Serious Game Development for chronic disease management

by

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Abstract

This master's thesis focuses on the development of a Serious Game, named Avitar, tailored for chronic disease management through an interactive approach. Traditional health apps often fail to engage users due to their perceived monotony. Avitar addresses this challenge by utilizing Unity and HealthKit API to create a visually appealing environment where an Avatar serves as a dynamic representation of the user's health status.

The game incorporates data from the HealthKit App, including heart-related metrics (heart rate, high/low heart rate events, irregular rhythm events), activity data (steps, distance walking/running), and vitals (blood glucose, insulin deliveries) over the past 24 hours. Avitar acts as a personalized guide, offering simple tips derived from this data to motivate users without being overly prescriptive.

The methodology involves two key components: efficient data retrieval and structuring from HealthKit and the aesthetic aspect of creating the Avatar using UModeler X library. The InWorld UNITY SDK breathes life into Avitar, enabling dynamic interaction with the user's health data.

While the emphasis lies on implementation, the thesis acknowledges the need for further research in refining the user experience. The game's success is measured not only by its technical prowess but also by its ability to provide a satisfying and motivating digital health experience, addressing a gap in the current landscape of health apps.

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Any opinions, findings, conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the «funding body» or the view of University of Piraeus and Inst. of Informatics and Telecom. of NCSR “Demokritos”.

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"Inworld AI is proud to support and enable academics in exploring how immersive characters can positively affect the end user experience, especially for Serious Games and Simulations. We will continue to improve our platform to make integrating our AI characters seamless and easy to customize.”

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1. Introduction

The intersection of artificial intelligence and healthcare has opened new avenues for innovative solutions. In this context, the development of a Serious Game, named Avitar, emerges as a novel approach for chronic disease management. Avitar seeks to bridge the gap between conventional health apps and user engagement by creating an interactive and visually immersive experience.

1.1. Background and Motivation

Within the landscape of health applications, a pervasive challenge lies in their recurring difficulty to captivate and maintain user interest. This widespread disengagement stems from a predominant perception of these apps as tedious chores rather than immersive experiences. The crux of this issue is frequently traced back to an unbalanced emphasis on technical and utility aspects, often to the detriment of the User Interface (UI) design. In this context, the UI serves as the gateway to user interaction and experience, yet its significance is often overshadowed by a disproportionate focus on functionality.

Moreover, the disconnect between users and health applications can be further attributed to suboptimal data handling practices. Frequently, these apps present vital health information in a raw and convoluted manner, manifesting as inscrutable charts and numbers that lack meaningful context. This visual complexity not only contributes to user disinterest but also perpetuates misunderstandings. Users, grappling with this overwhelming data presentation, may inadvertently divert their attention towards metrics of lesser consequence, potentially neglecting critical health indicators in the process.

The confluence of these factors creates a substantial gap between users and their health data, hindering the potential for informed decision-making and proactive health management. As this gap widens, the efficacy of health applications as tools for positive

behavior change and sustained engagement diminishes. Recognizing these challenges underscores the necessity for innovative solutions that transcend the conventional paradigms of health app design.

In response to this challenge, this master's thesis introduces Avitar, an innovative game designed to transcend the limitations of conventional health apps. Avitar not only monitors health metrics using the HealthKit API but also transcends raw data by translating it into a visually representative Avatar. The motivation behind Avitar arises from the imperative to provide users with a more engaging and enjoyable avenue for health management, with the ultimate goal of cultivating lasting commitment and positive behavioral changes. As technological advancements continue to unfold, the amalgamation of serious gaming and health monitoring emerges as a critical frontier, compelling exploration and innovation within this interdisciplinary domain.

The integration of personalization in the in-game character and environment, driven by user choices or behavioral patterns monitored in the background, aligns with established gaming practices. Drawing inspiration from games employing Non-Playable Characters (NPCs) that dynamically interact based on player decisions, this approach not only enhances re-playability and realism but also intensifies the user's engagement. Extending this strategy to medical applications represents a significant stride, leveraging the potential of Learning-Based Models (LLMs) to further enhance user experiences in health management.

1.2. Problem Statement

As of today, a conspicuous void persists in the form of an absence of a truly innovative platform that seamlessly translates the intricacies of an individual's health into an aesthetically pleasing and interactive experience, utilizing the capabilities of Artificial Intelligence (AI). Despite the proliferation of health apps, there is a marked dearth of successful applications that harness the power of AI to create a dynamic Avatar reflecting the user's health status. This visionary gap not only limits the potential for personalized

health management but also overlooks the transformative impact such an application could have on user engagement and long-term commitment.

Furthermore, the untapped potential of leveraging HealthKit data presents a pressing issue. The existing health apps largely fail to explore the full spectrum of possibilities offered by HealthKit, merely scratching the surface in terms of data utilization. This limitation represents a substantial opportunity cost, hindering the development of applications that could optimize health data from unique perspectives, providing users with valuable insights beyond the conventional health metrics. The untapped reservoir of HealthKit's potential, if unlocked, could revolutionize the paradigm of health app functionality.

Beyond the technical aspects, a significant societal challenge arises from the lack of user-friendly and diverting solutions for health management. The conventional approach of relying on notes, reminders, and complex health apps often results in fragmented, inconsistent tracking, particularly among the elderly population. Additionally, children grappling with chronic conditions, such as diabetes, face the arduous task of consistent insulin deliveries, often detesting the monotonous chore. The absence of an engaging diversionary tool exacerbates these challenges, highlighting the need for a visionary health application that transcends the conventional to address diverse user demographics and their unique health management needs.

Moreover, the prevalent complexity of health apps, dominated by charts, numbers, and tables, poses a universal hindrance to user engagement. A considerable portion of the population may not possess a proficient understanding of mathematical representations, making these apps inaccessible and discouraging for users with varying levels of numeracy. This accessibility gap underscores the necessity for an inclusive and visionary health application that transcends the limitations of conventional data representation methods, ensuring that health management remains intuitive and universally accessible.

A prominent challenge lies in the prevailing disengagement caused by the lack of a gamified and interactive approach to health management. Current health applications often struggle to sustain user interest, resulting in sporadic usage and limited effectiveness in fostering positive behavior change. The absence of an engaging and immersive platform contributes to a pervasive sense of apathy towards health monitoring, hindering users from actively participating in their well-being. Addressing this issue requires a visionary solution that not only captures user attention but also transforms health management into a dynamic and enjoyable experience, encouraging sustained interaction and fostering a sense of personal accomplishment.

Additionally, the current implementations lack a solution that seamlessly integrates personalized guidance based on individual health metrics. While data tracking is a common feature, the absence of tailored insights and recommendations diminishes the utility of these applications. Users are often left to interpret their health data in isolation, without clear guidance on how to translate these metrics into actionable steps for improved well-being. A visionary health app should not only collect and present data but should also function as an intuitive guide, offering personalized suggestions and nudges that empower users to make informed decisions about their health. The absence of such guidance perpetuates a gap in the market, limiting the transformative potential of health applications in facilitating positive lifestyle changes.

In essence, the amalgamation of these challenges signifies a pivotal moment for the inception of Avitar, a groundbreaking serious game that not only envisions overcoming these barriers but also seeks to redefine the narrative of health management through an innovative and user-centric approach.

1.3. Objectives

To revolutionize the topic, the primary objective is the development of a groundbreaking serious game designed to inject dynamism and engagement into the realm of health management. By employing innovative gamification techniques, Avitar aims to

transform the routine of health monitoring into a captivating and enjoyable experience, fostering sustained user interaction and enthusiasm for personal well-being.

Another key objective involves the integration of advanced AI-driven systems within Avitar to dynamically translate individual health metrics into an aesthetically pleasing and interactive Avatar. By leveraging state-of-the-art AI algorithms, Avitar will offer users a personalized and visually intuitive representation of their health status. This objective addresses the challenge of bridging the gap between complex health data and user comprehension, aiming to redefine how users interact with and understand their health metrics.

Maximizing the potential of the HealthKit API constitutes a significant objective, aiming to go beyond conventional data utilization. Avitar seeks to unlock the full spectrum of HealthKit capabilities, providing users with comprehensive and insightful health metrics. This approach redefines the standard for health app functionality by extracting valuable insights from the rich HealthKit dataset, contributing to a more holistic approach to health monitoring.

