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VIRTUAL REALITY VISUAL FIELD TESTING DEVICE

Caleb Mok Kah Hou
2689719m

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Outline

1. Introduction
2. Design
3. Implementation
4. User Study
5. Results
6. Conclusion

Introduction

- This project introduces a VR-based visual field testing (VFT) system built using consumer-grade VR hardware with eye tracking.
- The aim is to offer a flexible, low-cost, and extensible alternative to traditional clinical perimetry tools.

Why do all this?

Motivation

- **Early-stage** visual defects are **hard to notice** without proper testing.
- **Missed diagnoses** can lead to **severe** consequences:
  - loss of independence, employment, and quality of life.
- **Traditional** perimetry systems are **expensive** and **not widely accessible**.
- **VR** enables immersive environments for VFT that is much **cheaper** and **portable**.
- An **open-source** software reduces barriers and promotes **innovation**, especially in low-resource or academic settings.

Aims

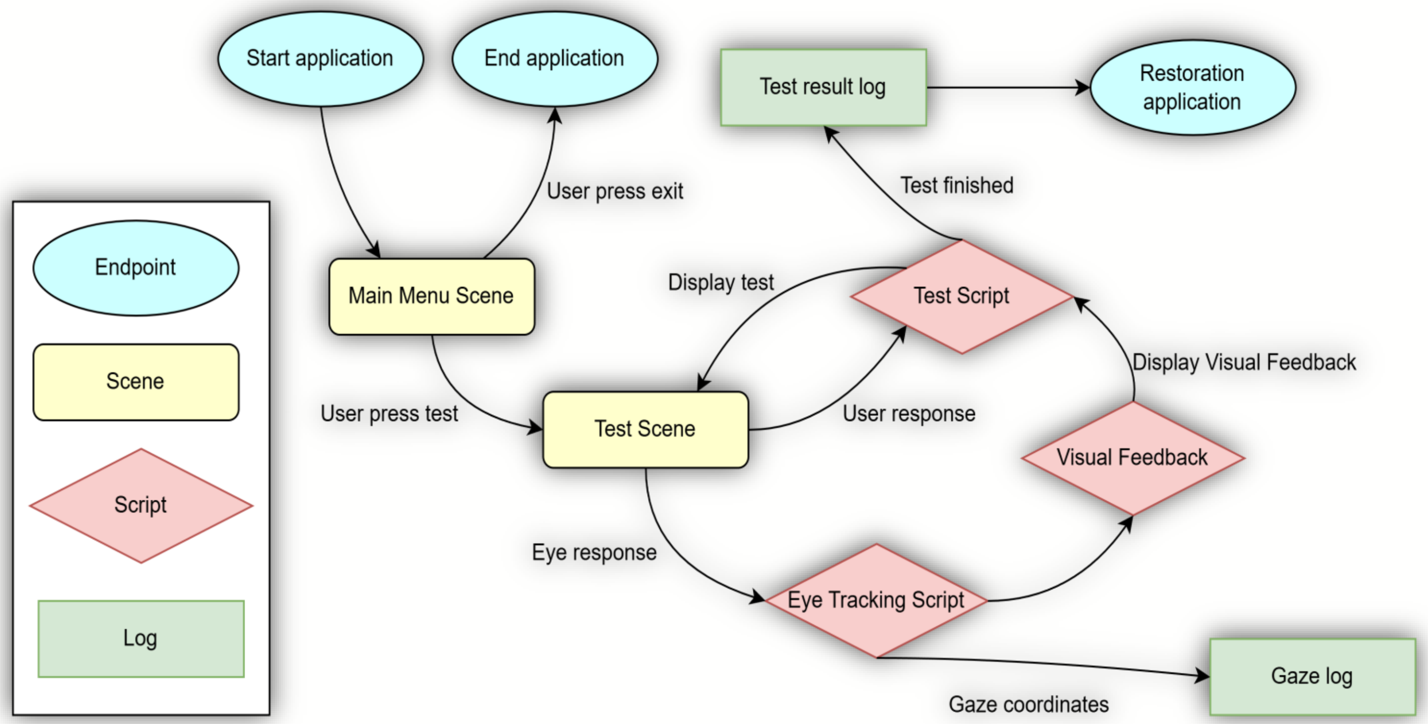
- **Goal**: Build a VR-based visual field-testing platform as a practical, affordable alternative to traditional perimetry.
- **Approach**: Uses consumer VR with eye tracking to tackle cost and accessibility issues.
- **Prototype Capabilities**:
  - Displays randomised visual stimuli in VR
  - Records responses
  - Logs data for analysis
  - Generates PDF report
- **Impact**: Aims to support early detection of vision loss, with strong potential for use in remote or resource-limited settings.

