Increasing the Intuitiveness of VROOM Using Standard Software Engineering and User Experience/User Interface Design Methodologies

By Sauhardha Pandey

Student Number: 14162465

Major: Software Engineering

Supervisor: Daniel Catchpoole

Project ID: AUT-24-17297

University of Technology Sydney

Author Note:

Dedicated to Professor Daniel Catchpoole's Research Team, a guideline on how to take VROOM closer to clinical integration via intuitive usability.

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Abstract

This paper explores the enhancement of the VROOM system, a virtual reality (VR) application for complex medical data visualisation in 3D; through the integration of standard software engineering and user experience/user interface (UX/UI) design methodologies by leveraging user-centered design principles, including proximity-based triggers, audio cues, and a virtual tablet interface. The improved design prototype is made in the StellarX simulation app and significantly improves the intuitiveness and usability of the proposed framework for applications like VROOM. We find the importance of iterative design and user feedback in developing effective VR applications for clinical user integration.

Preliminary observations indicate a notable reduction in cognitive load and enable the user to conduct smoother navigation, in turn allowing for more intuitive interaction with complex medical data. Future work is recommended to conduct comprehensive usability testing with a diverse group of medical professionals to validate the effectiveness of the enhancements. Additionally, further iterations could explore advanced features such as AI-driven assistance the integration of large language models within the app. Expanding the application to support collaborative work environments and multi-user interactions could enhance its utility in clinical practice. Ongoing updates and maintenance will also be essential to keep the system compatible with evolving VR hardware and software standards.

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1. Introduction and Literature Review

1.1 Key Concepts and Theories

The use of augmented and virtual reality (AR & VR) in medicine has versatile applications that have been enhancing clinical practice since the early '90s (Eckert 2019; Sielhorst et al., 2009). Practitioners could gain further benefits if AR and VR are seamlessly integrated into the clinical workflow. Research indicates that AR and VR's full potential can be realized when they merge with practice in a way that makes their layer imperceptible, allowing professionals to fully leverage augmented virtual data with properly integrated in situ information (Yeung, A. W. K., Tosevska, A., 2021; Sielhorst et al., 2009; Cipresso, P., Giglioli, I. A. C., 2018).The growth of VR/AR adoption adds to the number of systems used to represent information.

Previously, it was easier to visualise data with lower dimensions, such as exponential growth or particle behavior. However, the need for more suitable representations is growing. In recent decades, models have subjected data to spatial frameworks that provide more effective interaction means, such as with large biological data or computer processor circuitry in synthetic environments (Chalmers, 1995; Fahlén, L. E., Brown, C. G., Ståhl, O., & Carlsson, C., 1993). Early development in designing systems for complex data interaction considered several fundamental areas: semantics, contiguous (spatial), and social aspects of design (Chalmers, 1998).

1.2 Key Debates and Controversies

There remains an ongoing discourse about the most effective design or user interface representation for a VR/AR platform intended for clinicians. Exploring scientific methodologies in data representation (Olshannikova, E., Ometov, A., Koucheryavy, Y., & Olsson, T., 2015) is insufficient in this emerging field of technological integration. The consideration of beauty and elegance in interaction is also imperative to create a system that functions seamlessly (Hanchar, A., 2012). This necessity arises because an interaction method suitable for one plane may not transition well to another platform due to the nature of human-computer interaction (HCI) and concerns about cognitive load imposed by the data (Nina Hollender, Cristian Hofmann, Michael Deneke, Bernhard Schmitz, 2010).

While VR/AR systems for medical practice and intuitive 3D design for consumer use have been evolving in the marketplace, there is a gap in research combining various aspects for clinical use handling complex data. High-resolution and low-persistence display technology can be integrated with user-friendly interaction to elevate immersion in the user's experience (Sutherland, J., et al., 2019). Methods of image segmentation have been used to visualize anatomical models, and similarly, large complex data should be visualised with an implicit design language to avoid cluttering the practitioner's view and to circumvent human cognitive limitations.

1.3 Significance of the Problem

The use of augmented and virtual reality (AR & VR) in Medicine has been stated to have versatile applications which has been improving clinical practice since the early '90s (Eckert

2019; Sielhorst et al, 2009). Through constant evolution in the technological front and software design, Apple Inc. has maintained its success as an industry leader (Kim, J., Jeong, B., & Kim, D., 2021). Apple also entered the augmented reality in 2024 with it's "Vision Pro". With guidelines to their innovation and approach to complex human computer interaction, we can study it to adopt effective methods of design thinking. Apple has a core design philosophy seen in all of their products as the value of a well-designed user interface seamlessly blends with a comprehensive system architecture, encompassing both hardware and software components delivering a meaningful and practical service (Dey, P. et al, 2019). Developers and practitioners have realised that complex systems with intuitive GUIs cannot be made in one cycle, but rather, it is an iterative process that takes evolution and prototyping (Pressman, R., & Maxim, B., 2015; Dey, P. et al, 2019). Therefore, the next 5 years of mass adoption in VR/AR systems as they have long passed the trough of disillusionment, (Linden A, Fenn J, 2003) will refine the design language established by industry leaders like Apple, Meta & Magic Leap into a wider array of use cases. We can study the extensive best practices and design philosophy of Apple and other companies like Meta in the mixed reality space to ensure that HCI is fluent in the emerging market.

1.4 Gaps in Existing Knowledge

In the evolving field of user interfaces, incorporating natural modes of interaction that feel logical yet unobtrusive is crucial. Allowing users to directly manipulate 3D objects or models makes the experience more intuitive and immersive. Employing familiar gestures, maintaining simplicity in interactions, and using creative methods such as motion or proximity detection will bring the content to life (Apple Inc, 2023). This platform also holds significant potential for collaboration among users. Although developers have created various aspects of VR applications, there is no central application or framework designed specifically for clinical use, viewing large sets of medical data, or integrating with existing healthcare systems.

Improvements can still be made to working prototypes like VROOM to optimise scalability. When developing a VR application framework for representing interoperable clinical data and large sets of complex visualisations, integrating features through user feedback is essential to confirm usability and functionality. Ultimately, through multiple iterations, we can expect to develop an application model that serves as a valuable tool for clinicians.

1.5 Scope of the Study

The scope of this study is to simply improve the use of VROOM for new users by utilising effective user interface design and incremental improvements like audio cues and pop-up tutorial guides. These improvements will then be tested with a control group to use both interfaces and provide feedback (VROOM and the new UI model).

1.6 Objectives

The goal of this project is to arrive at a conclusion of the next steps to take in advancing a medical VR application which lacks guidance and user interface cues. A new user struggles to learn all the functions and behaviours that differ in a VR environment. Unskilled professionals who have no VR, software or modelling background will face challenges when trying to interface with a new environment, especially when it boasts complex medical data (Chamusca, et. Al., 2023). Therefore, a new guideline for solving this issue for new and long-term users will be synthesised in this paper.

2. Problem Statement

2.1 Current Challenges in VR Applications for Viewing Medical Data

The implementation of VR for viewing medical data still presents several challenges. First is motion sickness which is a very common issue and an immediate deterrent to the platform. Secondly, the high cost of VR equipent and the need to specialise training for someone to utlisise the application effectively poses logistic and financial barriers. Further, VR technology requires significant technical expertise for maintenance and troubleshooting, this means that for medical professionals adapting to VR systems, there is a considerable learning curve (Banyesadi, et. Al., 2020).

2.2 Limitations of Existing Solutions

There are many limitations to existing solutions still, from a software engineering standpoint. First is optimisation and performance as VR requires a high standard of graphics rendering and real time data processing (Smith, J., & Johnson, A., 2020). The interoperability and compatibility issues must also be highlighted as developing VR applications which seamlessly integrate with various devices and software frameworks requires careful consideration of compatibility standards and a robust software architecture (Brown, C., & Lee, R., 2019).

