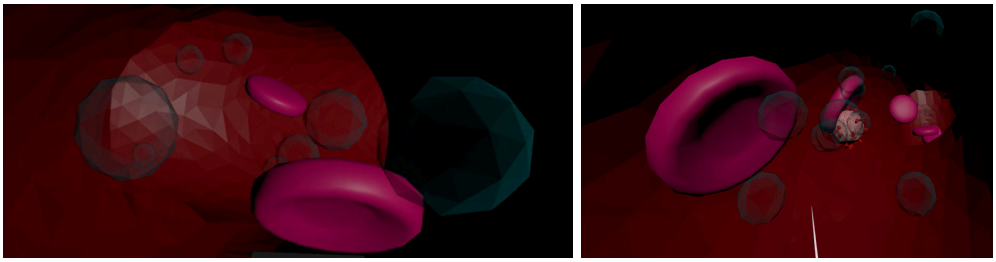


*Figure 3.3.1.5: Spawned NPC Entities*

## 3.3.2 Red Blood Cell Ship – Player

### (a) Player Perspective

In the red blood cell mode, the player will be in first-person perspective in a red-blood-cell-like ship inside the bloodstream to make the experience more immersive (Figure 3.3.2.1).

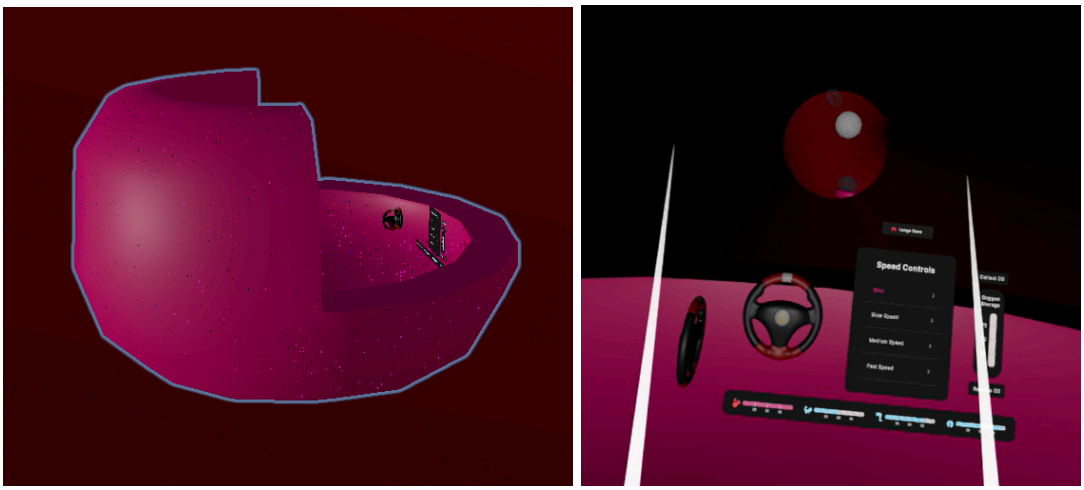



*Figure 3.3.2.1: Left: Red Blood Cell Ship; Right: Player's perspective inside the ship*

### (b) Ship Movements and Controls

#### Forward Movement

The ship can only move forward, just like how blood flows in one way. The player can control the speed of the ship's forward movement via the Speed Controls Panel (Figure 3.3.2.2). There are 4 speed options – Stop, Slow, Medium, and Fast.

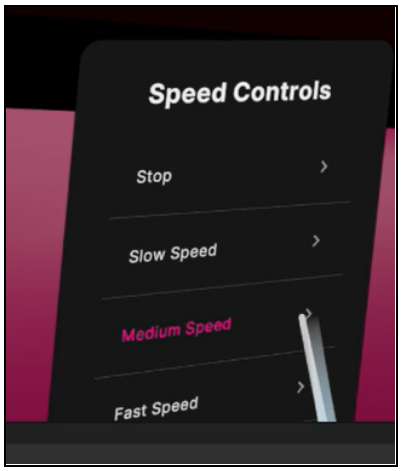



*Figure 3.3.2.2: Speed Controls Panel*

### Yaw and Pitch Controls

The player can control the Yaw and Pitch of the ship via the 2 steering wheels as shown in Figure 3.3.2.3. The player can only turn the ship a maximum of 45 degrees in either direction, and some angular friction is added to make the controls more realistic. These Yaw and Pitch Controls allow the player to have more freedom in moving inside the bloodstream and when choosing which direction to go at path forks.