Inclusivity is a core objective, with Avitar designed to address the unique challenges faced by diverse user demographics. The user interface and interaction mechanisms will be tailored to accommodate both elderly users, struggling with fragmented health tracking, as well as children with chronic conditions. This ensures a diverting and user-friendly experience for individuals of all ages, aligning with the vision of Avitar as an inclusive health management solution.

To infuse health management with an element of enjoyment, Avitar aims to integrate gamified elements into its design. Avitar's gamification strategy transforms health-related tasks into engaging activities, fostering positive behavioral changes and promoting long-term commitment to health management.

A key objective is to redefine the approach to health data representation within Avitar. The conventional reliance on complex charts and tables will be replaced with intuitive and universally accessible visualizations. This ensures that users with varying levels of numeracy can effortlessly interpret and engage with their health metrics, addressing a widespread accessibility barrier in conventional health apps.

The objective of providing personalized guidance sets Avitar apart from traditional health apps. By incorporating machine learning modules, the app will analyze individual health data and offer tailored insights and recommendations. This personalization empowers users with actionable information, guiding them towards informed decision-making for sustained positive lifestyle changes, thereby enhancing the impact of health management.

To enhance the technical sophistication of the application, a crucial objective involves seamless integration with major state-of-the-art APIs and libraries. This objective ensures it leverages cutting-edge tools to provide a robust and feature-rich serious gaming experience in the realm of health management. The integration of these technologies elevates the implementation, positioning it at the forefront of innovation in the intersection of artificial intelligence and health applications.

1.4. Scope and Limitations

This work aims to transcend conventional health applications by introducing gamification elements and leveraging advanced AI techniques. The focus lies on creating an engaging and dynamic platform that not only monitors health metrics but also transforms the user's health data into an interactive and visually intuitive self-reflection. The project also involves the exploration and integration of major state-of-the-art APIs and libraries to enhance the its technical sophistication, ensuring it remains at the forefront of innovation in the intersection of artificial intelligence and health applications.

Furthermore, the scope extends to the utilization of the HealthKit API to its full potential. The integration of HealthKit is not just limited to data retrieval; instead, the project aims to explore comprehensive data utilization, unlocking the richness of HealthKit's capabilities. It aspires to redefine the standard for health app functionality by extracting valuable insights from the extensive HealthKit dataset, contributing to a more holistic and insightful approach to health monitoring.

The inclusive design is a significant scope, accommodating diverse user demographics. This involves tailoring the user interface and interaction mechanisms to ensure that Avitar is user-friendly for both elderly users, grappling with fragmented health tracking, and children with chronic conditions. The project aims to provide a diverting and universally accessible experience, catering to individuals of all ages and health management needs.

While it holds great promise, its effectiveness is inherently dependent on user adoption and sustained engagement. The success of the serious game is contingent on users actively incorporating it into their health routines and engaging with it consistently. Thus as it will be described later, two interviews with people with diabetes have taken place to discuss the user cases.

The project's dependency on the HealthKit API introduces a limitation, primarily related to compatibility. The app’s seamless integration with HealthKit is tailored for iOS platforms, potentially limiting its reach to users on non-iOS devices. Apart from that, another issue is the dependancy of version tracking of the APIs used, as it will be discussed later.

Technical constraints may pose challenges to the seamless integration of all desired state-of-the-art APIs and libraries. Unforeseen issues during the integration process could potentially impact the optimal functioning of the project.

The effectiveness of gamification elements within the app is subject to individual preferences and age groups. While efforts are made to make these elements universally engaging, user preferences may vary, impacting the overall effectiveness of gamification in certain demographics. For instance, it is usual for younger people to like more diverse, colorful and fast animations and aesthetics, while the elders often prefer simpler and straight to the point mobile applications.

Machine learning guidance may have limitations in addressing complex medical conditions. The scope of personalized health guidance, while ambitious, is constrained by the complexity of certain medical conditions that may require specialized and individualized attention.

User interface adjustments for elderly users may face usability challenges. Despite efforts to make it inclusive, the adaptability of the interface to the unique needs and preferences of elderly users may encounter limitations.

External validation of the impact on long-term health outcomes is limited in this project. While the serious game is designed to foster positive behavioral changes, its direct influence on sustained health improvements requires further longitudinal studies and external validation beyond the scope of this project.

Ethical considerations regarding data privacy and security pose inherent limitations. While it prioritizes user privacy and data security, the project operates within ethical boundaries and regulatory frameworks, recognizing the constraints associated with handling sensitive health information.

Despite efforts to track library updates, the project acknowledges the inherent challenge of maintaining immediate compatibility with the latest versions of libraries and APIs. Unforeseen issues may arise during the integration of updated libraries, potentially impacting the seamless functionality of the app and necessitating prompt adjustments to maintain optimal performance.

The InWorld library usage limitation presents a practical constraint. While the chat bot enhances user experience, its utility is subject to a predefined usage limit before users are required to pay for extended access. This limitation may influence the frequency and depth of user interactions, necessitating strategic usage planning within the constraints of the chat bot's operational model.

1.5. Significance of the Study

This research holds profound significance within the scientific community, offering a pioneering approach to health management through the development. By infusing innovative gamification elements, advanced AI-driven systems, and cutting-edge APIs, this study seeks to revolutionize the functionality of health applications. The essence of this research lies in its potential to redefine conventional methods of health monitoring, fostering a dynamic and engaging user experience that transcends routine tasks and inspires sustained commitment.

A paramount contribution of this study is evident in the unique ability to dynamically translate individual health metrics into an interactive and visually intuitive Digital Reflection. Departing from traditional data representation, this innovation not only enhances user understanding but also sets a precedent for a more intuitive and visually compelling approach to health monitoring. The study's significance lies in its capacity to transform health management from a mere routine into an enjoyable and motivating experience, thereby encouraging prolonged user interaction.

Practically, the outcomes of this study can inform the future development of health applications by demonstrating the benefits of comprehensive HealthKit data utilization. Unlocking the full potential of HealthKit, it exemplifies a holistic approach to health monitoring. The study's findings may guide industry professionals and developers in optimizing health data from unique perspectives, providing users with comprehensive metrics beyond conventional health parameters. This has the potential to enhance the overall effectiveness of health applications in facilitating positive lifestyle changes.

The inclusive design of the app, accommodating diverse user demographics, aligns with the global imperative for accessible and user-friendly health solutions. Addressing the unique challenges faced by both elderly users and children managing chronic conditions, Avitar signifies a move towards a more universally applicable health management tool. This inclusivity not only broadens the potential user base but also underscores the social responsibility inherent in the development of health applications.

In conclusion, this research assumes considerable significance by pushing the boundaries of innovation in health application development. Its potential to make health monitoring engaging, intuitive, and universally accessible is poised to have a transformative impact on how individuals interact with their health data. The study's contributions extend beyond the immediate academic realm, reaching into the practical domain by influencing the development of future health applications and promoting a more user-centric approach to health management.

1.6. Structure of the Thesis

The journey through this thesis begins with the "Introduction," a comprehensive overview that introduces the theme of serious game development for chronic disease management. The opening chapter sets the tone, elucidating the motivation behind the development of Avitar, highlighting the inadequacies of existing health applications, and establishing the overarching objectives of the research.

Moving seamlessly into the "Literature Review," the second chapter provides a comprehensive exploration of existing knowledge, particularly focusing on serious games in health & fitness management. It critically examines previous health avatar implementations or projects with other similar aspects and delves into trends and challenges in health game development, and provides an overview of essential tools and platforms, offering a robust foundation for the subsequent research.

The research methodology is meticulously detailed in the aptly titled "Methodology" chapter. This section outlines the systematic approach taken in the development of the project, from conceptualization to the intricate steps involved in data gathering, HealthKit API integration, Avatar and environment creation, and the incorporation of machine learning modules for personalized guidance. The methodology serves as the blueprint that guides the execution of the research objectives.