Ultimately, the applications must be maintained regularly to address essential bugs, features and ensure ongoing compatibility with evolving VR hardware and platforms, this can be achieved with dedicated resources to the continuous software development in order to keep the applications up to date and ready to use for a clinical setting (Oculus VR, 2020).

3. Project Objective and Methodology

3.1 Procedures

The new UI design prototype is a representation of the VROOM space that takes place on the StellarX application which is a unity-based simulation environment on the Quest VR (Meta Quest 3). This new UI system with its incremental upgrades will be compared to the VROOM prototype from 2019. Participants will be recruited from diverse backgrounds and will be informed on the purpose of the study. The VR environment will be set up in a virtual workspace on the same headset and each participant will be guided through a series of tasks aimed at assessing the usability or intuitiveness of both designs. After the participant is done with the procedure, feedback and performance metrics will be recorded (see section 3.2.2) during the test session alongside a simple survey which will be conducted immediately after the session. Both the qualitative and quantitative data will be analysed where we can then draw conclusions on the effectiveness of the new methods in the StellarX model.

3.1.1 Development of VR Prototype

The demo environment with user interface improvements is made in the StellarX app, Meta Quest 3. The environment takes place in a studio with a table in the centre which has two buttons. One button is to instantiate a solo patient model and the other is to instantiate a dual patient comparison model. This visualisation environment has been set up with programming flows to activate based on proximity and user interaction, i.e. when the user stands in a zone, a menu or pop-up or audio instructions are activated so the user doesn’t have to compute their interaction, it happens naturally (Oculus, 2024; Bailenson et. Al., 2008). This is the philosophy for which the new UI design is based on.

3.1.2 Implementation of Pop-ups & Proximity

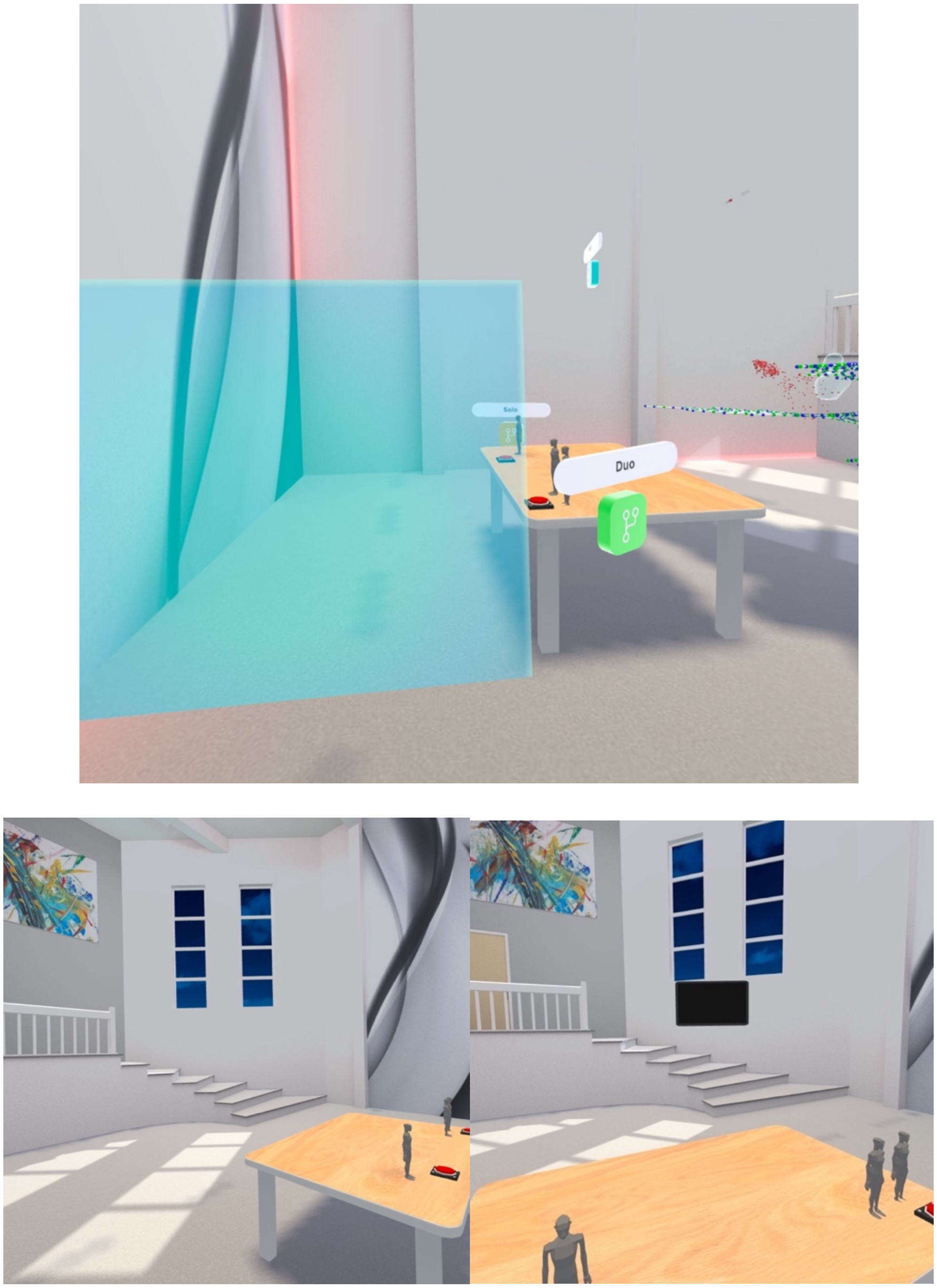

Figure A, B, C: Area Activated Action

Figure A shows a blue cube that triggers a media screen to pop-up in front of the user when they are standing inside it; see Figure B then C for the transition. This sort of system is known as proximity-based trigger which improves the impact of spatial memory allowing for enhanced navigation and other tasks in VR with reduced cognitive load (Vinnikov, et. Al. 2017).

3.1.3 Implementation of Media Cues

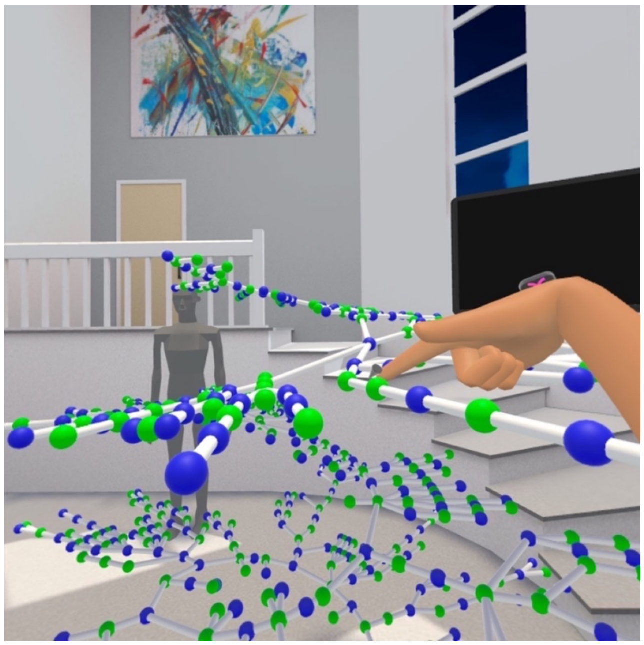

Figure D: Media Screen Next to Interactive Object

Figure D (above) shows a pop up media screen which can be used to play a video relevant to the object the user is interacting with in this scenario. Additionally, audio cues that announce the details of what is being observed or simple cues that let the user know to progress to the next stage of the workflow can greatly enhance the user's cohesion and reduce the cognitive load while performing multiple tasks as it reduces the amount of reading and thinking required (Holdack et. Al, 2020).