*Figure 3.3.2.3: Steering Wheels (Left: Pitch; Right: Yaw)*

### Auto-steering

As the bloodstream paths go in various directions, we implemented an auto-steering feature that automatically steers the ship in the correct direction and angle so that the player moves in the correct direction and can see what is in front of the ship. This is achieved by nudging the ship towards the end of the nearest path segments whenever necessary. This enhances the gameplay and accessibility significantly as the player does not need to constantly steer the ship while possibly getting used to virtual reality.

(c) Collecting and Depositing Oxygen

As shown in Figure 3.3.2.4, the player can collect and deposit oxygen by clicking on the corresponding buttons in the ship. When oxygen has been collected in the Lungs Zone, “Oxygen Balls” will be added to the ship and the “Oxygen Storage” gauge will begin to top up. On the other hand, when oxygen is deposited in the Arms/Legs/Brain Zone, “Oxygen Balls” will be removed from the ship and the “Oxygen Storage” gauge will drop. At the same time, the oxygen level in the corresponding zone’s body part will increase.

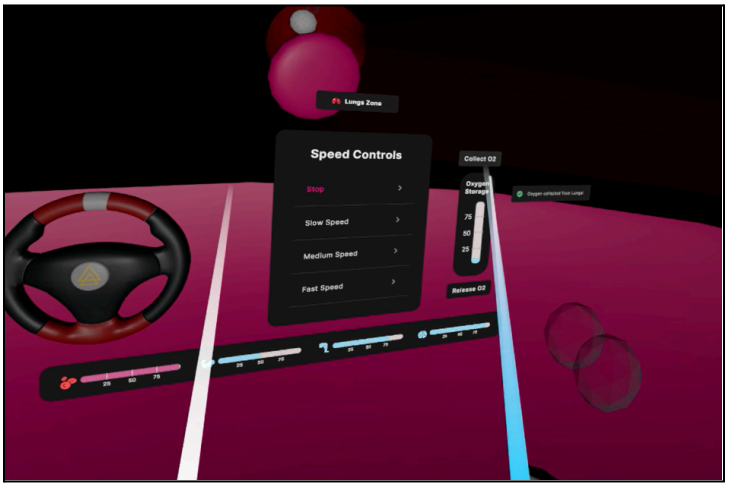



*Figure 3.3.2.4: Collecting and Depositing Oxygen + Oxygen Storage*

A maximum of 100 oxygen levels can be collected and stored in the “Oxygen Storage”, and each oxygen ball contains 5 oxygen levels.

## 3.4 Game Menu

We implemented a Game Menu (Figure 3.4.1) where the player can see the difficulty level of the game, switch between the Human Mode and Red Blood Cell Mode, and quit the game.

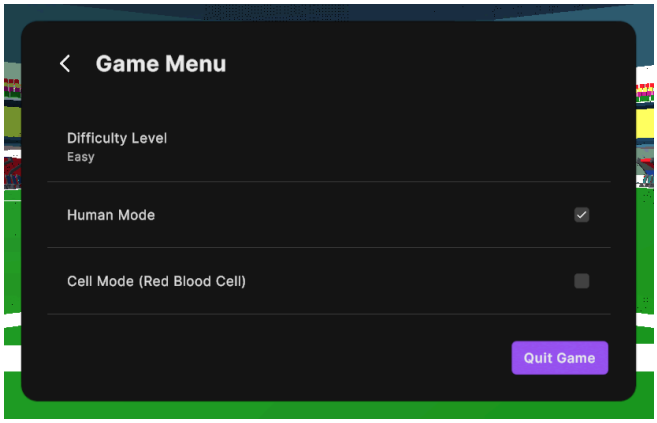



*Figure 3.4.1: Game Menu Panel*

## 3.5 Meta Quest 3 Hand Controller

We have configured the meta quest 3 hand controllers to perform functions specific to LifeLine VR as shown in Figure 3.5.1. For example, button X opens/closes the Game Menu, the right trigger button triggers actions and events according to the interactable the player is interacting with, and etc. This instruction is shown to the player via a Controllers Menu as shown in Figure 3.5.2.