The "Experiments" chapter marks a pivotal phase, unveiling the empirical journey undertaken in the study. This section provides insights into the dataset used, the experimental design, and the results and analysis, unveiling the dynamic response of the machine to user data and metrics gauging user interaction and engagement. It encapsulates the empirical foundation upon which the study's findings rest.

The ensuing "Discussion" chapter interprets the outcomes of the experiments, offering a nuanced examination of the implications for chronic disease management. It assesses user experience metrics, unpacks challenges and limitations encountered during the study, and explores the broader implications of the project’s development in the context of such applications.

Culminating the narrative is the "Conclusion" chapter, a synthesis of key findings and contributions. This concluding section not only summarizes the research outcomes but also underscores the significance of the research in that sector. It lays the groundwork for future directions and recommendations, encapsulating the holistic journey undertaken in the pursuit of redefining health application experiences.

2. Literature Review

The following section embarks on a comprehensive exploration of existing scholarship surrounding serious games in health management. It is basically, an examination of prior implementations of similar applications, dissecting their successes and shortcomings. The section places a particular focus on elucidating the tools and platforms integral to this domain, providing a solid theoretical framework for understanding the landscape. As stated in the introduction of one of the most significant pieces of work found in the topic [1], the term “serious games (SGs)” was first put forward by a famous American scholar in the book Serious Games in 1970 [2]; and SGs are designed to achieve purposes other than entertainment [3].

2.1. Serious Games in Health Management

In the fascinating world of Serious Games (SGs) for Health Management, Wang et al.'s [1] groundbreaking research lights the way of our research, as a great library of papers related to the matter. What is interesting about both the research as well as the implementations that we are going to discuss later, is that conceptually the ideas were near what this master thesis seeks to achieve, but this could not be possible in the way we know it now that the Artificial Intelligence growth emerged. Following are some great examples of SGs that had remarkable results to both the medical research and the patient education and guidance.

In a significant study addressing adolescents and young adults facing cancer, the psycho-educational video game "Re-Mission" emerges as a powerful tool for health education [4]. The purpose of this game is to actively engage young individuals in their cancer treatment journey, addressing issues stemming from a lack of interest in self-care and illness knowledge. The study, conducted through a multi-site, randomized, controlled approach involving 375 cancer patients, compared those who played the regular commercial game with a group that engaged with both the regular game and Re-Mission. The results demonstrated a substantial improvement in cancer-related knowledge

among the Re-Mission group, emphasizing the positive impact of serious games on enhancing health education in adolescents and young adults facing chronic illnesses [4].

In another medical sector, we have explored the effectiveness of virtual reality exercises using the Nintendo Wii Fit [12] system as an adjunctive therapy for stroke patients [5]. This randomized controlled study involved 70 stroke patients, with 23 meeting the study criteria and randomly assigned to either the experimental group (n = 12) or the control group (n = 11). Assessments, conducted by a blinded evaluator, utilized various outcome measures, including the Berg Balance Scale, Functional Reach Test, Postural Assessment Scale for Stroke Patients, Timed Up and Go Test, and Static Balance Index. The study revealed significant group-time interactions in key parameters, indicating substantial improvement in both groups, with the experimental group exhibiting greater enhancements than the control group. These findings suggest that incorporating virtual reality exercises with the Nintendo Wii system could serve as a valuable adjunctive therapy to traditional treatment, particularly in enhancing static and dynamic balance in stroke patients [5].

From another perspective [6], serious games extend beyond traditional gaming by serving educational, training, and health-promoting purposes. Notably, there is a noticeable shift towards leveraging mobile and digital platforms, virtual reality, and machine learning to tailor interventions.

As presented in [7], SGs echo a growing interest in leveraging technology for well-being. With a focus on applications in health, these serious games extend beyond conventional approaches, offering innovative means to enhance training, education, and rehabilitation. Aligned with the World Health Organization's comprehensive definition of health, the games mentioned not only address phases of illness but also promote healthy habits, including exercise. The diverse scope, coupled with advancements in technology, underscores the potential of serious games to revolutionize health experiences. This survey, organized meticulously from concepts to detailed analyses,

stands as a valuable guide, shedding light on the multifaceted dimensions and future trajectories of serious games in health [7].

By looking, from all those angles, with their similarities and differences we can certainly assume that apart from the outstanding work that has already been done, in terms of research as well as implementations, there exists potential, by taking advantage of the present growth of Artificial Intelligence, that can bring concepts and ideas, which until now were referred to as hypothetical or utopian, to life. Although, none of the ideas above actually resembles the concept brought by this thesis, thus while prepared with great bibliography, we still sale on strange tides.

2.1.1 Previous Health Avatar Implementations

S Health Buddy

In 2013, Samsung introduced the S Health Buddy app, a health application tailored for its Android-based Galaxy S4 smartphone. This innovative app featured avatars that dynamically adjusted their appearance, reflecting the user's changes in weight and physical activity. The S Health Buddy app offered a selection of five distinct characters, including two female, two male, and one animal avatar, allowing users to visualize their health journey through these animated representations. Exclusively available in Samsung's home market of Korea at the time, the app enabled users to monitor their calorie balance by considering recorded food intake, exercise duration, and the user's initial input of height and weight. Although a noteworthy competitor to Apple in the smartphone market, especially with its Galaxy S4 model, Samsung faced tough competition from Apple in the mHealth sector. Apple's iPhone and iPad devices were already dominating the clinician side of the mHealth market, as indicated by a 2012 report from research firm KLAS. While Samsung's S Health app aimed at transforming smartphones into health monitoring tools, Apple was preparing to unveil its iWatch by the end of 2013, a device rumored to incorporate activity tracking capabilities. This is a great example where competition in the industry as well as the lack of resources in terms of technological gateways brought a similar idea as Avatar to an end. The irony here is

that the same tool (iWatch) that is getting used by our project (in some cases), was the same reason for the demise of the mentioned application back in 2013.

SimPHARM

SimPHARM, developed by Education Management Solutions, stands out as a virtual and clinical pharmacology healthcare simulation solution. This applied game serves as a web-based platform, offering learners and inter-professional education teams a realistic experience in patient care training. By employing mathematical models of physiological systems, SimPHARM simulates authentic reactions to diseases and drugs. Its engine incorporates up-to-date drug information, considering categories, formulations, side effects, and interactions while adhering to pharmacokinetic and pharmacodynamic principles. Learners can explore the consequences of therapeutic decisions, facilitated by a dynamic learning algorithm that ensures diverse outcomes for each case. This clinical pharmacology-based simulation software is adaptable for both undergraduate and graduate-level education programs.

Vital Signs: ED

Developed by BreakAway Games, Vital Signs: ED is a healthcare simulation serious game designed to immerse learners in the high-pressure environment of an emergency department. In this applied game, players assume the role of a physician, facing the stress and chaos of handling difficult trauma cases while managing the influx of patients requiring triage. The game replicates the urgency of the ED, presenting distractions, disruptions, and paperwork requirements within a limited time frame. Learners are challenged to make critical clinical decisions under pressure, offering a dynamic and realistic training experience for healthcare professionals.

Touch Surgery

Touch Surgery, a revolutionary serious game for surgical training, utilizes AI, data, and visualization to train surgeons effectively. With a user base exceeding three million globally, Touch Surgery offers an interactive surgical simulator that guides medical simulation trainees through various procedures. The app allows users to learn, test their

knowledge, and rehearse surgical techniques. Notably, the Touch Surgery app features the DS1 Computer, the first surgical simulation video recorder equipped with real-time AI. This innovation automatically redacts sensitive frames in surgical videos, ensuring secure and seamless access to surgical content. Touch Surgery plays a crucial role in enhancing surgical skills, ultimately contributing to improved patient outcomes and safety.

2.1.2 Trends and Challenges in Health Game Development

The realm of health game development is witnessing notable trends and grappling with significant challenges, as evidenced by various applications and research studies. The emergence of serious games, such as SimPHARM, Vital Signs: ED, and Touch Surgery, reflects a growing trend in leveraging technology for immersive and realistic healthcare simulations. These applications not only facilitate hands-on training but also embrace innovative features like AI-driven surgical simulation and dynamic learning algorithms. On the flip side, the challenges in health game development, highlighted by research studies [1], [4], and [5], include the need for standardization in design and evaluation, a deeper understanding of underlying mechanisms of action, and limited integration into existing healthcare systems. The identified gaps underscore the importance of further research to comprehend the full potential and limitations of serious games in healthcare. As technology continues to evolve, health game developers must navigate these trends and challenges to ensure the continued effectiveness and relevance of their applications in enhancing medical education and patient outcomes.