Design

Overview

Workflow:

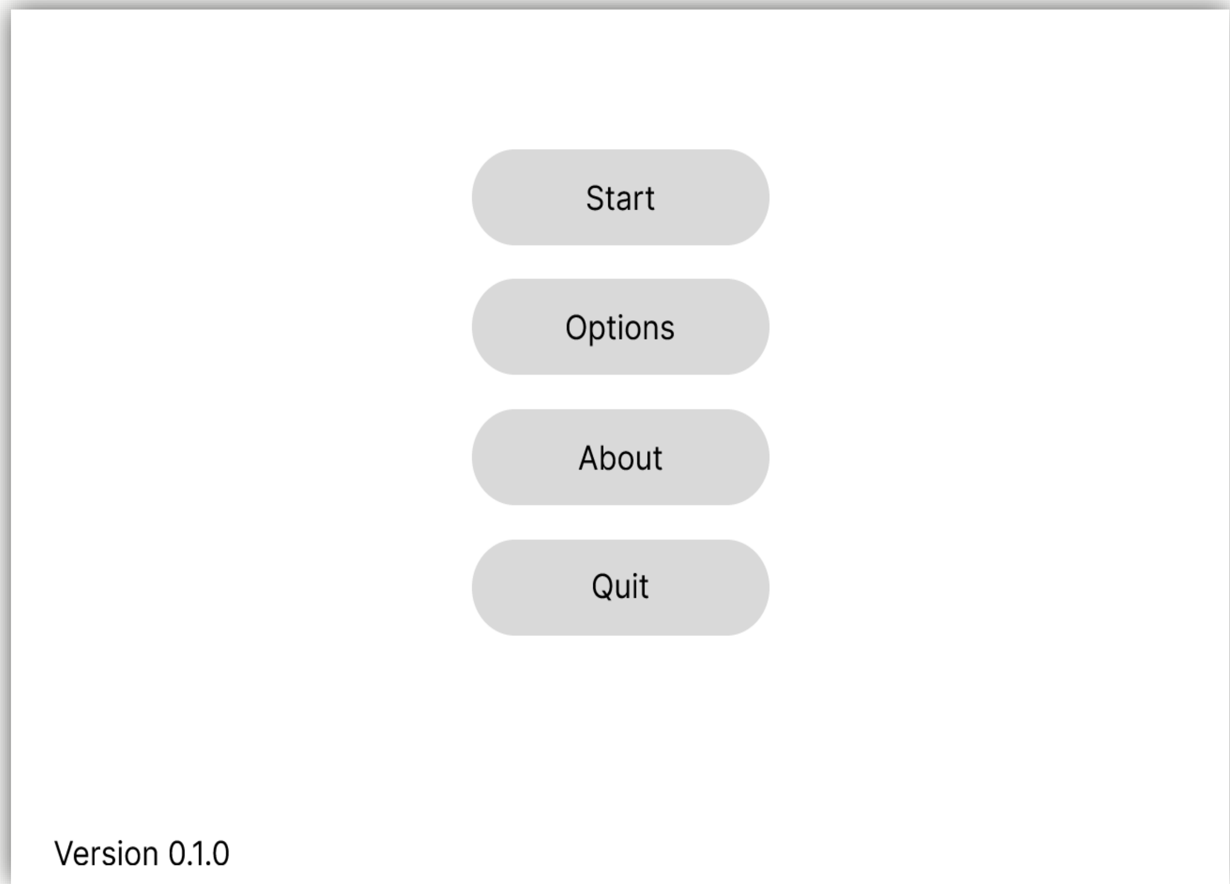
1. Session Initialisation
2. Main Menu Navigation
3. Pre-Test Countdown
4. Stimulus Generation
5. Fixation Monitoring & Feedback
6. User Response Logging
7. Test Completion & Data Export
8. Report Generation