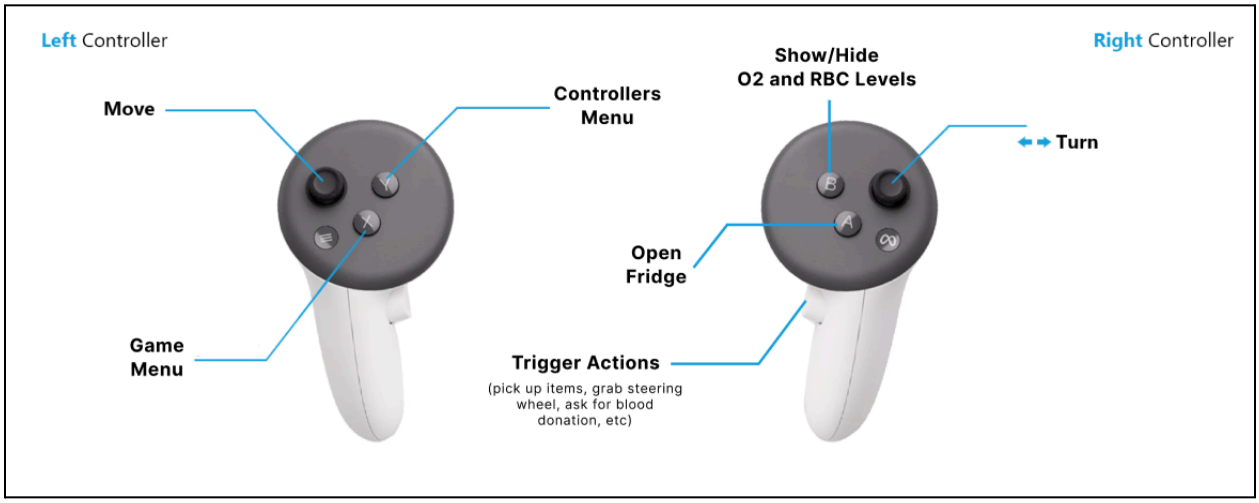



*Figure 3.5.1: Meta Quest 3 Hand Controller*

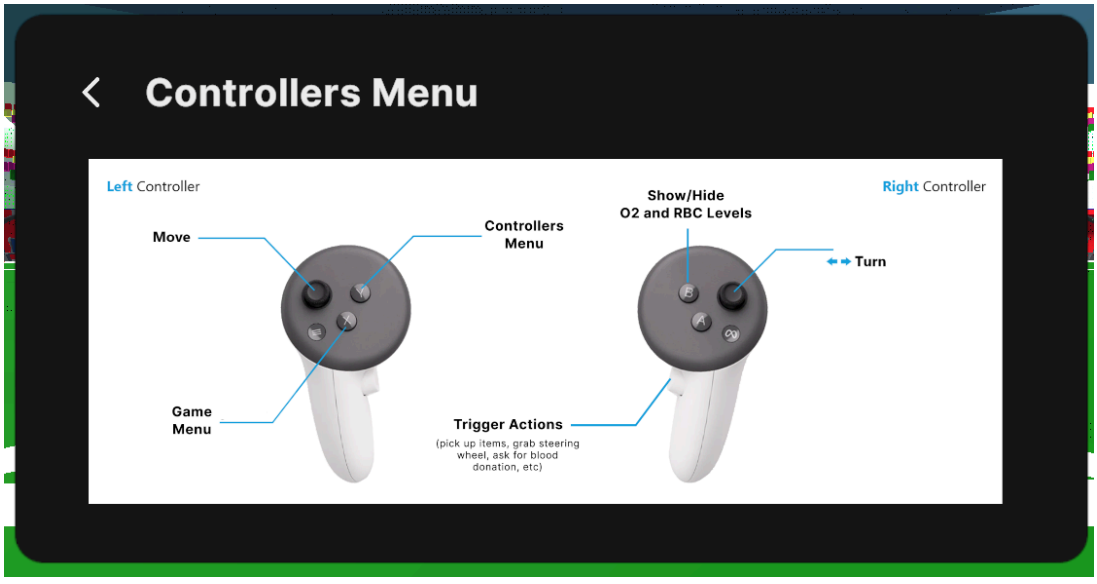



*Figure 3.5.2: Controllers Menu Panel*

## 3.6 Key Implementation Steps

We implemented LifeLineVR using a modular approach so that different members can work together in parallel without one blocking the other too frequently. This is done by splitting the application into different domains – Main Menu, Human Mode, Red Blood Cell Mode, and Misc Domains. Within each domain, we further split them into subdomains. For example, in the human mode, subdomains include Human NPCs, Running motion, Lifting Dumbbell motion, Player perspective, etc. Each domain/subdomain can be built in parallel before combining them together. This enabled us to develop LifeLineVR efficiently and effectively, while leveraging on our individual strengths in domains/subdomains we are proficient in.

Additionally, before we got started with coding the application, we built our custom 3D models in Blender while simultaneously testing the basic game mechanics to test the feasibility of the idea and refine it. This ensured that we had a clear and achievable goal to attain when we started the actual development of the application.