2.2. Tools and Platforms in Health Game Development

In pursuit of our project objectives, we strategically employed cutting-edge libraries to ensure both current effectiveness and future adaptability. Unity Engine, chosen as our framework, stood out for its comprehensive features, facilitating not only the development process but also ensuring easy maintenance and potential extensions for the app. The integration of the HealthKit API enriched the game's functionality by

providing a robust data-gathering mechanism. For streamlined design creation, UModeler X emerged as a pivotal tool within the Unity Engine, eliminating the need for an alternative like Blender. To breathe life into our app, the InWorld Unity SDK served as the final touch, elevating the project with its advanced capabilities. Each component in our toolkit was carefully selected to synergize, resulting in a powerful, cohesive, and forward-looking development environment.

2.2.1. Overview of Unity and HealthKit Integration

Unity Game Engine stands as a powerhouse, commanding the respect and preference of indie game developers with its unparalleled capabilities. Its supremacy isn't limited to the gaming realm; Unity emerges as a dynamic force in diverse fields, including architecture, simulations, Augmented Reality (AR), Virtual Reality (VR), mobile development, and both 3D and 2D projects. What truly elevates Unity to a league of its own is its adaptability, serving as a collaborative workspace for engineers, developers, scientists, and hobbyists who seek excellence in their creations. Unlike its counterparts, Unity's brilliance lies in its ability to demand minimal computing performance while offering a seamless cross-platform export feature, allowing developers to unleash their creations across a spectrum of devices. In a landscape teeming with competitors like Unreal Engine and Godot, Unity stands tall, fortified by a vibrant and supportive community spread across platforms like Discord, web forums, and Stack Overflow. The icing on the cake is Unity's extensive asset store, a treasure trove of resources that empowers developers, cementing its status as the unrivaled tool for our implementation. Unity isn't just a game engine; it's a dynamic catalyst propelling creators towards unparalleled heights of success and innovation.

HealthKit stands as a robust technological framework that revolutionizes the access and sharing of health and fitness data, all while upholding user privacy and control. Operating seamlessly on iOS, iPadOS, macOS, Mac Catalyst, watchOS, and visionOS, HealthKit provides a centralized repository for collecting, storing, and exchanging health-related information on iPhone and Apple Watch. With user consent, applications can communicate with the HealthKit store, contributing to the creation of a

comprehensive and personalized health and fitness experience. This involves tasks such as data collection and storage, data analysis and visualization, and the facilitation of social interactions. HealthKit adopts a collaborative approach, allowing apps to focus on specific tasks of interest, promoting flexibility and diversity in the health and fitness app landscape. Users can choose their preferred apps for specific health metrics, such as weight tracking and step counting, with HealthKit ensuring seamless data exchange among them. Furthermore, HealthKit is adept at managing and merging data from various sources, offering users a unified view in the Health App, reinforcing the platform's commitment to user-centric control and customization. Some of the data are collected automatically by the device (iPhone) or in some cases by external devices that are connected with the phone such as the iWatch for heart rate or a continuous blood glucose monitoring device for people with diabetes. All the metrics can be added manually as well, with some of them being manually only. The selection of HealthKit as a datasource was made because of its versatile aspect of access through plenty sources of data. The only con that needs to be mentioned is the fact that the app needs to be build for any of the Apple's softwares mentioned in the start of the paragraph.

Now that we have a brief idea of what our two technologies can do, we can assume that the combination of the two makes Avitar an iOS mobile application, made with Unity 2022.3.12f, that gathers its data directly from the HealthKit and indirectly from the sources mentioned above depending on the data value. [9]

2.2.2. UModeler X for Avatar Creation

UModeler X emerges as a state-of-the-art 3D asset creation solution seamlessly integrated into Unity as a valuable plugin. This tool empowers users to craft and refine high-quality 3D models directly within the Unity Editor, eliminating the need for external applications like Blender or Maya. UModeler X encompasses an array of advanced features, including modeling, UV editing, rigging, painting, and AI texturing capabilities. With a focus on real-time editing, users can effortlessly shape high-polygon models, create smooth curves, and add intricate details. The platform simplifies UV editing, allowing easy unfolding of complex models for texture application. Modifiers

enable the preservation of the original model while applying various transformations. Brush editing facilitates precise adjustments to 3D models, while rigging and auto-rigging enhance dynamic movements. Additionally, UModeler X offers 3D painting and AI texturing features, enabling users to paint directly on models and leverage AI for texturing. The tool's flexibility extends to supporting various 3D data formats, allowing seamless modification and improvement within Unity. UModeler X provides these advanced 3D asset creation features free of charge, with potential costs for advanced features in the future. This Unity plugin enhances productivity and quality for users engaged in 3D content creation. [10]

2.2.3 InWorld SDK for Dynamic Interaction

InWorld stands at the forefront of AI-driven character creation, offering users a powerful platform to design lifelike characters for diverse applications, including video games, branded experiences, entertainment, and training. With a no-code approach, InWorld empowers users to effortlessly create characters within minutes, enabling the development of open-world NPCs, virtual ambassadors, and immersive educational experiences. In an era of rapid evolution in the AI space, InWorld remains at the cutting edge of generative AI by continually updating its features to enhance character creation. Beyond serving as a starting point, InWorld encourages users to explore and experiment within the platform, unlocking the full potential of its AI technology for deeply immersive interactions. In our case the Unity SDK offered by the platform came in handy as it made the Avatar come to life with within the scope of health, medicine and fitness. More details about the integration will be mentioned later in the Methodology chapter.

2.3 Measuring Stress with Wearable Devices

The exploration of wearable devices for health monitoring, particularly focusing on chronic physiological stress measurement, has gained substantial attention in recent research. Bruneel's insightful article, "Measuring chronic physiological stress with the Apple Watch and the Swift language”[24], delves into the realm of stress assessment

using Apple Watch and Swift programming. This section extends the literature review by discussing the methodologies and findings presented in the article.

It begins by elucidating the connection between stress and heart rate variability (HRV). Stress, characterized by heightened sympathetic nervous system activity, can be effectively measured through variations in HRV. The sympathetic division, associated with stress, and the parasympathetic division, linked to relaxation, operate in opposition within the autonomic nervous system (ANS). HRV emerges as a pivotal physiological indicator, with decreased HRV correlating with stress and increased HRV indicative of recovery.

The accuracy of data collected by wearable devices is crucial for meaningful health representations. It highlights a study [25] from the University of Zaragoza, Spain, affirming the Apple Watch's accuracy in stress monitoring based on HRV, particularly when compared to other monitoring devices such as the Polar H7 band.

Accessing health records from wearable devices, it emphasizes the significance of Apple's HealthKit. The HealthKit store securely stores health records, facilitating synchronization with iOS devices. However, the challenge lies in obtaining long-term data for comprehensive stress measurements. It discusses query mechanisms within HealthKit that allow the retrieval of health data.

The article delves into two distinct measurement types for assessing chronic physiological stress: night measurement and morning measurement. Night measurement involves analyzing HRV samples during periods of rest, providing insights into baseline HRV levels. Morning measurement, requiring manual intervention through the Breathe app, focuses on recording stress-free HRV samples during wakefulness. It emphasizes the necessity of consistent user participation for accurate morning measurements.

Despite the potential offered by these measurement types, it notes limitations. Night measurement, reliant on few and randomly taken samples, faces challenges in capturing sufficient data. Morning measurement emerges as the more viable option, yet its effectiveness hinges on user compliance in regularly taking Breathe sessions.

In the pursuit of real-time stress measurements, he acknowledges current limitations imposed by the Apple Watch's data recording capabilities. Real-time stress assessment necessitates constant live monitoring, a functionality not currently supported by the device.

In conclusion, while his exploration presents valuable insights into stress measurement with wearable devices, including the Apple Watch, the existing constraints in data recordings and sample collection methods pose challenges to achieving real-time and comprehensive stress assessments. The article encourages further exploration in the field, indicating potential advancements in wearable technology for enhanced stress monitoring.