3.1.4 Using a Local Graphical User Interface for Interaction and Navigation

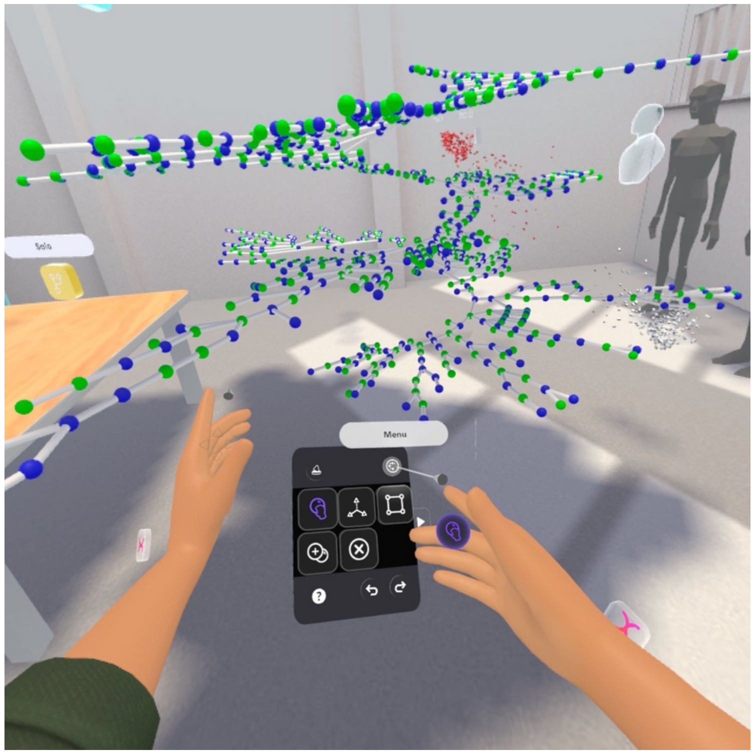

Figure E: Virtual Tablet for User Interface

4. Data Collection

The data collection for this experiment should be qualitative and quantitative. Feedback from users and some objective performance metrics will be gathered from users who try the new UI prototype alongside VROOM (2019). This allows for evaluation of the intuitive UI compared to the existing application's UI.

4.1.1 Sources of Data

The primary source of data will be the users who interact with both the new UI prototype and the existing VROOM application. Additionally, the data from the VR system's logs shall also be collected to view user's behaviour, preferences and usability performance.

4.1.2 Data Collection Methods

- **User Testing**: A control group (approximately 3-6) participants will be recruited to engage with both applications, the new UI design and the VROOM. During these sessions, users will be asked to perform specific tasks and provide feedback so we can gather insights into how they perceive both UI designs.

- **Performance Metrics**: Data from performance metrics such as task completion time (in seconds), error rates, memory recall and user interaction will be recorded as users participate in the usability sessions.

4.3 Data Analyses

After the new improvements are implemented, conducting usability tests with a range of participants will allow for a clear view of the efficacy. The participants should vary from new users to the VR/AR platform and experts of clinical practice as follows.

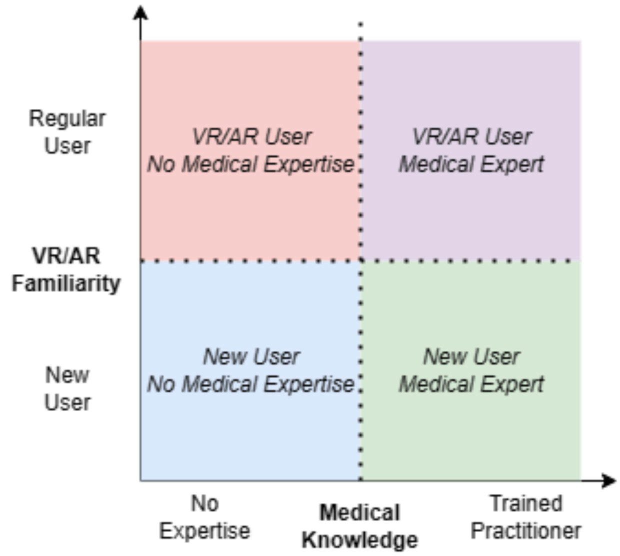

Figure F: Target range of research participants in future

4.4 Validity of Results

The validity of results from the above method (see 4.3) depends on the inclusivity of user base. By incorporating participants from the four quadrants, new users without medical expertise, new users with medical expertise, regular VR users without medical expertise and regular VR users with medical expertise– the study will ensure a diverse evaluation of UI usability. This diversity allows diagnosis of usability issues that effect specific quadrants of user groups. Furthermore, we can do a robust assessment of the system's adaptability across varying levels of familiarity with VR and mixed reality technology as well as medical knowledge. This means that the usability tests will be reliable and reflective of real-world clinical scenarios, ultimately making a guideline to further the intuitiveness for an effective user interface design for all users.

4.5 Potential Limitations

Although this is a comprehensive approach for usability feedback, new users may struggle with articulating specific issues while experienced users might overlook basic usability problems. Further, using a small sample size might not capture all the possible user interaction scenarios. Ensuring a consistent testing condition for a varied group may also prove difficult and the time required to recruit a diverse participant pool can be significant which can reduce the scope of improving the design on an iterative basis.

5. Blueprint of VROOM and StellarX Prototype Improvements

The following sections will detail a one-to-one comparison of the iterated improvements using software design methodologies to ensure a more cohesive and intuitive user experience. Each sub-section has one VROOM feature or design in the first figure with its corresponding improvement in StellarX following that.

5.1 One to One comparison of Environments

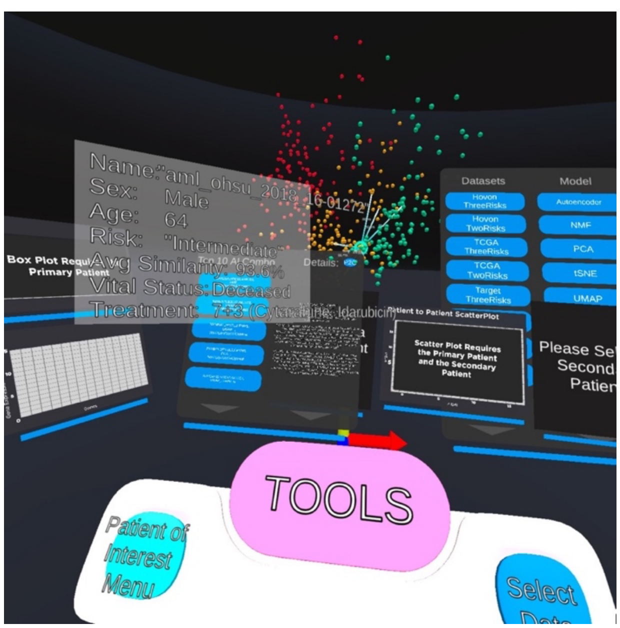

Figure G: Standard Workflow Environment (VROOM)

Figure G (above) shows the standard workflow in VROOM, a static table with tools and options to enable features for analysis such as selecting data pools, adding windows for tasks like single patient analysis and the 3D model graph i.e. Circos plot for data interrogation. Figure H (below) also has a static table but for the different purpose of giving physical familiarity to the user; the menu options are available in a hand carried virtual table rather than on the operating area itself. Standing in the operating area proximity allows you to select which model to view alongside a media screen that guides the user on how to use the software. Overall, the StellarX prototype utilises a physical room with proximity-based triggers to orient the user, a virtual menu system that follows the user wherever they go for ease of access and audio/video cues to ensure the user is aware of the next steps in their workflow.