Our testing process was methodological as well to ensure good player experience. With each change made to the game, another member will vet the changes and test the application using the VR headset to experience first-hand how the player experiences the game. There, feedback and refinement of the change is done iteratively.

# 4. Adjustable Parameters

## 4.1 Adjusting Player's Perspective

The player can adjust their perspective between a Human and a Red Blood Cell easily via a click of a User Interface button. This allows the player to switch between the two seamlessly while playing the game. This is critical in making the game experience immersive – by having a relatable Human mode perspective and a vastly different Red Blood Cell mode perspective.

## 4.2 Adjusting Game Difficulty Levels

As shown in Table 4.2.1, to make the game more beginner friendly, 2 difficulty levels are introduced – Easy Difficulty and Hard Difficulty.

| | | **Easy Difficulty** | **Hard Difficulty** |
|---|---|---|---|
| Human Mode | Walking | Yes | Yes |
| | Running | Yes | Yes |
| | Lifting Dumbbells | Yes | Yes |
| | Asking for blood donation | - | Yes |
| Red Blood Cell Mode | Collect and Transport Oxygen | Yes | Yes |
| Common | Red blood cells level decrease over time | - | Yes |
| Goal | Keep oxygen levels above 0 | Yes | Yes |
| | Keep red blood cells level above 0 | - | Yes |

*Table 4.2.1: Game Difficulty Levels and their information*

# 5. Technical Stack, Tools, Frameworks, and Assets Used

## 5.1 Technical Stack

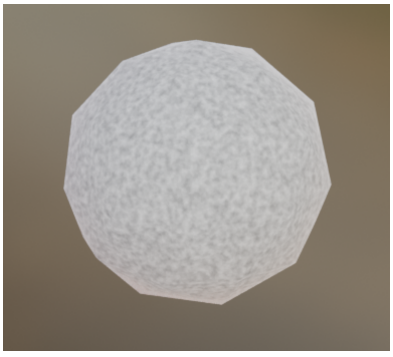
The technical stack used in the development of LifeLineVR includes:

- **Unity 2021.3.18f1**, for VR development
- **Git & GitHub**, for version control and remote collaboration
- **Figma**, for wireframing UI
- **Blender**, for modelling custom 3D models
- **C#**, for scripting

## 5.2 Tools and Frameworks

### 5.2.1 Blender

We used **Blender** to model our own custom 3D models as shown in Figure 5.2.1.1. This allowed us to create custom 3D models that are unique to LifeLineVR and in accordance with LifeLineVR's theme.

| Name | Custom Model |
|---|---|
| Red Blood Cell |  |
| White Blood Cell |  |

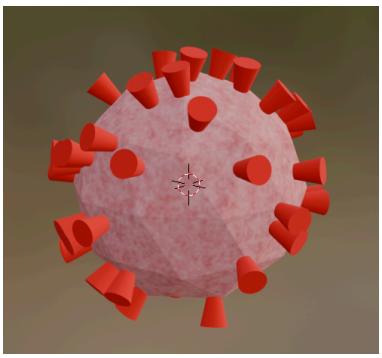
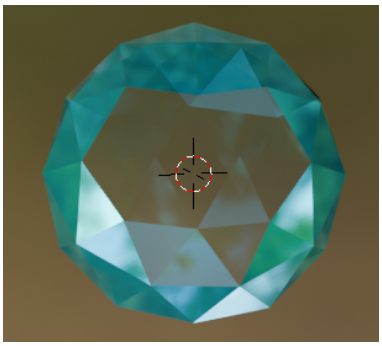
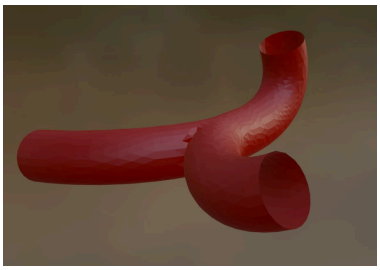
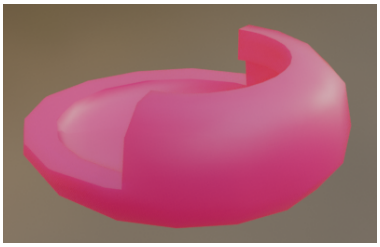
| | |
|---|---|
| Virus |  |
| Oxygen Ball |  |
| Blood Vessel |  |
| Red Blood Cell Ship |  |
| Blood Pack |  |

*Table 5.2.1.1: Custom 3D Models modelled in Blender*

### 5.2.2 Figma

We used Figma to create wireframes for key UI panels (Figure 5.2.2.1). This separates designing and implementing UI panels, which enhances our productivity.