2.4 Stress Measurement Techniques in Swift

In a compelling exploration of stress measurement methodologies, Tibo Bruneel sheds light on innovative approaches utilizing the Apple Watch and Swift language. The article, delves into the intricacies of stress assessment, presenting a distinctive focus on Swift and the capabilities of the Apple Watch.

It initiates the discourse by emphasizing the fundamental understanding of stress, elucidating the role of the sympathetic and parasympathetic nervous systems in the autonomic nervous system (ANS). Notably, stress manifests as heightened activation dominated by the sympathetic division. Heart Rate Variability (HRV), a proven indicator of ANS activity, is highlighted as a crucial element for gauging physiological stress levels.

The research navigates through the intricacies of accessing Apple Watch records, elucidating the secure storage in the HealthKit store. It underscores the synchronization of data with the iOS device's health store, providing a comprehensive understanding of data accessibility and purging protocols. HealthKit's role as a central repository for health and fitness data is detailed, showcasing its significance in the realm of stress measurement.

The crux of the research lies in innovative stress measurement techniques developed in Swift. Distinguishing between night and morning measurements as mentioned in the previous section, he unveils the challenges and potentials associated with each.

The article adopts a nuanced approach to stress categorization, steering away from simplistic percentage-based metrics. Instead, he advocates for Low, Medium, and High stress levels derived from baselines and historical data. In his final conclusions, Bruneel candidly assesses the present limitations of Apple Watch data recordings, contemplating the future of stress measurement possibilities. He directs readers interested in HRV readings to the HRV4 Training App, endorsing its efficacy and openness in the field.

2.5 Welltory app

The Welltory app provides a comprehensive guide to Heart Rate Variability (HRV), a crucial metric for understanding physiological stress levels and overall health. HRV measures the variation in time between heartbeats, scientifically known as R-R intervals, expressed in milliseconds. Initially developed in the 1960s for assessing astronaut health in space, HRV has evolved into a widely-used diagnostic and predictive tool. While early measurements used medical-grade ECG machines, the precision of PPG tracking (Photoplethysmography) allows accurate measurements down to milliseconds.

Welltory supports both PPG and ECG measurements taken with BLE heart rate monitors like Polar, Apple Watch, Samsung HRM, other HRV calculator apps, and even your phone’s camera. HRV is distinct from heart rate and plays a crucial role in assessing

overall health and the state of the autonomic nervous system (ANS). The app uses algorithms to analyze data and provide Predictive, Personalized, Preventive, and Participatory insights, simplifying healthy living.

The ANS, regulating body processes, comprises the sympathetic (fight or flight) and parasympathetic (rest and digest) branches. Welltory emphasizes the importance of considering additional factors influencing HRV, such as heart automatic performance, extrasystoles, and hormonal influence. The app recommends analyzing each system separately to gain insights into stress levels and coping mechanisms.

There is no one-size-fits-all interpretation of HRV, as it varies between individuals and depends on factors like age, gender, and circadian rhythm. A healthy heart typically exhibits high HRV, while low HRV may indicate sympathetic regulation dominance. Welltory's HRV measurement, validated against the Polar H7 chest strap, is associated with various health assessments, including cardiovascular health, risk of sudden death, strength training optimization, pneumonia risk, hypertension monitoring, immune response tracking, and prognosis of heart transplant patients.

Improving HRV involves adopting a healthy lifestyle, including regular exercise, proper nutrition, breathing patterns, meditation, quality sleep, hydration, and avoiding risk factors like alcohol and smoking. Welltory provides detailed metrics, including Mean RR, SDNN, rMSSD, MxDMn, pNN50, and AMo50, offering insights into daily body-system activities. The HRV Score, based on lnRMSSD, reflects parasympathetic nervous system activity, with a higher score indicating better variability. In essence, Welltory empowers users to understand their bodies, make informed lifestyle changes, and achieve holistic well-being.

3. Methodology

This section provides a detailed walkthrough of how the Avitar iOS mobile application was brought to life. We'll explore the step-by-step journey, starting from the initial design blueprints and the creative ideas behind each element, all the way to the finished product that defines the entirety of this project.

3.1. Conceptual Framework

Upon the proposal of Dr. Magklogiannis for the development of a "serious game app reflecting users' health status," numerous concepts began to emerge. Initially, the notion of establishing a continuous monitoring system for data values seemed beyond my initial perspective. However, diligent research revealed the existence of applications and platforms equipped with reliable SDKs and APIs capable of realizing this fundamental element. Exploring the field, we discovered that live monitoring devices for blood glucose offered dedicated apps with high accuracy in live data provision. Engaging with relevant communities on platforms like Reddit, including Diabetes, Diabetes Type 1, and Diabetes Type 2, led to a compilation of popular API solutions. Following insightful interviews—ensuring privacy for the involved individuals—we opted for the integration of Freestyle Libre Glucose Monitoring [13]. Despite the convenience this tool could provide, its subscription cost was deemed unsustainable. Simultaneously, we deliberated on the importance of having control, either full or partial, over the API and data structure. Instead of committing to a diabetes-centric approach, we aimed for a more generalized application from the outset, offering flexibility beyond a specific health topic. This is where the concept of integrating HealthKit emerged.

Simultaneously with the exploration of data sources, design emerged as a central focus of our project. While grounded in scientific principles for a master's thesis, the endeavor inherently resides in the realm of art. This amalgamation intertwines the biological realities of the natural world with the digital domain, recognizing that the infusion of artistic elements is essential to create a captivating "world." The app's appeal and

replayability are pivotal for its success among similar applications. Opting for a minimal and aesthetic approach from the outset, our design choices drew inspiration from games like Sky: Children of the Light [14] and Journey [15], both crafted by the same creators. Employing simple color palettes and low-poly designs for characters and environments not only bestowed aesthetic appeal but also ensured an efficient balance between visual allure and practical considerations such as development time and computing power. Our primary concern in the design phase was to strike a delicate balance between simplicity and aesthetic appeal. The diverse user base, spanning from potentially more conservative elderly individuals to younger users, including children and teenagers, necessitated a design that caters to varied perspectives and tastes. Ensuring clarity and comprehensibility in guiding users through the app and presenting data in an understandable manner remained a top priority. Consequently, we opted for a clean color palette, both for the user interface (UI) and the in-game environment. White and gray were established as dominant colors, offering a neutral backdrop, while tint colors were selectively introduced to enhance visual interest without overwhelming the user. This strategic choice aimed to facilitate ease of navigation and readability, accommodating users with varying preferences and ensuring a universally accessible and user-friendly design.

The inspiration for our project's overarching concept is rooted in the early seasons of the television series "Black Mirror," where the theme of a digital reflection is explored. Although the series often navigates horror and drama, it is crucial to recognize that the futuristic scenarios it envisions are progressively becoming a reality. In a specific episode, the protagonist inhabits a dystopian world dominated by technology and pervasive advertising. Notably, the episode emphasizes physical fitness by satirizing those deemed "not fit enough," thereby motivating the population to engage in physical training. It is important to stress that our project diverges from this stressful depiction, aiming to utilize similar technologies for positive purposes [16]. Presently, the creation of a digital counterpart is not only plausible but also has the potential to become an everyday tool, akin to the ubiquitous presence of smartphones in our daily lives.

3.2. Use Case Definition

Like any new idea coming to fruition, for it to succeed in the market and gain widespread usage, it must address a problem, whether it be a general everyday issue or a specific one. This principle applies to our project, Avitar, as well. Through intense brainstorming sessions and two successful, informative interviews, we delved into understanding what functionalities this app should provide. It is worth noting that the correct term is "people with diabetes" rather than “diabetics.”

1. Access to Health Data:
    - Objective: To comply with app store regulations and phone restrictions. [17]
    - Steps:
        1. A panel opens with all the health data of the user retrieved from the HealthKit API.
        2. Users grant access to all, some or none of the data.
        3. User clicks continue when ready.
2. Home Scene Initialization:
    - Objective: To introduce users to the app's virtual environment.
    - Steps:
        1. After health data initialization, users are directed to the Home Scene, represented as a floating island.
        2. The Radial menu appears
        3. The chat option appears
3. Radial Menu Navigation:
    - Objective: To allow users to explore specific health and fitness data islands.
    - Steps:
        1. User clicks the button on the center-bottom of the screen for the radial menu to pop-up.