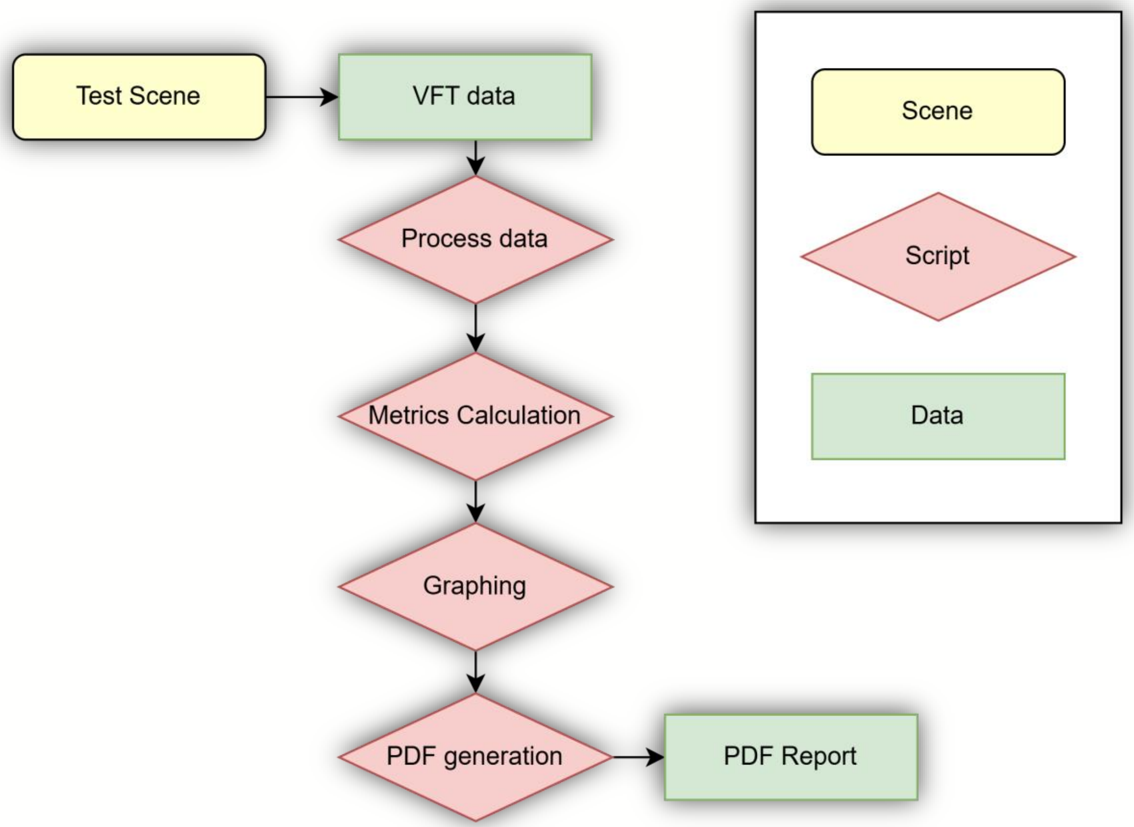
Repeated Fixed Intensity Strategy

- Instead of using complex thresholding algorithms like SITA, we implemented a **non-threshold strategy** based on **fixed-intensity stimuli**.
- Due to **hardware limitations** preventing **absolute brightness calibration** on VR headsets, we used a **single consistent brightness level** for all stimuli.
- Each stimulus is shown **multiple times at each test point** in a randomized order.
- Participants indicate whether they see each flash, and the system classifies each location as:
  - **Consistently Seen** – detected **more than 3 times**
  - **Inconsistently Seen** – detected **1–2 times**
  - **Unseen – 0 detections**
- **Simple and robust method**, ideal for **preliminary screening**, when full sensitivity data isn't needed.

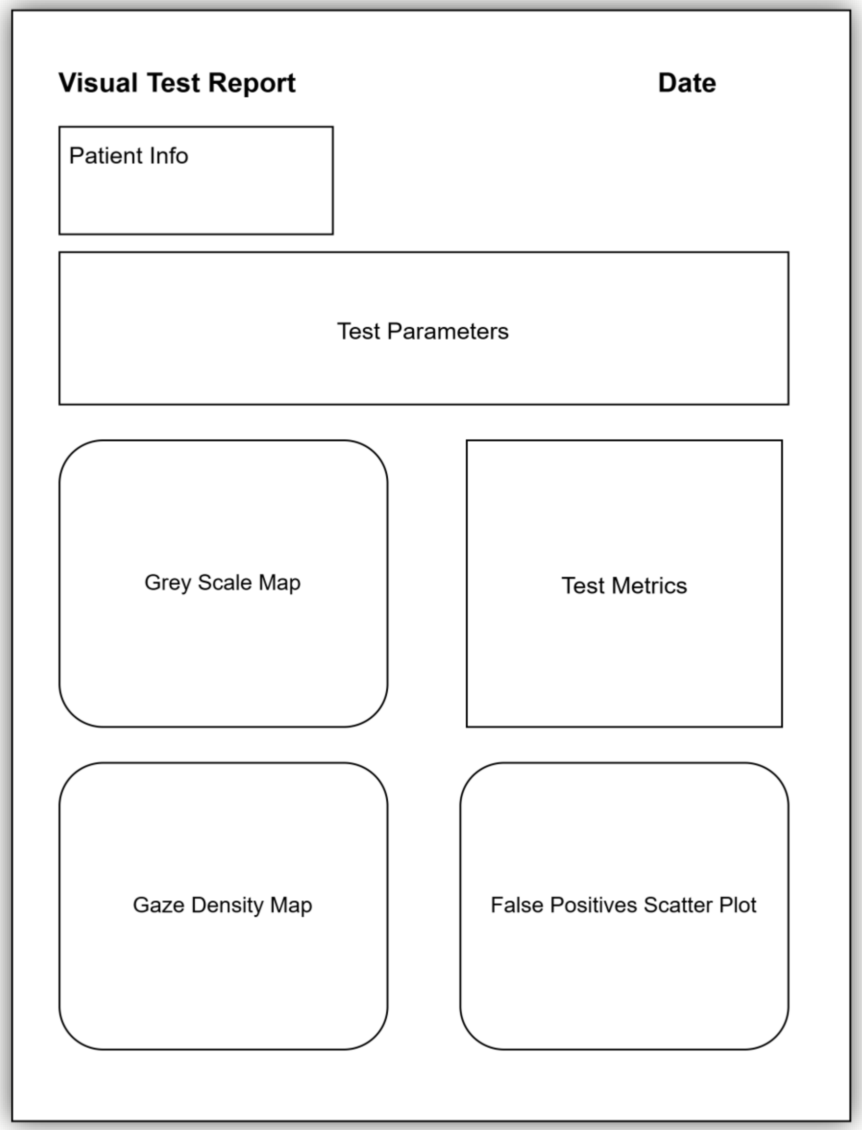
User Interfaces and Inputs



Report Generation



Report Generation Workflow



Report Generation Wireframe

Implementation

Hardware and Software

HTC Vive Pro Eye

Workstation:

- CPU: Intel Core i9-12900K
- GPU: NVIDIA RTX 3080 Ti
- RAM: 64 GB

Unity:

- Unity editor 2019
- SRanipal SDK
- Steam VR

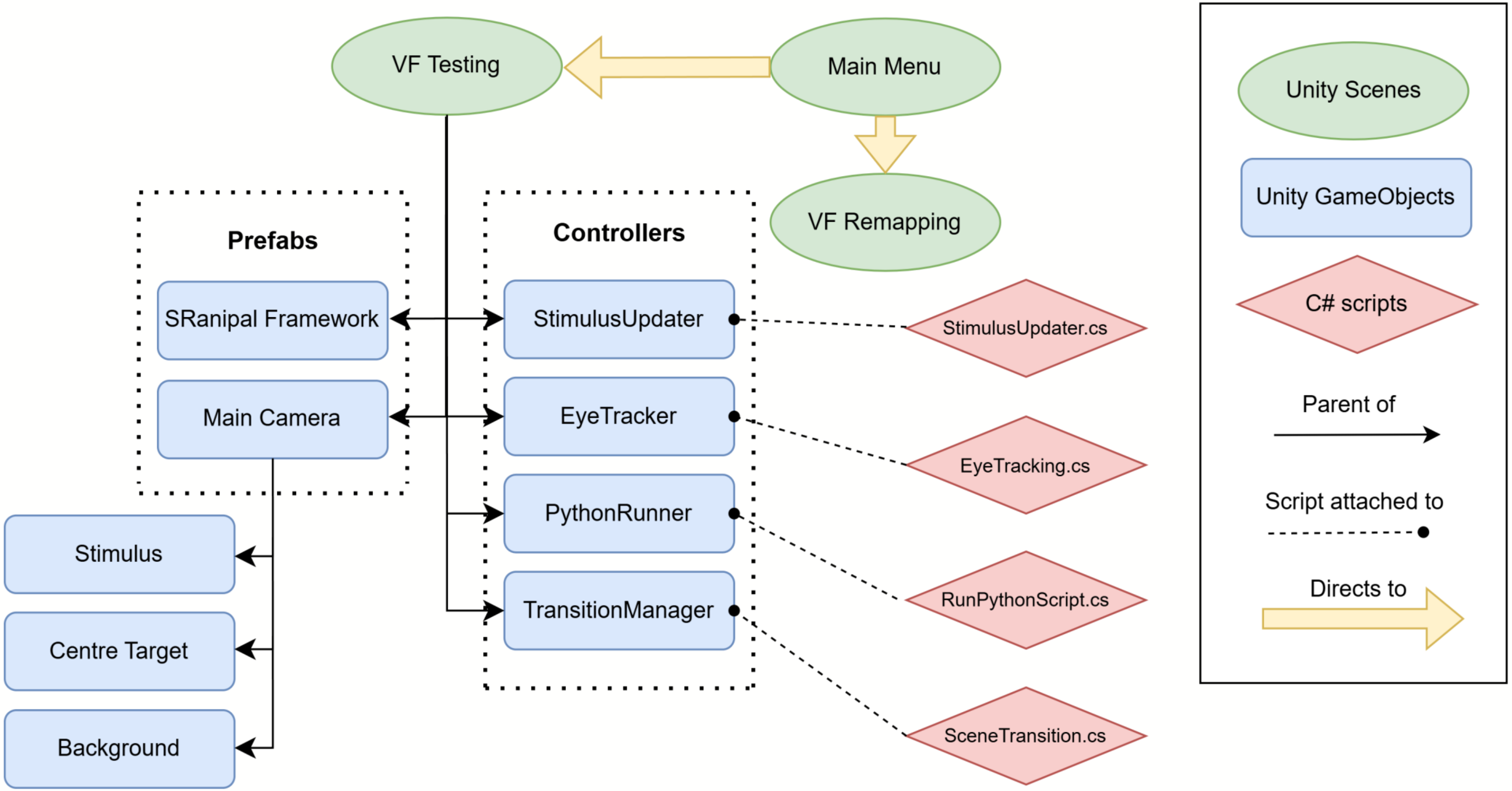
Scripting:

- VS code
- Jupyter

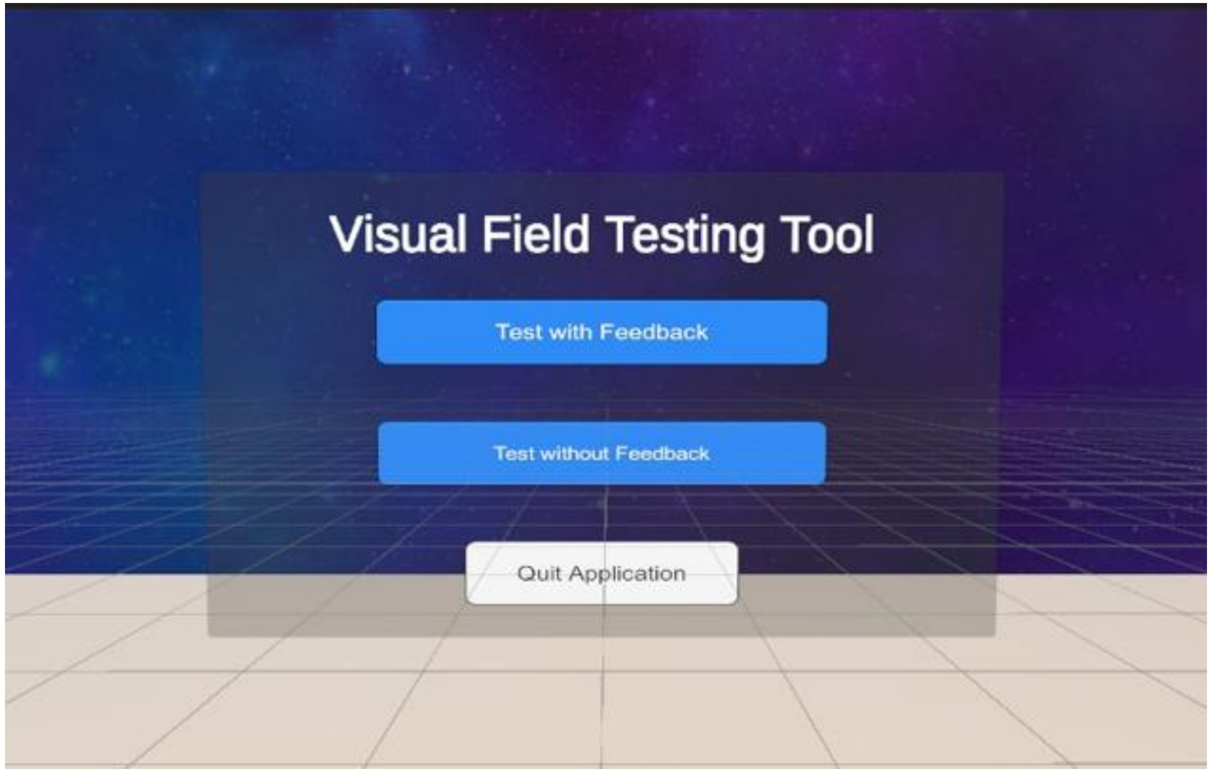
Version Control:

- Gitlab

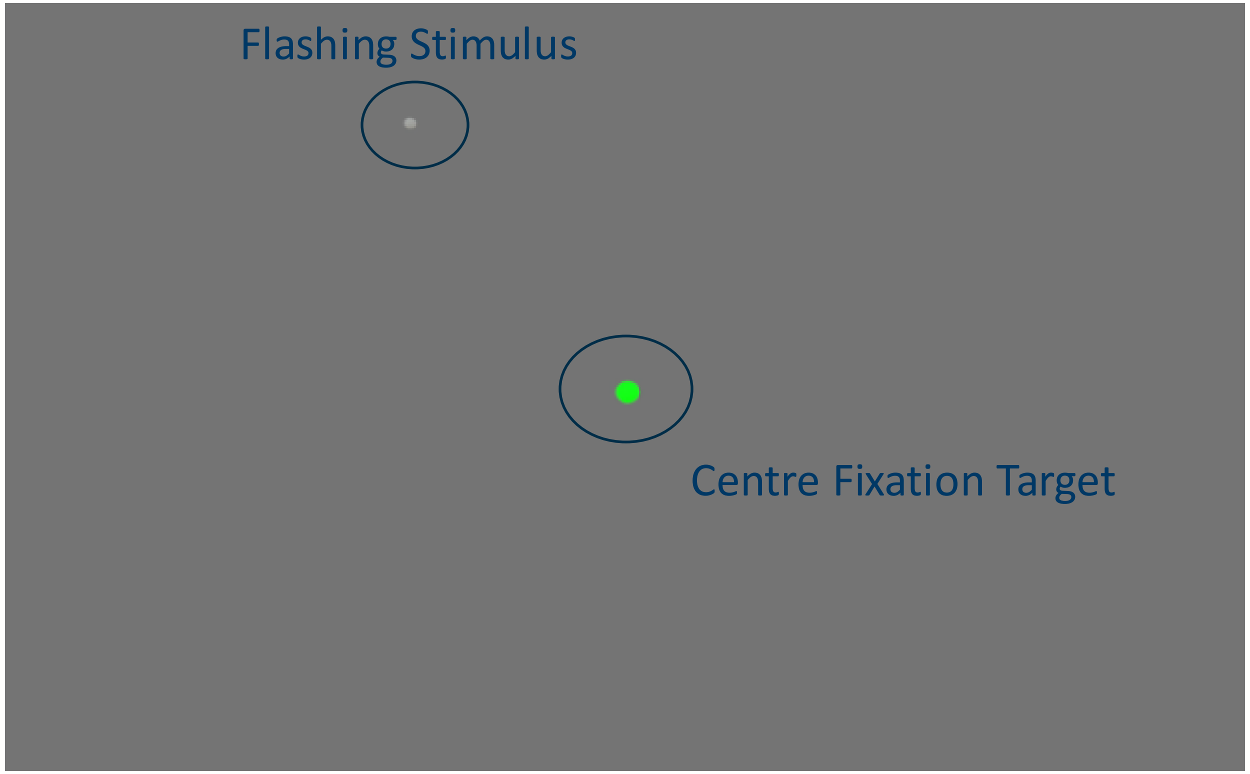
Unity Environment Hierarchy



Environment



Menu Scene



VFT scene

Generated Report

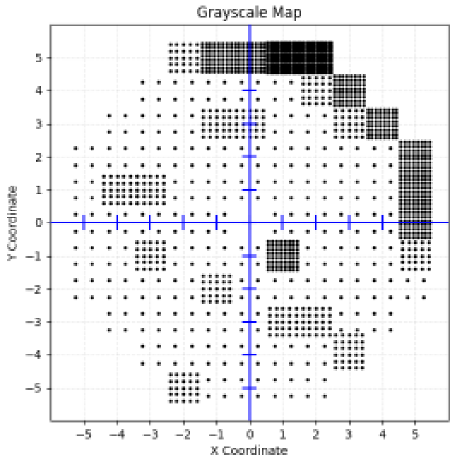
Visual Test Report

2025-03-14 23:30:09

Name: REDACTED
Age: REDACTED
Test Duration: 233.70s

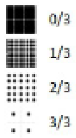
Fixation Monitor: Gaze
Fixation Target: Central
Flash Duration: 50.00ms
Number of stimuli: 288

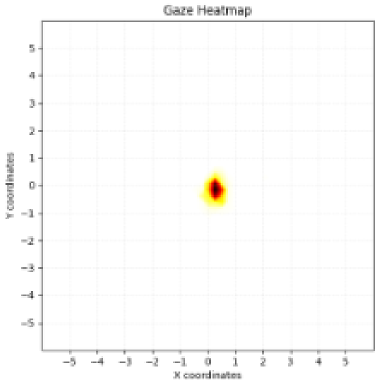
Stimulus: White 0.05
Background: RGB(32,32,32)
Canvas: Plane
Strategy: Repeated Fixed-Intensity