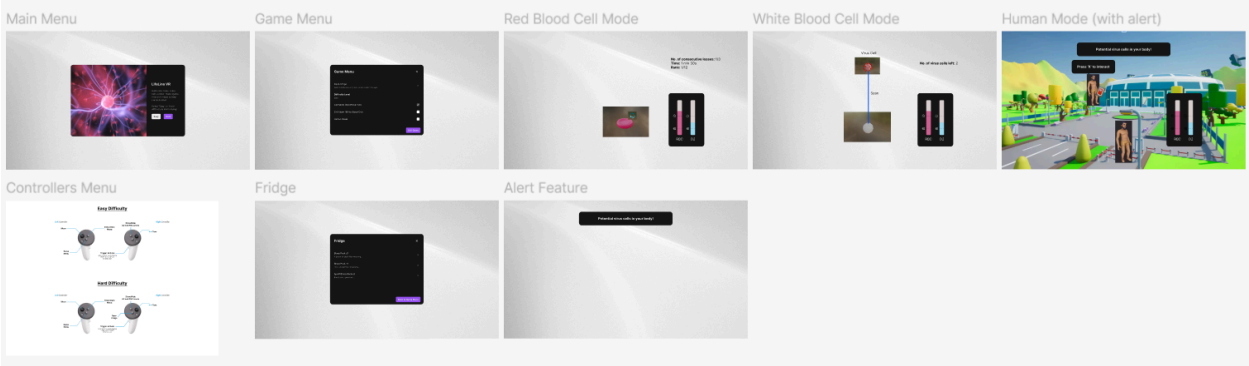



Figure 5.2.2.1: Figma wireframing

### 5.2.3 XR Interaction Toolkit

XR Interaction Toolkit is a key tool for our development of player interactions in LifeLineVR. The player is represented by XR Origin Set Up (Figure 5.2.3.1) with the main features being tied to the XR Rig, which determines the player perspective and interaction in the application, and the locomotion system which handles how the player moves in world space. Further customisations are done to make the XR Origin Set Up align with LifeLineVR game mechanics.

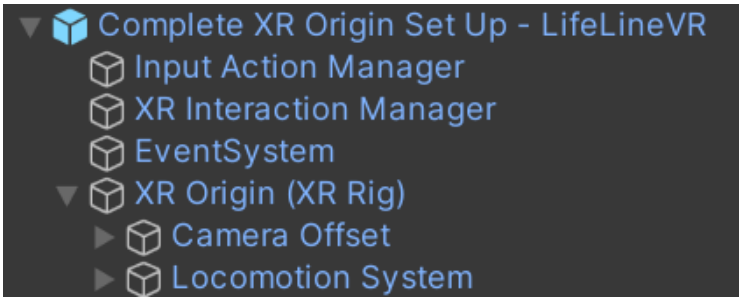



*Figure 5.2.3.1: Customised XR Origin Set Up*

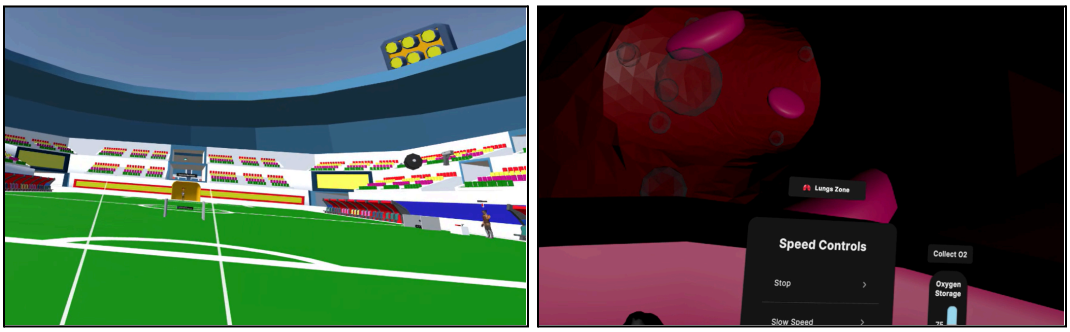



*Figure 5.2.3.2: Player's Perspective in Human Mode (Left) and Red Blood Cell Mode (Right)*