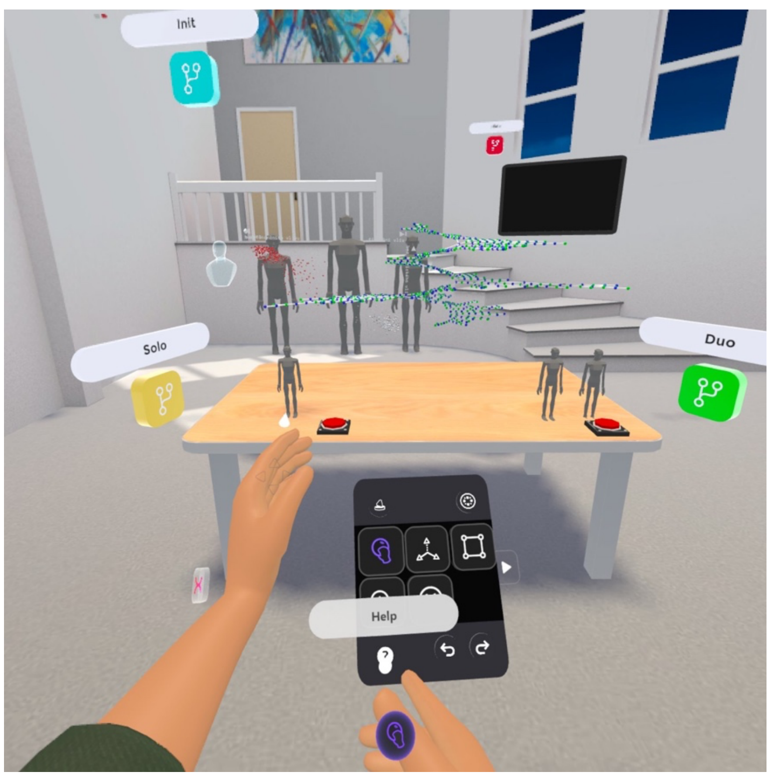

Figure H: Standard Workflow Environment (StellarX Prototype)

5.1.1 Local Orientation

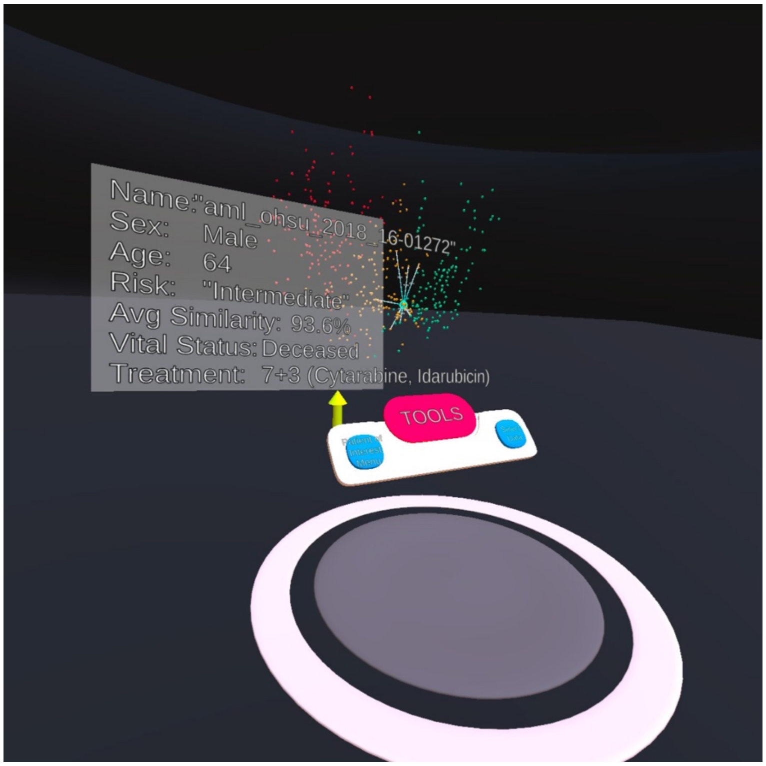

Figure I: Surrounding Area with Workspace (VROOM)

Figure I (above) shows how the operating area in VROOM is static, to move closer or farther away, the user must physically walk. The surrounding background also confuses some users as its simply a gray virtual environment. Improvements to help ease the user's orientation are as follows in Figure J (below). In Figure I, the user is placed in a virtual room or studio with walls and windows so it reduces cognitive load to ensure correct orientation and is more natural. The user can also point their left hand at any space in the floor to teleport (see image below) which enables the user to use the software in any limited space or room; essential for accessibliity in a clinicians office that is not able to freely move around.

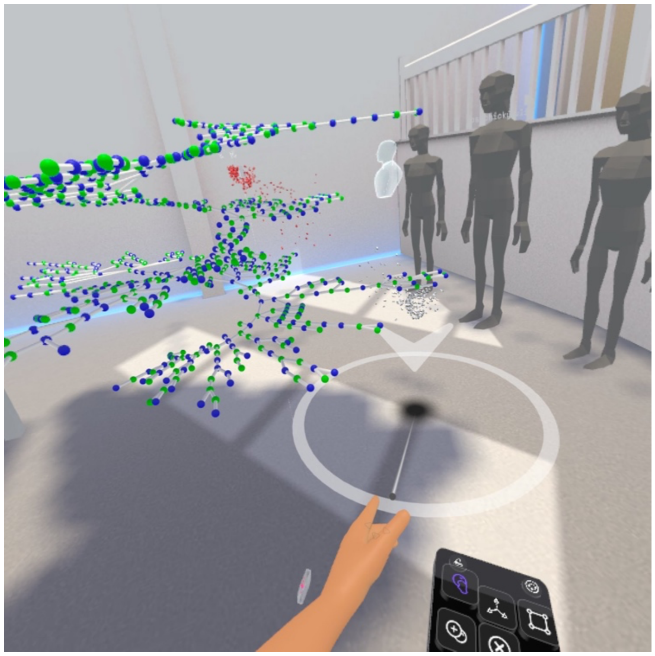

Figure J: Surrounding Area with Workspace (StellarX Prototype)

5.1.2 Graphical User Interface

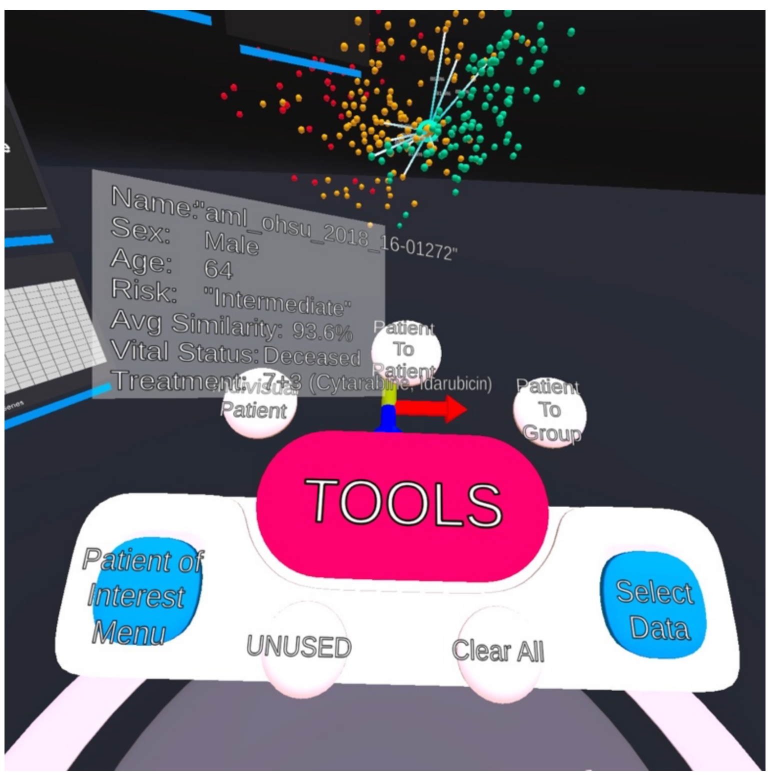

Figure K: Close Up of Static Menu (VROOM)