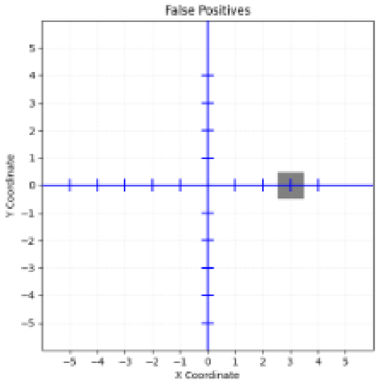


Test Metrics

False Positive: 1/288
False Negative: 35/288
False Positive Error Rate: 0.35%
False Negative Error Rate: 12.15%
Average Reaction Time: 305.93ms
Center Fixation Percentage: 98.87%







Evaluation

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User Study (n=12)

- **Briefing & Calibration:**
  Participants were introduced to the system and completed eye-tracking calibration.
- **Counterbalancing**
  Latin square design varied eye (left/right) and feedback mode (on/off) to reduce bias.
- **Test conditions:**
  - **Condition A: with visual feedback**
  - **Condition B: without visual feedback**
- **Data Collection**
  Reaction times, detection outcomes, and gaze data were logged. SSQ completed after each condition, followed by final form.

Participant	Condition 1	Condition 2	Condition 3	Condition 4
Participant 1	Right w/ feedback	Left w/ feedback	Right w/ no feedback	Left w/ no feedback
Participant 2	Left w/ feedback	Left w/ no feedback	Right w/ feedback	Right w/ no feedback
Participant 3	Left w/ no feedback	Right w/ no feedback	Left w/ feedback	Right w/ feedback
Participant 4	Left w/ no feedback	Right w/ feedback	Left w/ feedback	Right w/ no feedback
Participant 5	Right w/ no feedback	Left w/ feedback	Right w/ feedback	Left w/ no feedback
Participant 6	Right w/ no feedback	Left w/ no feedback	Right w/ feedback	Left w/ feedback
Participant 7	Left w/ feedback	Right w/ no feedback	Left w/ no feedback	Right w/ feedback
Participant 8	Left w/ feedback	Right w/ feedback	Left w/ no feedback	Right w/ no feedback
Participant 9	Right w/ feedback	Left w/ feedback	Right w/ no feedback	Left w/ no feedback
Participant 10	Right w/ feedback	Left w/ no feedback	Right w/ no feedback	Left w/ feedback
Participant 11	Left w/ no feedback	Right w/ no feedback	Left w/ feedback	Right w/ feedback
Participant 12	Left w/ no feedback	Right w/ feedback	Left w/ feedback	Right w/ no feedback
Participant 13	Right w/ no feedback	Left w/ feedback	Right w/ feedback	Left w/ no feedback
Participant 14	Right w/ no feedback	Left w/ no feedback	Right w/ feedback	Left w/ feedback
Participant 15	Left w/ feedback	Right w/ no feedback	Left w/ no feedback	Right w/ feedback
Participant 16	Left w/ feedback	Right w/ feedback	Left w/ no feedback	Right w/ no feedback

Latin Square

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Results

Quantitative Data Analysis

Performed paired t-test:

- **Null hypothesis**:
  - ➢ There is no difference in performance metrics between the two conditions.
- **Alternative hypothesis**:
  - ➢ There is a difference between the two conditions (two-sided test).

Performance metrics:

- Centre fixation percentage
- Reaction time
- False Positive rate
- Negative rate

Center Fixation Percentage

Test Condition	CF %	m_D	s_d	SEM	t	p	d
Without Feedback	60.31 %	14.71 %	16.98 %	5.12 %	2.87	0.017	0.87
With Feedback	75.01 %						

- **Hypothesis**: Real-time feedback improves centre fixation
- **Results (All Participants)**:
  - ➢ Slight improvement with feedback ($p \approx 0.071$), **not statistically significant**.
- **After Removing Outlier (Participant 8)**:
  - ➢ Significant improvement ($p \approx 0.017$), **large effect size** ($d \approx 0.87$).
- Supports the hypothesis that **visual feedback enhances fixation**.

Reaction Time

Test Condition	RT (ms)	m_D	s_d	SEM	t	p	d
Without Feedback	306.31 ms	12.28 ms	14.39 ms	4.34 ms	2.83	0.018	0.85
With Feedback	318.59 ms						

- **Hypothesis**: Feedback would lead to faster responses.
- **Results**:
  - With feedback: **318.59 ms**
  - Without feedback: **306.31 ms**
  - Participants were **~12 ms slower** with feedback
    ($p \approx 0.018$, $d \approx 0.85$).
  - Feedback had a **statistically significant but opposite effect** than expected.

False Positive Rate

Test Condition	*FP* %	m_D	s_d	*SEM*	t	p	d
Without Feedback	16.87 %	-12.19 %	13.86 %	4.18 %	-2.92	0.015	0.88
With Feedback	4.69 %						

- **Hypothesis**: Feedback reduces button presses when not fixating.
- **Results**:
  - **-12.19% decrease** in false positives with feedback.
  - **Statistically significant** (p ≈ 0.015), **moderately large effect** (d ≈ 0.88).
  - Feedback improves **response accuracy**.