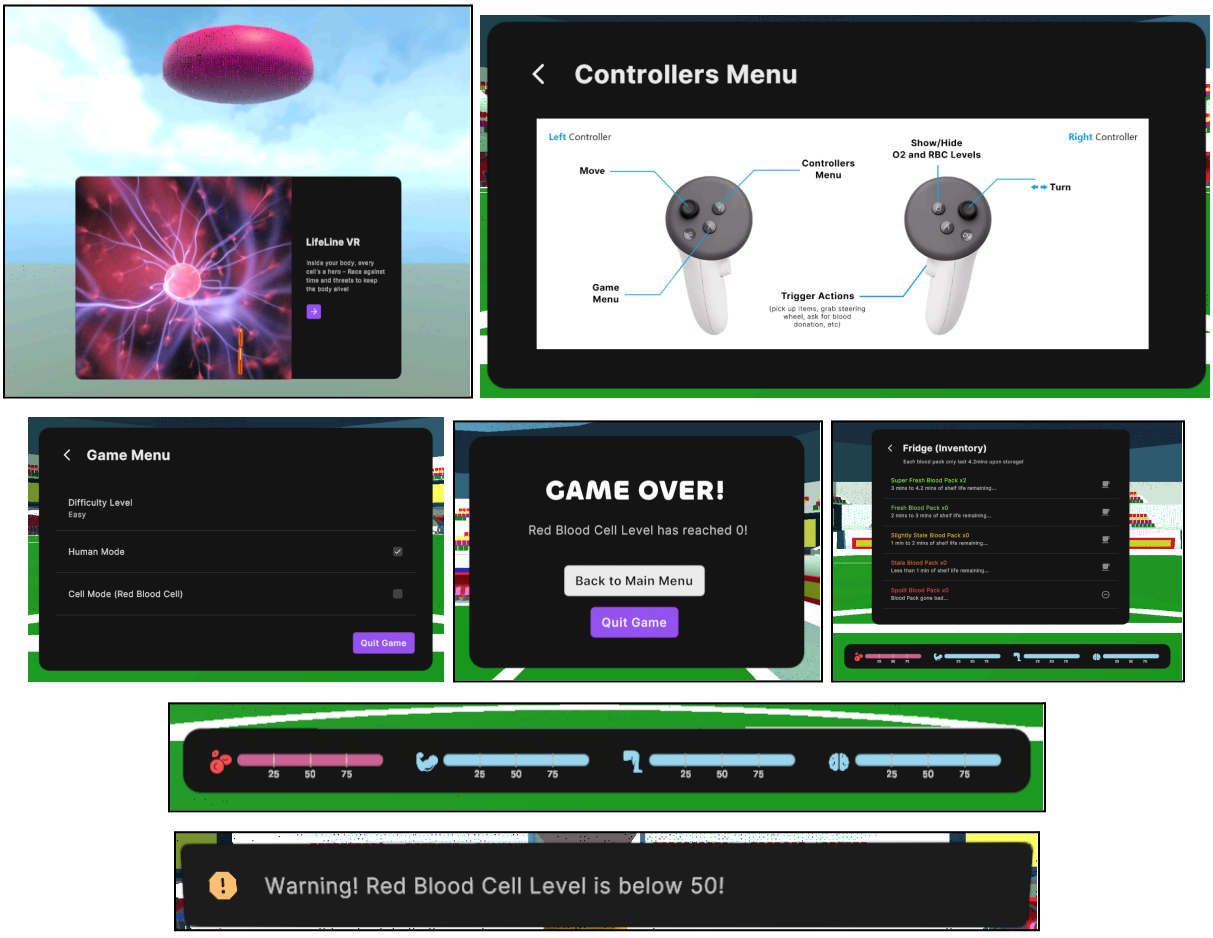
Interaction functionality is mainly handled by the various scripts available and preset input actions as part of the package. For example, elements like dumbbells were made interactable (e.g.: grabbable by player) by attaching scripts as part of the package.

## 5.3 Key Assets Used

### 5.3.1 FloatGrids

FloatGrids, [https://floatgrids.com/](https://floatgrids.com/), is a library of ready to use and customizable UI components for VR applications. We used and customised FloatGrids for all the UI elements that the player sees and interacts with in the game. For example, the Game Menu, Notification Panel, Fridge Panel, NPC interaction panels, Red Blood Cell Ship Control Panels, etc (Figure 5.3.1.1).

With FloatGrids, we can focus more on developing the core game logic rather than building user interfaces from scratch.