2. Users can utilize the radial menu on every scene to navigate to different islands.

4. Heart Island:

- Objective: To provide detailed heart-related health data.
- Data Available:
    1. Heart rate.
    2. Number of high heart rate events.
    3. Number of low heart rate events.
    4. Number of irregular heart rhythm events.

5. Vitals Island:

- Objective: To offer insulin delivery insights.
- Data Available:
    1. Insulin deliveries for the last 24 hours.
    2. Latest Blood Glucose levels

6. Activity Island:

- Objective: To present physical activity-related information.
- Data Available:
    1. Steps count.
    2. Walking and running distance.

7. Health Chat on Home Island:

- Objective: To engage users in health-related conversations with Avitar.
- Options:
    1. Users can chat with Avitar about health and fitness.
    2. Users can inquire about their own health based on gathered data.

These defined use cases form the foundation of Avitar, providing a structured approach for users to explore and interact with their health and fitness data within the app's virtual landscape.

3.3. Data Gathering and Structuring

In this phase, we employ a systematic approach to collect and organize health and fitness data for the Avitar application. The HealthKit API serves as the cornerstone, seamlessly integrating with the iOS ecosystem to access and share comprehensive health data while maintaining user privacy. Simultaneously, UModeler X plays a pivotal role in shaping the digital environment and crafting the avatar within the Unity framework. Leveraging its versatile 3D asset creation capabilities, UModeler X ensures a visually engaging and dynamic representation of health-related information, fostering a seamless integration of data and visual elements within the app.

3.3.1. HealthKit API Integration

At this juncture, a deep dive into the coding realm becomes imperative. As previously stated, Unity version 2022.3.12 served as our chosen platform for Serious Games (SG) development. To seamlessly integrate Swift [19] with C# [20], we employed BeHealthKit [18], a tool facilitating accessibility to the iPhone's HealthKit using the latter programming language. A meticulous examination of data types and the library's comprehensive features enabled us to construct the desired data structure. To achieve this, we implemented a class named UserData, adhering to the singleton design pattern in object-oriented programming. This design pattern ensures accessibility from any part of the code. Within this class, three dictionaries are instantiated, as illustrated in figure 1.

```
public Dictionary<string, List<QuantitySample>> QuantityTypeValues { get; set; }
6 references
public Dictionary<string, List<CategorySample>> CategoryTypeValues { get; set; }
10 references
public Dictionary<string, Characteristic> CharacteristicTypeValues { get; set; }
```

Figure 1: Data Structure dictionaries

Subsequently, we developed a HealthKitManager class responsible for initiating the process by seeking the user's consent for accessing their health data. Upon obtaining permission, a loop was implemented to iterate through our data readers, covering all

data categories for which permission was granted. The aforementioned readers represent abstract classes designed for each data type. The following types are considered. It is crucial to note that these data types remain independent of the categorization employed within our app. For example, metrics related to heart health may be included in any of the subsequent data value types (e.g., heart rate categorized as a quantity type and high heart rate events as a category type).

Quantity type:

In the context of our project, a quantity sample, as defined in the HealthKit documentation, encompasses one or more HKQuantity objects. Each of these quantities serves as a data point, representing a singular numeric value with its associated units. For instance, this structure enables the recording of diverse health metrics such as the user's height, current heart rate, or the caloric content of a meal, allowing for versatile tracking of health and fitness features. In other words, these data points come in batches split by timestamps that all together have an average, a minimum a maximum and a most recent value.

Category type:

The category samples denote a specific time period when the user is in a specific state, for instance either in bed or asleep. It's important to note that samples with distinct values can have overlapping time intervals. For instance, when a user is both in bed and asleep simultaneously, the database involves creating an in-bed sample and an asleep sample with overlapping times. The HKCategorySample class, functioning as a concrete subclass of HKSample, adheres to immutability principles, ensuring that its properties are established during creation and remain unalterable thereafter.

Characteristic type:

The HKCharacteristicType class, plays a distinct role in HealthKit. Unlike other types, characteristic types do not facilitate the creation and storage of new HealthKit objects. Users are required to enter and modify their characteristic data through the Health app. Instead, the HealthKit store is utilized to access the data only for reading. HealthKit

encompasses five characteristic types, namely biological sex, blood type, birthdate, Fitzpatrick skin type, and wheelchair use. Significantly, these types are exclusively utilized when seeking permission to read data from the HealthKit store. The unique nature of characteristic types in HealthKit necessitates an understanding that they serve specific purposes related to users' personal information, emphasizing the importance of user interaction in managing this category of data.

Now that we have elucidated the functionality of the various value types, we will proceed to delineate the structure of the data flow as illustrated in Figure 2. The procession involves filling the UserData fields, where for each requested data type, the corresponding reader extracts values only if the data has the necessary permissions. Subsequently, calculations and data handling are performed to store the most useful format of the value in the respective dictionary. These values are then stored in the UserData dictionaries, utilizing their identifier number as a key.

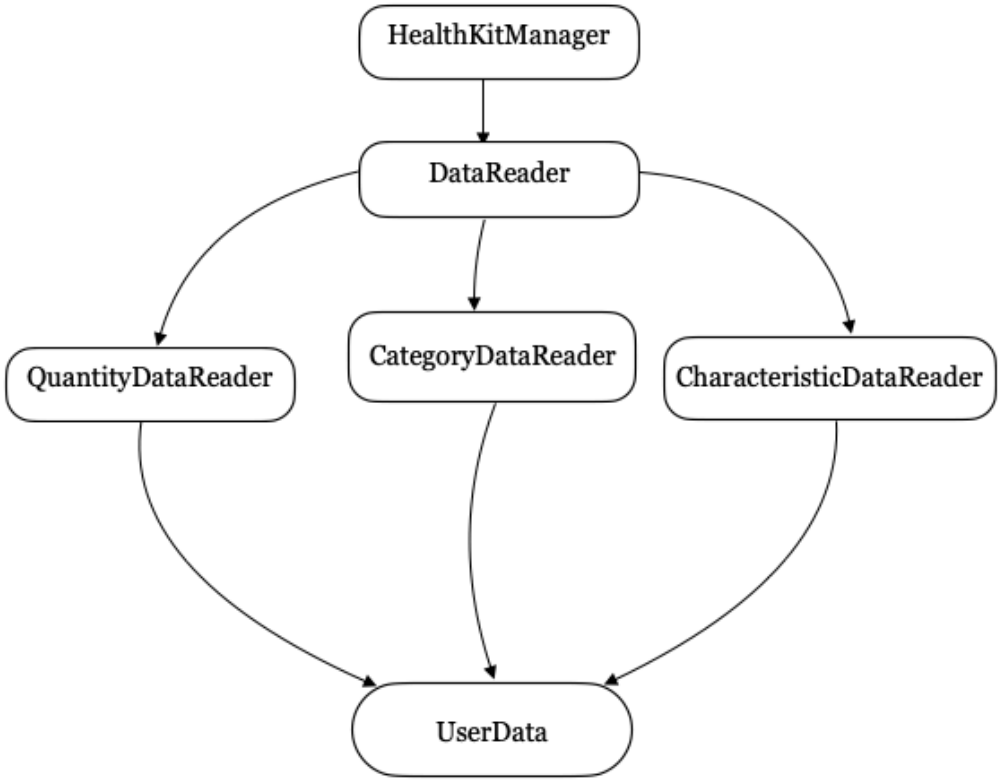

Figure 2: Data Reading

In order to test the proper functioning of the application's data retrieval, we utilized Xcode [21], a necessary tool for exporting iOS and Apple-related applications. Once the process stabilized, recurrent rebuilding posed a considerable time constraint. To address this, we implemented a Fake Database for testing minor changes within the application's editor. This database generates artificially created values resembling a manually handwritten/hardcoded random code, providing a quasi-realistic perspective. This approach facilitated the monitoring of read values without the need for frequent rebuilding or an iWatch or any other external device for healthKit API data gathering. The operation of this FakeDB is illustrated in Figure 3.