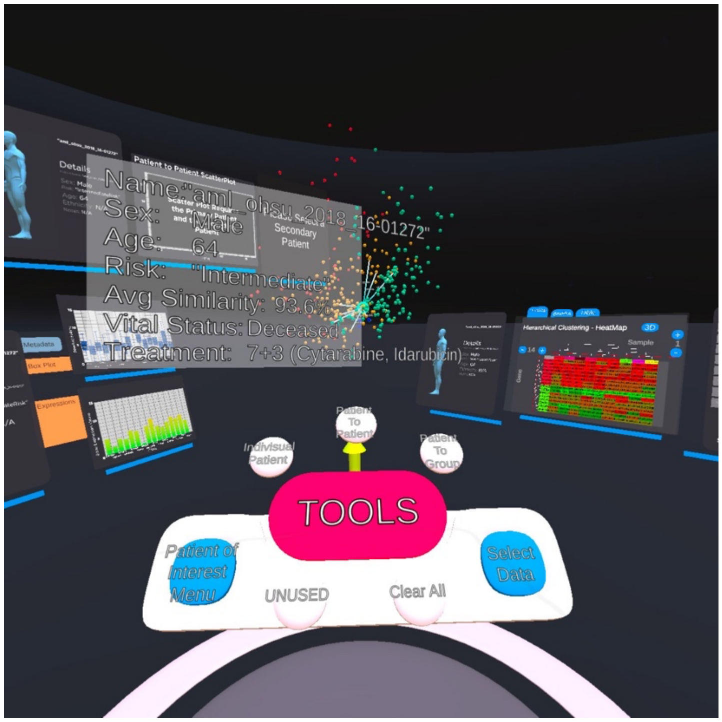

Figure L: Wide Shot of Static UI Menu and Panels (VROOM)

Figure K and L (above) show how the user interface menu and data are represented in VROOM, the multifunctional panels area a great way to set up a working environment with different displays that can be moved around and adjusted. The main menu is a static table with one red button “tools” and two blue buttons “Patient Menu” and “Select Data”, this is a nice and simple way to represent the UI however it can be made more intuitive and accessible. Figure M and N (below) show an improvement on the menu UI by moving the menu to a virtual tablet on the left hand (Figure M) which can be toggled and a pop-up menu which appears in front of the users face on button press (Figure N). Having a local menu on command is akin to having a tablet or smartphone in real life, users will naturally understand how to toggle and change elements in their virtual environment as if using a remote control (Medeiros et. Al., 2013).

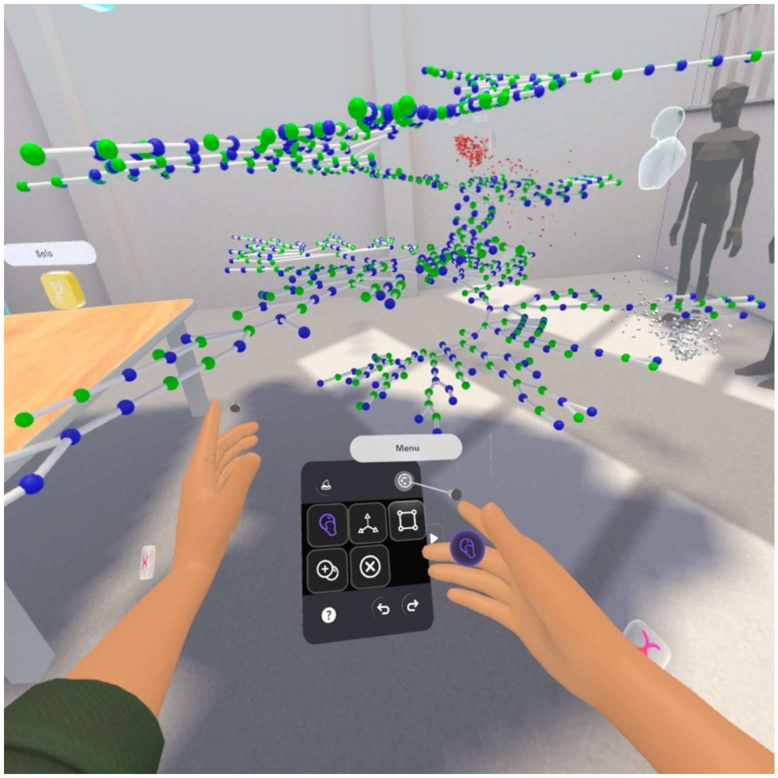

Figure M: Hand Tracked Tablet Menu (StellarX Prototype)

Figure N: Head Oriented Additional Menu (StellarX Prototype)

6. Results and Discussion

6.1 Presentation of Findings

The prototype design in StellarX introduces multiple enhancements to the user interface of VROOM. The new design primarily focuses on intuitiveness and interaction efficiency and accessibility via the integration of proximity-based triggers, media cues and a virtual tablet interface that significantly improves the UX (user experience). All of these improvements are aimed at making the navigation smoother and reducing cognitive load when using the software; with these improvements, users can more easily engage with complex medical data as the interface is more intuitive and less cumbersome.

6.2 Interpretation of Results

The iterative improvements in the StellarX prototype demonstrate the effectiveness of integrating user-oriented design principles in VR applications. By introducing the above-mentioned improvements and interaction methods (see 6.1) the application becomes more accessible and user-friendly and the design changes which reduce cognitive load allow users to allocate their cognitive focus on priority tasks rather than the intricacies of the virtual reality environment/interface. Ultimately, the shift towards a more intuitive user experience will facilitate a greater acceptance and usage of VR technology in a clinical setting.

6.3 Discussion on Implications

The improvements made in the StellarX prototype can significantly impact the future design and development of VROOM and medical VR applications as whole if implemented well. By making the application more intuitive with software UI/UX (user experience/user interface) principles, we can reduce cognitive load for the user and help medical professionals rapidly adopt VR systems. This can lead to wider integration of VR in clinical workflows enhancing clinician's capacity to interrogate complex data and improve patient outcomes. The ease of use in the suggested prototype would ensure that VR applications like VROOM can become a practical tool in clinical practice rather than a niche technology.

Although we did not get to rigorously test performance metrics with a control group, the success of the user-oriented design changes on trial will ensure that these design changes provide a valuable framework for future development in medical VR technology. By prioritising the user experience and incorporating iterative feedback into the design process, we can ensure more effective and intuitive application across various fields. The iterative design model in software engineering highlights the importance of continuous enhancement and adaptation to the changing landscape or VR technology (version management/codebase maintenance) and user needs which not only benefits medical practitioners but also sets a precedent for designing intuitive applications in other complex data focused industries.

7. Summary and Recommendations

7.1 Summary of Findings

This paper has explored the enhancement of intuitiveness of the VROOM application system using standard software engineering and UI/UX principles through proximity-based actions, audio/visual and media cues, naturally oriented environment and an improved graphical user interface via a virtual tablet. These enhancements all combine to reduce cognitive load and make navigation more natural and facilitate a more seamless interaction with complex data-driven software for new users; ultimately with the undertaking of this project we also find the importance of iterative design and user feedback in developing effective software in an emerging market, especially regarding virtual reality.