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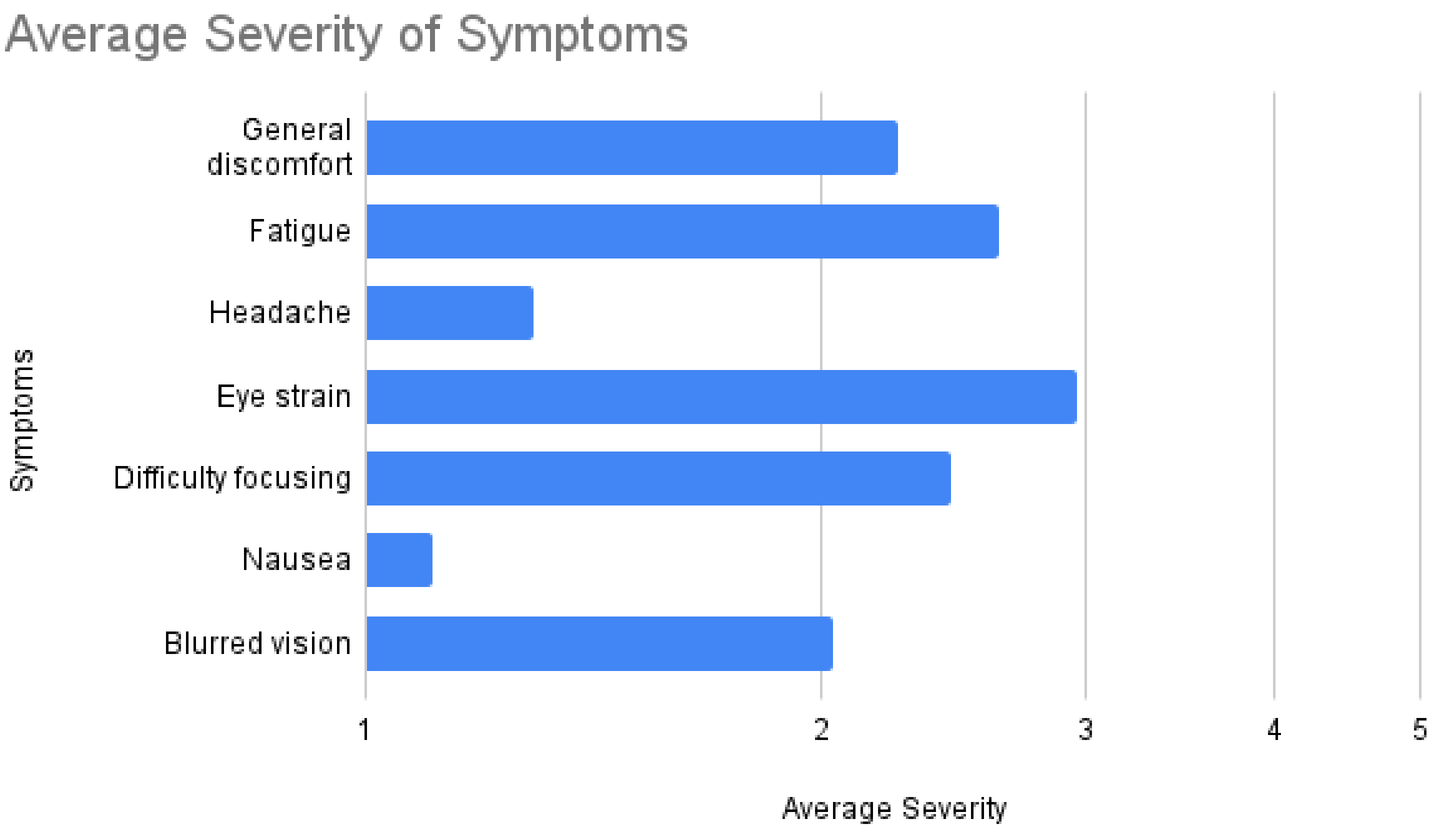
Negative Rate

Test Condition	N %	m_D	s_d	SEM	t	p	d
Without Feedback	15.25 %	2.29 %	5.35 %	1.61 %	1.42	0.19	0.43
With Feedback	17.54 %						

- **Hypothesis**: Feedback has no negative effect on detection accuracy.
- **Results**:
  - Negative rate slightly **increased** with feedback.
  - **Not statistically significant** (p ≈ 0.124), medium effect (d ≈ 0.43).
  - Suggests a potential trade-off: improved accuracy but at the cost of **missing some stimuli**.