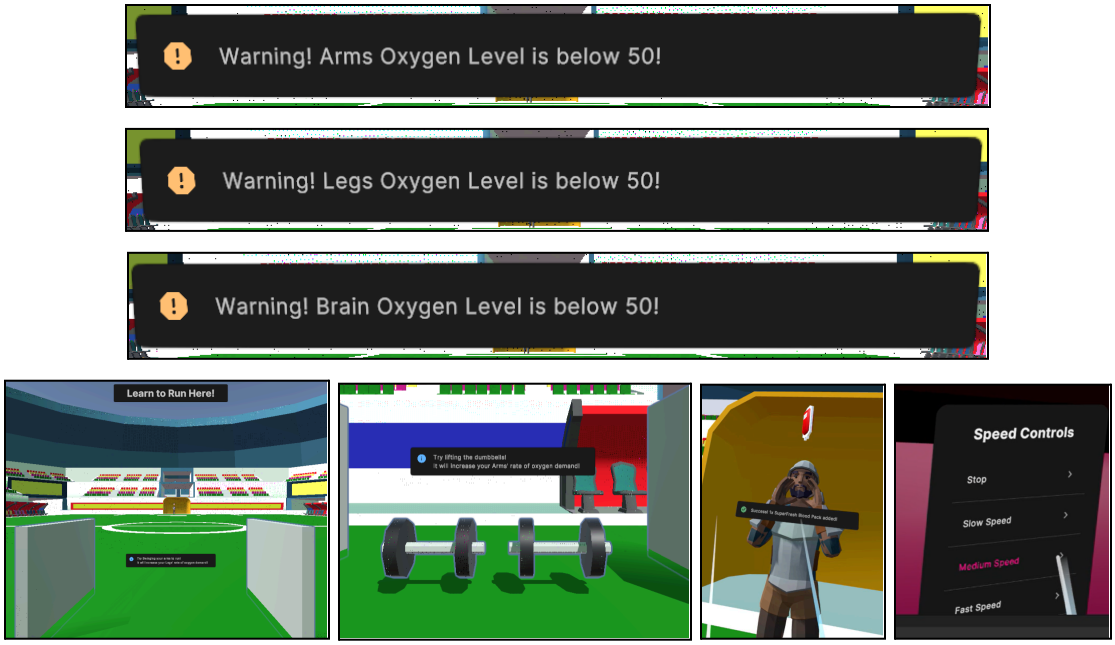
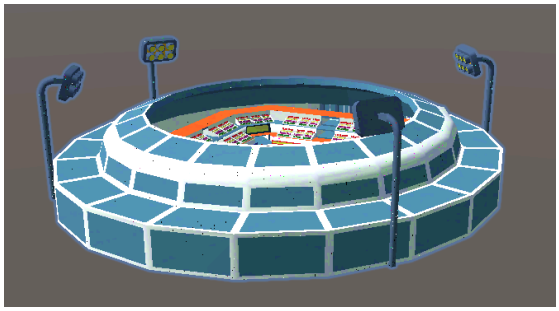



*Figure 5.3.1.1: Examples of where FloatGrids UI components have been used.*

### 5.3.2 3D Assets

We imported and used the following 3D assets in developing LifeLineVR (Table 5.3.2.1).

| **Name** | **Link** | **Asset** |
|---|---|---|
| Stadium | https://assetstore.unity.com/packages/3d/environments/urban/grand-stadium-v2-0-254584 |  |
| Human NPC | https://assetstore.unity.com/packages/3d/characters/humanoids/fantasy/free-low-poly-human-rpg-character-219979 |  |

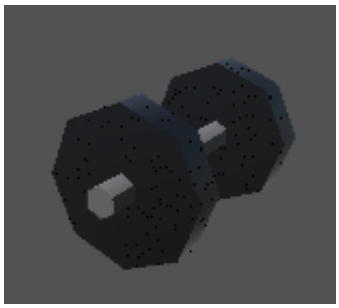
| | | |
|---|---|---|
| Dumbbell | https://assetstore.unity.com/packages/3d/props/furniture/furniture-free-low-poly-3d-models-pack-260522 |  |
| Steering Wheel | https://sketchfab.com/3d-models/steering-wheel-2-e81c3a62808b46998b2e35124028a614 |  |

*Table 5.3.2.1: 3D Assets used*

### 5.3.3 Icons8

Icons8, https://icons8.com/, was primarily used to get nice looking icons for the Red Blood Cell ( ), Arms ( ), Legs ( ), and Brain ( ) for the UI panel (Figure 3.1.3.1).

# 6. Conclusion

## 6.1 Challenges

### 6.1.1 Implementing Auto-steering of Red Blood Cell Ship

We faced challenges in implementing the auto-steering feature of the Red Blood Cell Ship as the bloodstream paths were generally windy in the third dimension, and the representations of the paths were discrete. However, discrete movements may feel unrealistic and induce motion sickness in the player.