7.2 Recommendations for Future Work

Future work should focus on conducting usability testing amongst a diverse group of users (see Figure F) to validate the effectiveness of new features through gathering quantitative and qualitative data on task completion times, error rates and general user feedback. Furthermore, with the rapid integration of large language models and AI in software design (Rao et. Al., 2023), additional integration of AI on top of media cues could tailor a more personalised user interface that understands and learns a clinician's needs whilst using the application. AI can also enhance the clinical workflow by further reducing cognitive load with tasks and memory recall.

Expanding the application to support collaborative work environments and multi-user interactions may also enhance its utility in clinical practice. Finally, the ongoing maintenance of software is essential to keep the system compatible with the evolving VR landscape (software & hardware) and ensuring the long-term viability of transformative tools like VROOM.

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8. Appendix

Figure A, B, C: Area Activated Action

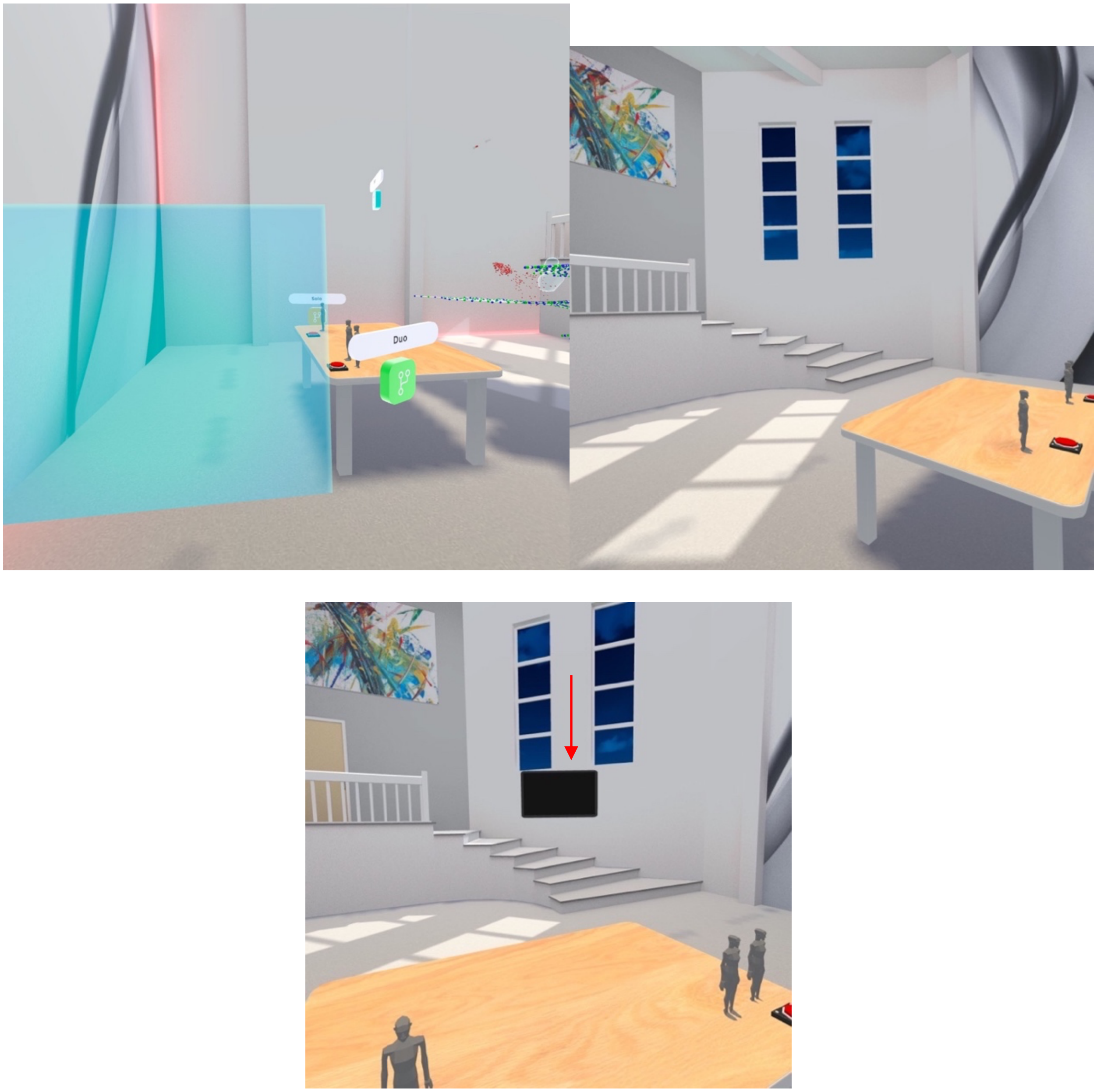


Figure D: Media Screen Next to Interactive Object

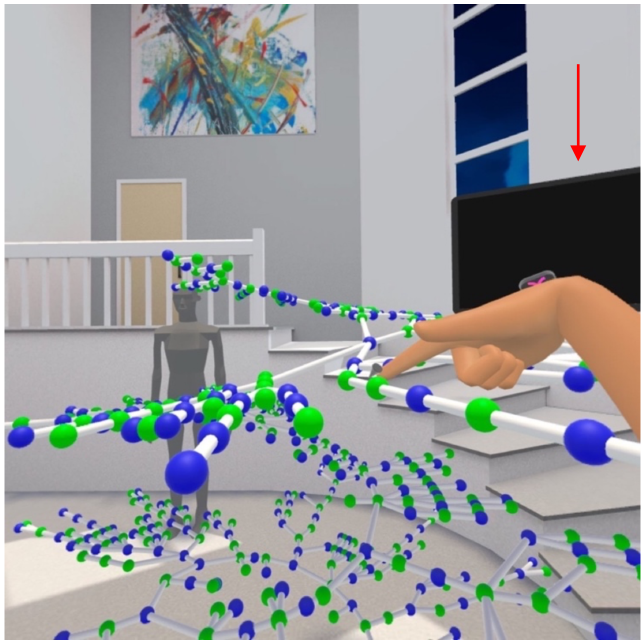
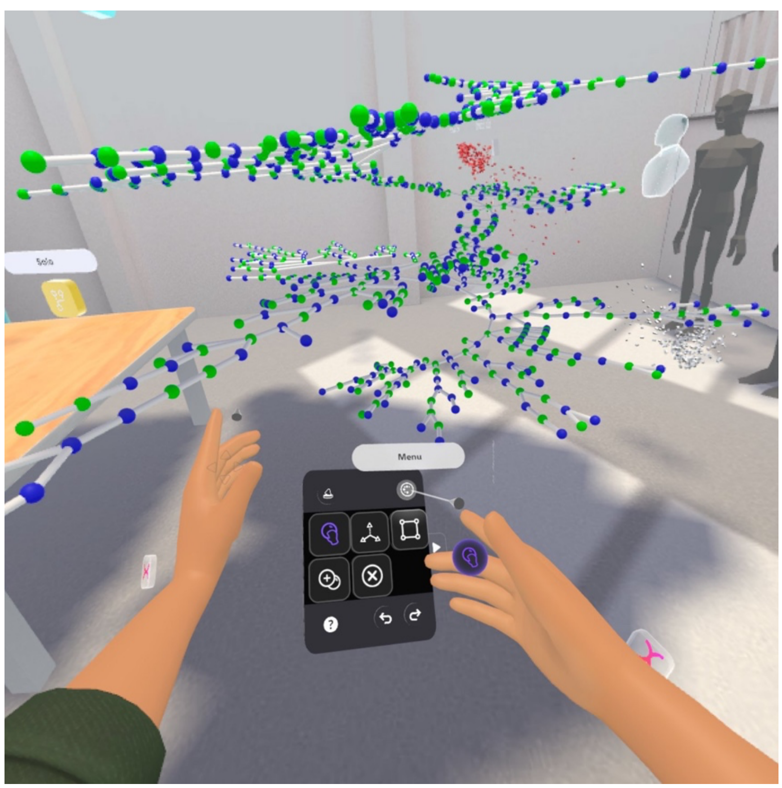