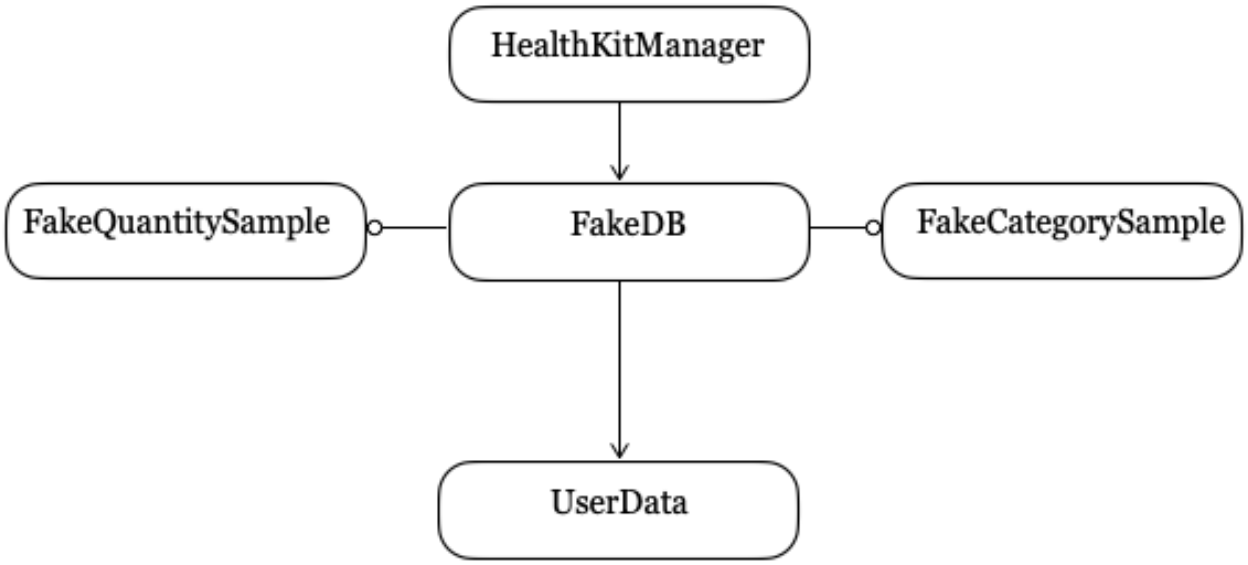

Figure 3: Fake Database

Let's take a step back and examine the entire process from a higher level. The orchestrator of the entire operation is the GameManager class. This type of class is commonly employed in Unity projects as the central class that connects various major manager operations and ensures that these operations occur in the correct sequence. In our scenario, data retrieval must occur after the permission checks, and it is crucial that this takes place before UI elements or environmental elements request the utilization of that information or data. Once all the data is established and appropriately stored in the UserData, it is time for the GameManager to take action. Figure 4 provides a

comprehensive overview of the entire process, encompassing data permission, data reading, and subsequent data utilization through the UI manager.

In conclusion, In our application's structure, the GameManager class plays a central role in orchestrating various managerial tasks within Unity. This class ensures a specific sequence of operations, crucial for the success of our project. We focus on the orderly execution of tasks, such as conducting permission checks before data retrieval, all happening before UI or environmental elements need the information. UserData is a vital component acting as a repository for organized health metrics. It handles different sample types like quantity, category, and characteristic samples through specialized readers. The HealthKitManager class, integrated into Unity, takes charge by seeking authorization for health data access, distinguishing between iOS and editor platforms. The ReadData method guides the data acquisition process. In editor mode, the system uses FakeDB for testing with simulated but realistic values. In the iOS environment, asynchronous data reading occurs through specialized readers. The UserData class, designed as a singleton, efficiently organizes data into dictionaries based on sample type identifiers during the application's lifecycle. The UIManager class manages the user interface, ensuring a seamless user experience with radial menus, option panels, and island transitions. Th structure involves Unity classes and custom scripts working together. GameManager acts as the conductor, overseeing data retrieval and UI management, UserData serves as the repository, and UIManager shapes the visual interface for a user-friendly health-monitoring experience. Together, they form a cohesive ensemble driving the narrative of health and well-being in our innovative application.

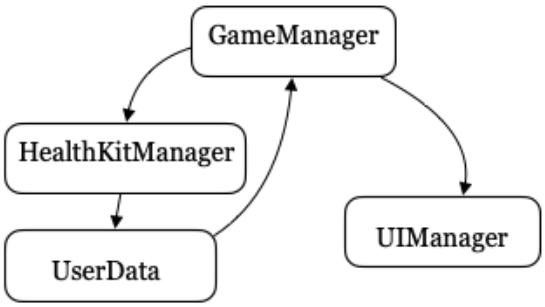

Figure 4: Data permission, reading and utilization

```
public class GameManager : MonoBehaviour
{
    [SerializeField]
    2 references
    HealthKitManager _healthKitManagerManager;

    [SerializeField]
    1 reference
    UIManager _uIManager;

    [SerializeField]
    1 reference
    Avatar avatar;

    0 references
    private void Awake()
    {
        UserData.Instance.InitializeDB();
    }

    1 reference
    public void CallLoadDataFromHealthKitAsync()
    {
        StartCoroutine(LoadDataFromHealthKitAsync());
    }

    1 reference
    IEnumerator LoadDataFromHealthKitAsync()
    {
        _healthKitManagerManager.ReadData();

        // Wait for the data to be ready
        while (!_healthKitManagerManager.IsReady)
        {
            yield return null;
        }
        avatar.SetColors();

        _uIManager.InitPanels();
    }
}
```

Figure 5: Game Manager class

3.3.2 Environment Implementation with UModeler X

With our health data meticulously processed and stored within the UserData singleton class, the next phase entails the creation of our 3D world environment. As elucidated in preceding sections, a delicate equilibrium must be maintained between two guiding principles. The initial principle emphasizes simplicity, practicality, and clarity, while the

second principle strives for a visually captivating and aesthetically pleasing world designed to entice users and enhance replayability.

The process of developing the 3D environment involves intricate decision-making to align with these principles. During numerous brainstorming sessions, various inspirations surfaced, including Nomada Studio's Gris (2018), an exemplary work that has significantly influenced the gaming industry, offering a fresh perspective and setting new standards. The project adopted a minimalistic approach with a low-poly design. To achieve this, suitable 3D models from the free asset store were employed for props and environmental entities. The alpha version of the application features five islands, with the central one serving as the 'Home' or 'Lobby,' while the others represent specific categories such as 'Heart,' ‘Activity, ’Nutrition' and 'Vitals.' A visual representation of these floating islands in 3D space is presented in Figures 6 and 7.

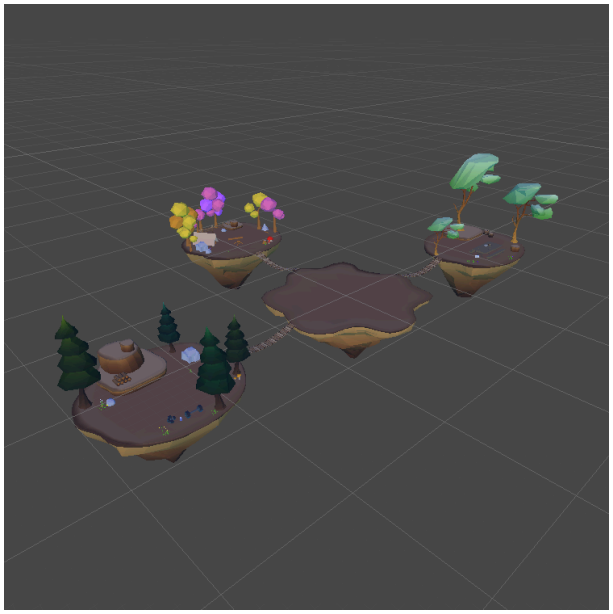

Figure 6: Environment

Figure 7: Activity, Heart, Vitals, Nutrition islands

The overarching concept for the environment aims to maintain a tranquil atmosphere, emphasizing nature and well-being for the user. Each island corresponds to a specific theme. The Activity Island features a serene forest setting with exercise equipment. The Heart Island portrays a camping scene centered around a campfire. The Nutrition one is related around the proteins, carbohydrates and fats consumed measured in grams. Lastly, the Vitals Island is represented by a large table with a book, providing a quiet

space for the avatar to sit and read. The remaining tasks include implementing lighting and effects, as well as refining the pipeline. Once these elements are incorporated, a mechanism will be added to detect the user's real-world local time. This feature enables adjustments in the in-game lighting to simulate day and night cycles. The anticipated outcome of these enhancements is illustrated in Figure 8.