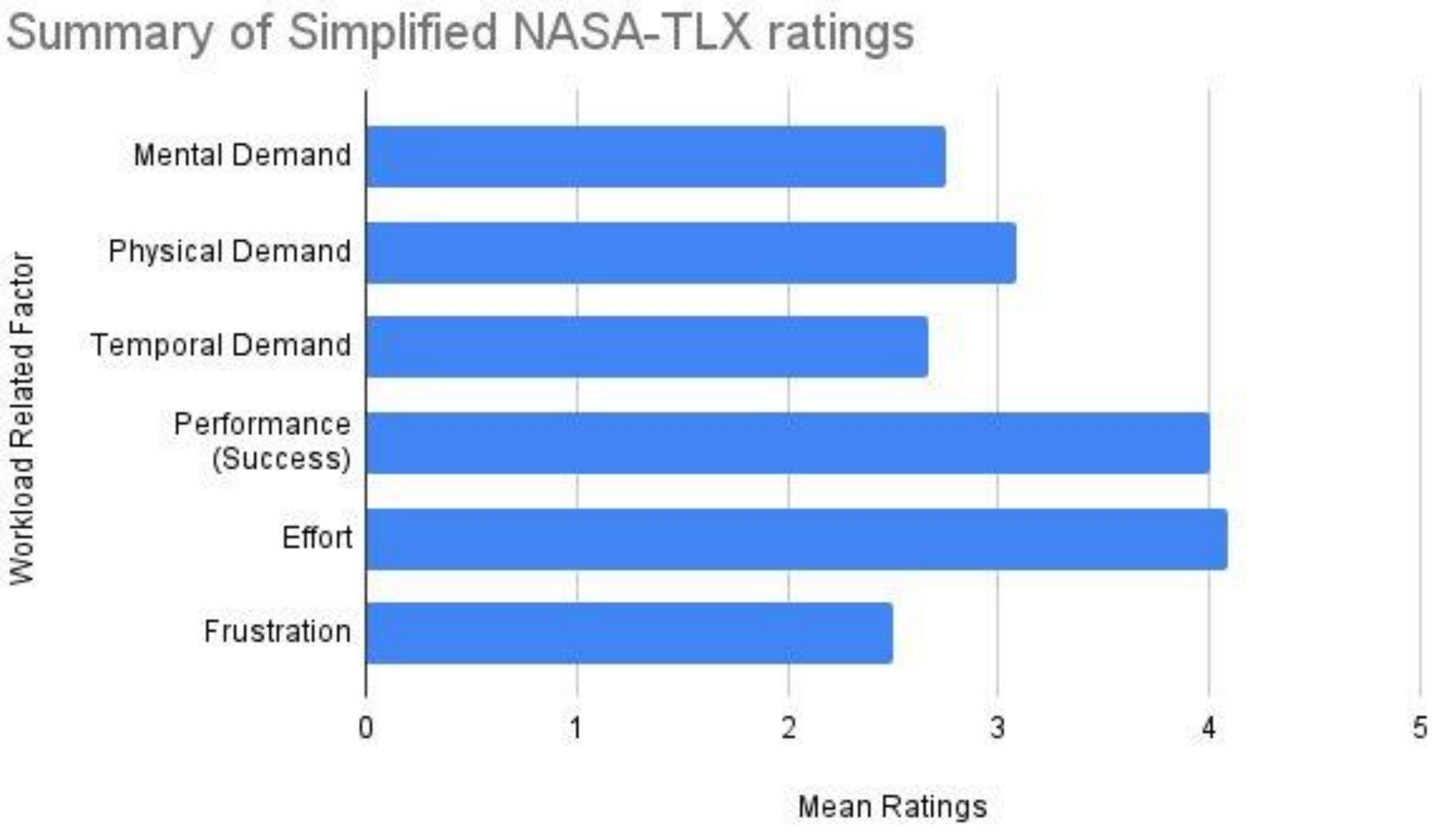
SSQ

- Visual and cognitive load was present but **well-tolerated**
- **No participants discontinued** the test
- Design features (neutral background, short sessions, rest breaks) effectively **minimised simulator sickness**



NASA TLX

- The task was **moderately demanding**, but **well-tolerated**
- Participants felt **successful, focused, and committed**
- Supports the test's **suitability for short-term use in VR environments**



Qualitative Feedback

- **Instruction Clarity**
  - **100%** found the instructions **very clear**
- **Focusing on Centre Target**
  - **33%** found it easy
  - **50%** were neutral
  - **17%** found it difficult
- **Visual Feedback Usefulness**
  - **75%** found it helpful for maintaining focus
  - **25%** found it distracting, preferring fewer visual cues
- **Overall Experience**
  - Most participants found the test **interesting and engaging**
  - **41.6%** also reported it to be **tiring**

Conclusion

Summary

- Developed a **VR-based visual field-testing system** using consumer-grade hardware with built-in eye tracking.
- Aimed to provide a **cost-effective, accessible alternative** to traditional clinical perimetry tools like the Humphrey Field Analyser.
- Built using Unity’s **Model-View-Controller** pattern, integrating:
  - ➢ User interface
  - ➢ Stimulus generation
  - ➢ Real-time fixation feedback
  - ➢ Structured data logging

Key Findings

Quantitative

- **Real-time visual feedback**
  - improved fixation (+14.71%, $p = 0.017$)
  - reduced false positives (-12.19%, $p = 0.015$).
- **Reaction time** slightly increased (+12.28 ms, $p = 0.018$), suggesting possible cognitive load.
- **Negative rate** increased slightly but were **not statistically significant**.

User Experience

- Participants rated the system as **comfortable and tolerable**.
- **Low simulator sickness**, with moderate eye strain and fatigue.
- Users reported feeling **successful and engaged** throughout testing.

Further Research

- **Advance Testing Algorithms**
  - Integrate dynamic methods like **ZEST** to estimate detection thresholds
- **Brightness Calibration**
  - Develop **hardware-based brightness calibration** using photometers or sensors
- **Advanced Eye-Tracking Features**
  - Add **dynamic gaze correction** and **gaze-based fatigue analysis**
- **In-App Tutorial & User Guidance**
  - Use **adaptive training sessions** to reduce early testing errors
- **Clinical Validation Studies**
  - Conduct trials comparing performance with **clinical standards**
- **Visual Field Remapping Modules**
  - Develop corrective tools for users with deficits, enabling **rehabilitation and visual correcting**

Demo


Menu
Dock VR View
Full Screen
Last calibration:
3/17/2025 2:52 PM
CALIBRATE
Use Eye Tracking
17:01

Any Questions?


Thank you!
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