Figure E: Virtual Tablet for User Interface



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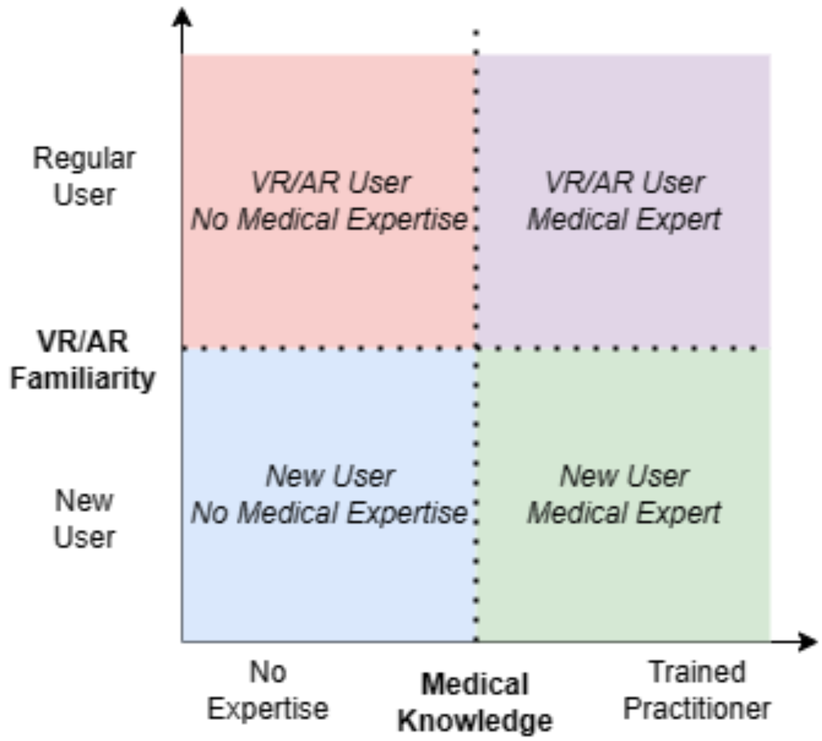

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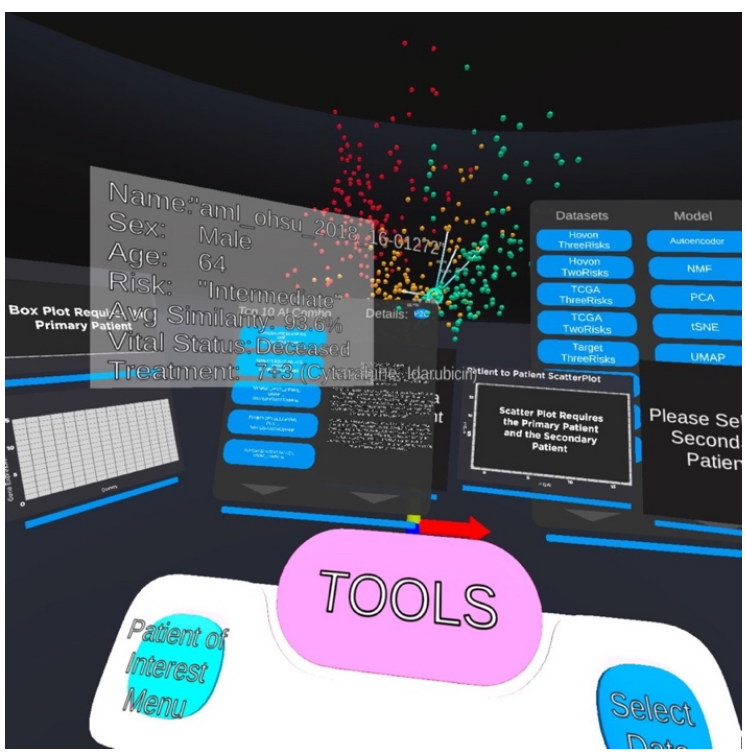

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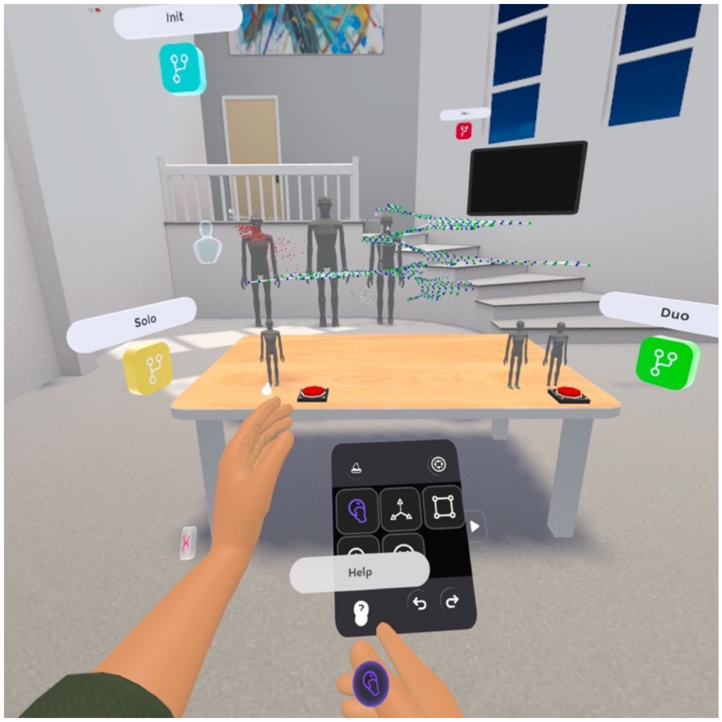

Figure I: Surrounding Area with Workspace (VROOM)

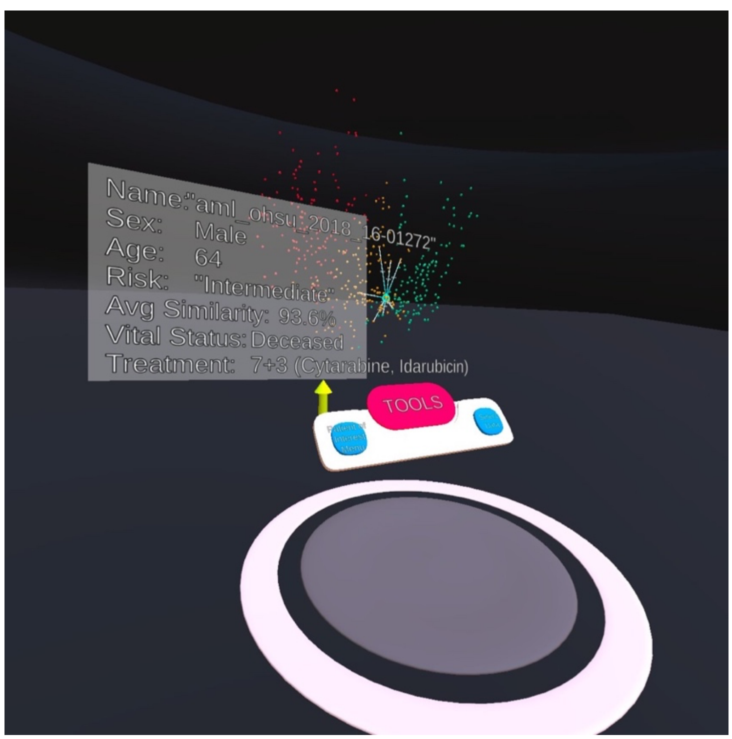

Figure J: Surrounding Area with Workspace (StellarX Prototype)