To solve this challenge, we first implemented a foundational realistic physics model for the ship. The auto-steering is then implemented by applying forces on the ship, creating realistic and smooth movement. To smoothen out the discrete changes in the path segments, a smooth damp function was used to interpolate between path segments when it changes. To deal with late-turning due to this, path segments end early (before the player reaches the end of each segment), except in the case of forked paths.

Some non-forced-based steering is still used, such as when forcing the player to face in the correct direction. However, this does not kick in until the player is 60 degrees away from the correct direction, which is rather large, as this is a last-resort solution.

### 6.1.2 Creating The Bloodstream Map

We faced challenges in creating the three-dimension bloodstream map, due to its spatial complexity. To solve this challenge, we created an editor tool that allowed the next path to be created, conjoined to the end of the current path, at a user-specified angle.

The main path model that was used was a blood vessel that splits into two. This worked naturally as a splitting path. However, we also required merging paths; this was done by reversing the split-path model. The main challenge was in connecting two unrelated paths together from a distance. This required a liberal use of merging paths – which doubled up as a "straight" path if one of the inputs were left unconnected – as well as actual straight paths, which was used to connect paths together in a suboptimal but usable manner when close together.

### 6.1.3 Only 1 Meta Quest Headset Available

As there was only 1 Meta Quest Headset available for use per team, we faced challenges during our development phase as our members lived far from one another and we needed the headset frequently to test the interactable features.

We solved this challenge by assigning the headset to one member, and through constant and clear communication between members, we coordinated the development and testing of the implemented features overtime.

## 6.2 Limitations

### 6.2.1 Limited Human Mode Activities Variety

While LifeLineVR is immersive and educational, the human activities are restricted to walking, running, and lifting dumbbells. This may limit long-term engagement and learning opportunities as players may get bored with the game quickly and the currently available activities do not come close to mimicking the potential activities that a real-world human could perform.

### 6.2.2 Effect of Human Mode Activities not Fully Captured

The human mode activities, such as running and lifting dumbbells, only increase the rate of oxygen demand for one specific virtual body part. For example, running increases oxygen demand for Legs. While this is partially true, it does not capture the full nuance of how a real-world human body works. Running, for example, affects more than just the legs. Thus, LifeLineVR is limited in portraying the impact of physical activities on body parts, and this may impart wrong information regarding oxygen demand to the players especially since LifeLineVR is intended to be educational.

### 6.2.3 Interactions with Human NPCs does not Capture Complex Aspects

For blood donation players can only prompt NPCs to donate blood via a simple click of a button, with outcomes based on fixed probabilities. This does not fully capture the complex social and emotional aspects of real-world blood donation, which will be useful for the players to learn and experience.

### 6.2.4 Motion Sickness

While we employed techniques to reduce VR motion sickness via tunnel vignette, some players may still experience motion sickness especially during prolonged periods in the red blood cell mode where auto-steering is enabled.

## 6.3 Ideas for Future Improvement

### 6.3.1 Adding More Physical Activities

More types and intensities of physical activities such as doing pull-ups, sports games (like football, basketball, etc), or obstacle-based activities can enhance player engagement and immersiveness while allowing for a more comprehensive showcase of how various activities impact oxygen demand of specific body parts of the body. Hence, reinforcing LifeLineVR's educative purpose regarding the importance of red blood cells in supporting physical activities.

### 6.3.2 Multiplayer Mode

A multiplayer mode can be enabled for 2 or more players to work together to keep a virtual body alive. For example, for 2 players, one person can control the human mode while the other can control the red blood cell mode. For 3 or more players, multiple players can be in the red blood cell mode working together to transport oxygen in a collaborative manner. This enhances the gameplay and highlights the importance of collaboration between red blood cells, and between red blood cells and the human body, which mimics real-world mechanics.

### 6.3.3 Enhanced Human NPC Interaction

Human NPC interactions can be enhanced by introducing more complex dialogues and behaviors that require the player to persuade the NPC to donate. NPCs can also provide reasons for donating or rejecting to simulate more realistic donation scenarios and introduce empathy-based learning.

### 6.3.4 Narrative Expansion

The narrative could be expanded beyond the initial introduction. The storyline could continue into the game, where the player follows their own journey through treatment and recovery from the red blood cell disorder. This introduces more gameplay interaction and lets the player experience the hardships someone with a red blood cell disorder goes through. Thus, reinforcing the importance of red blood cells and constant blood donations.

### 6.3.5 Adding Audio

Audio can be added to elevate the sensory experience of both game modes, making LifeLineVR more immersive for the player. The addition of music such as ambient music will enable a deeper focus into the game for the player, and the inclusion of sound effects will act as a form of auditory feedback towards the player's actions and choices in the application.

# 7. References

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