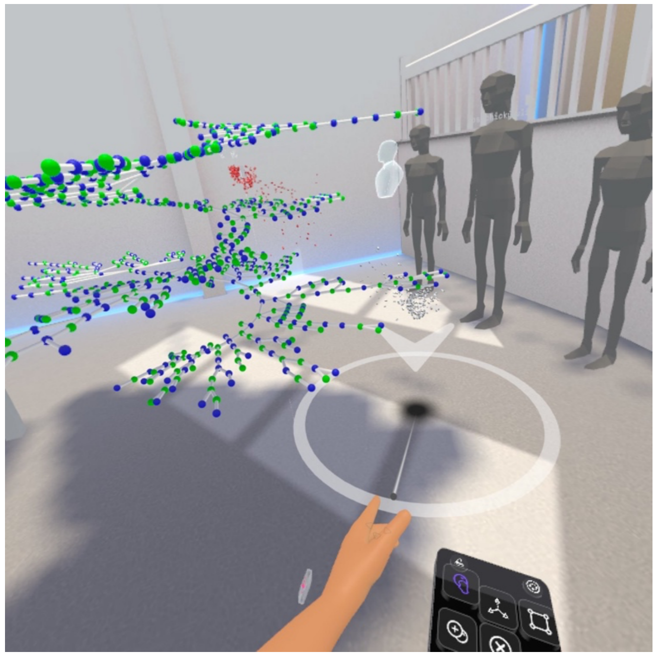

Figure K: Close Up of Static Menu (VROOM)

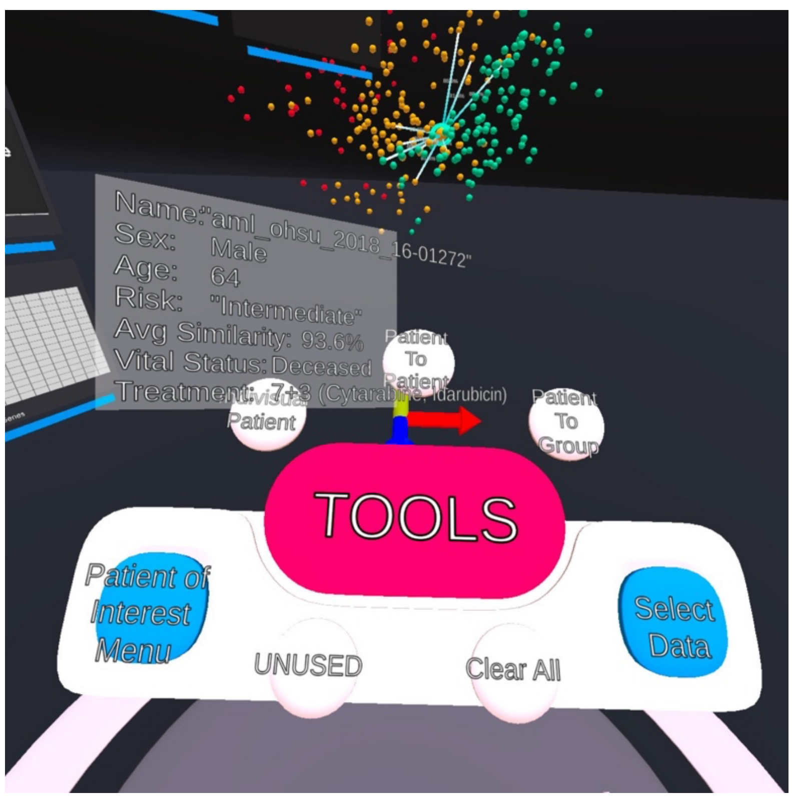

Figure L: Wide Shot of Static UI Menu and Panels (VROOM)

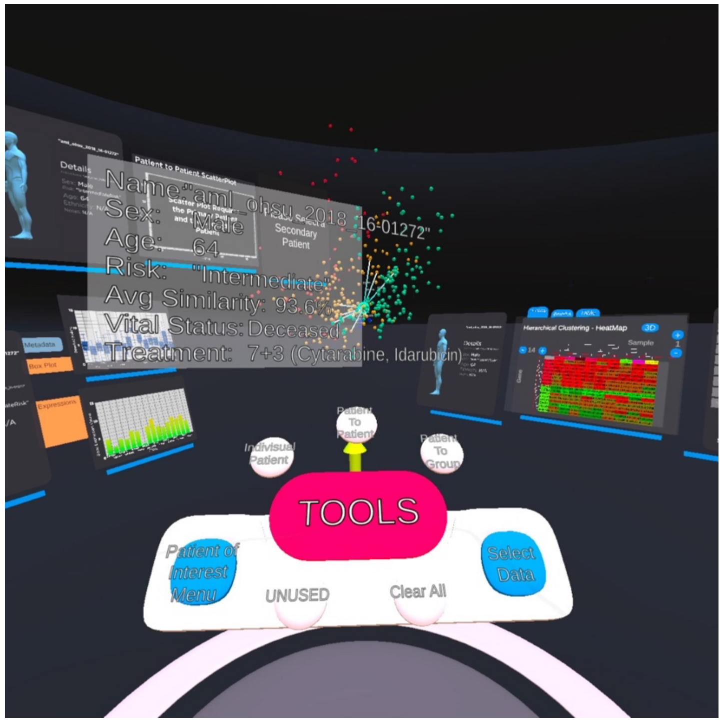

Figure M: Hand Tracked Tablet Menu (StellarX Prototype)

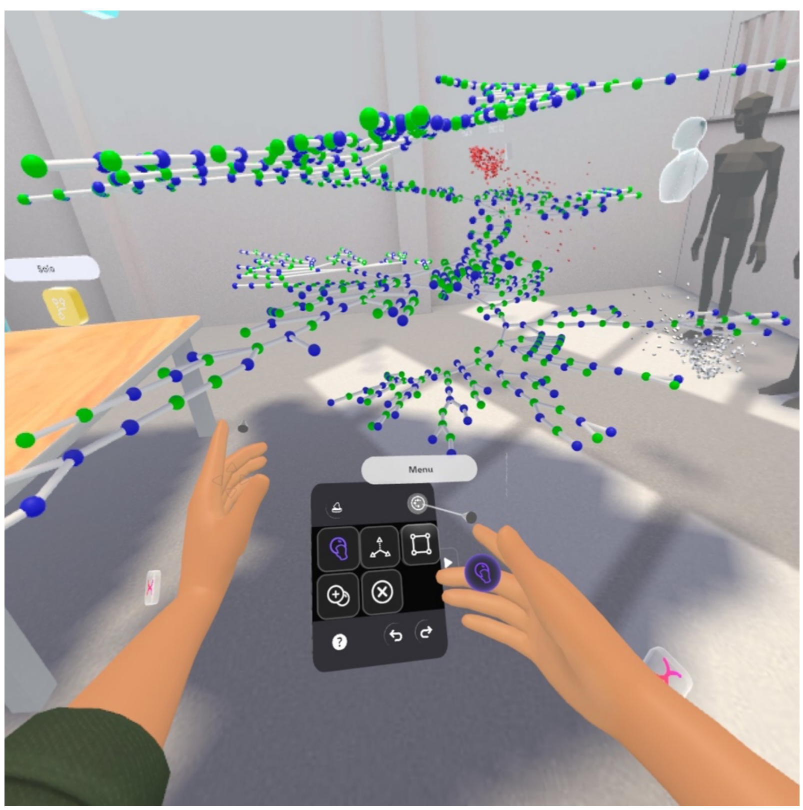

Figure N: Head Oriented Additional Menu (StellarX Prototype)