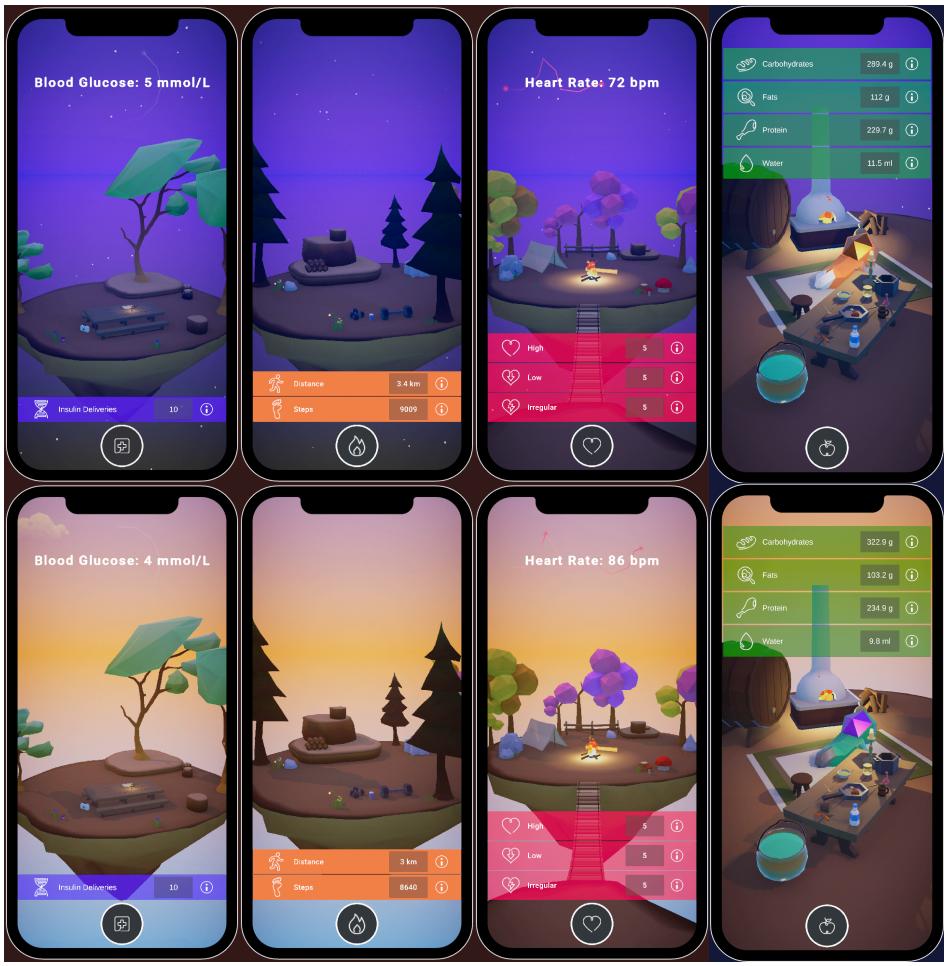

Figure 8: Lighting and tuned rendering

As depicted in Figure 8, beyond the visuals and the constructed 3D environment, each category features a user-friendly UI. This interface presents the data gathered in the previous section in an easy-to-read and well-organized manner.

3.3.3 Avatar Implementation with UModeler X

Now that our scene has been set, it's time for the actor to take the stage. The Avatar adheres to the same principles of simplicity and minimalism. Some of the preliminary designs can be observed in Figure 9. The idea was to avoid unnecessary details, such as adding hands or feet to the character's limbs. This decision expedited both the animation process and the 3D modeling phase.

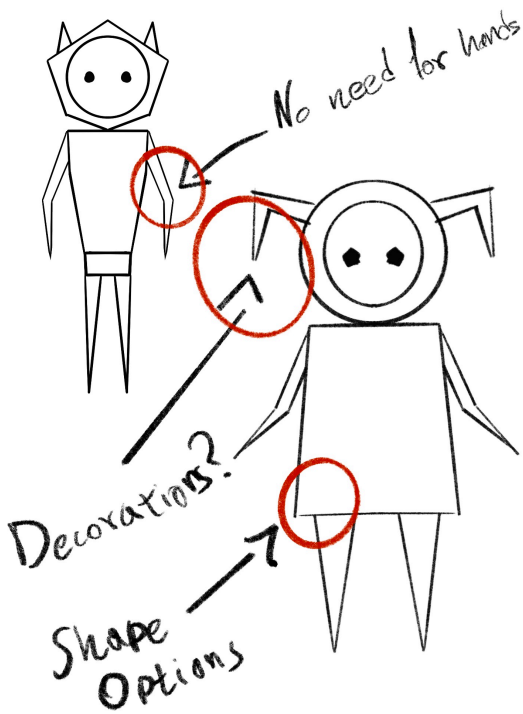

Figure 9: Draft designs of the character

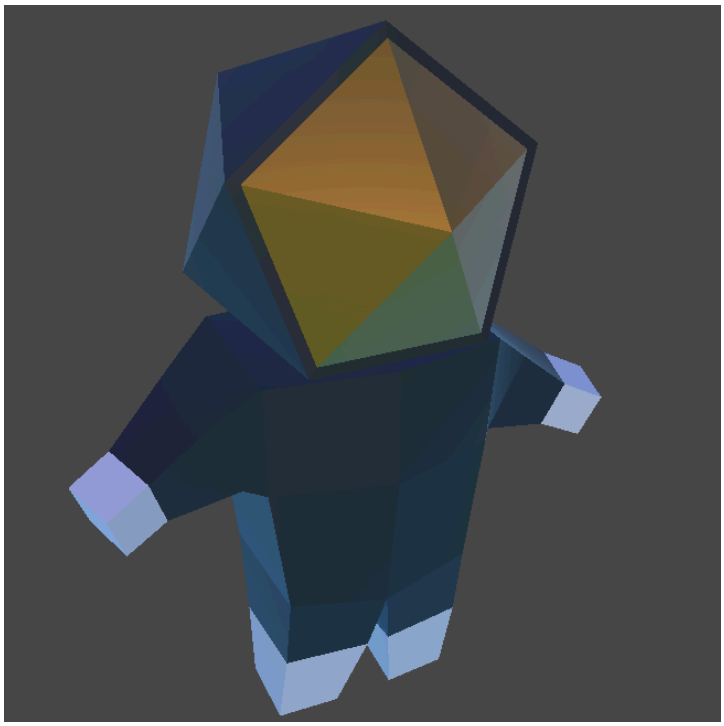

Figure 10: Character

The ultimate creation comprises a variation of a minimalistic figure available in the Unity Asset Store. Through the use of UModeler X, we further simplified the humanoid creature, as illustrated in Figure 10. In addition to the visible texturing, a diverse palette of meticulously selected colors has been curated as a library. This library dynamically constructs the texture during runtime, drawing inspiration from user characteristics obtained through the HealthKit value reading process. To be more precise, the three colors representing the hands and legs, the body costume, and the glass mask adapt according to the user's Biological Gender, Fitzpatrick Skin Type, and Blood type, respectively (refer to Figure 11). The character customization system in our application offers a diverse range of aesthetic variations to enhance user engagement. With 9 different mask variations, 7 costume variations, and 4 options for hands and feet, a total of 252 unique characters can be created. However, it is essential to emphasize that the character color mapping is intentionally undisclosed to the user, creating an appearance of randomness in the customization process, adding an element of intrigue and discovery to the user experience. This design choice aims to enhance user engagement and curiosity within the application's virtual environment.

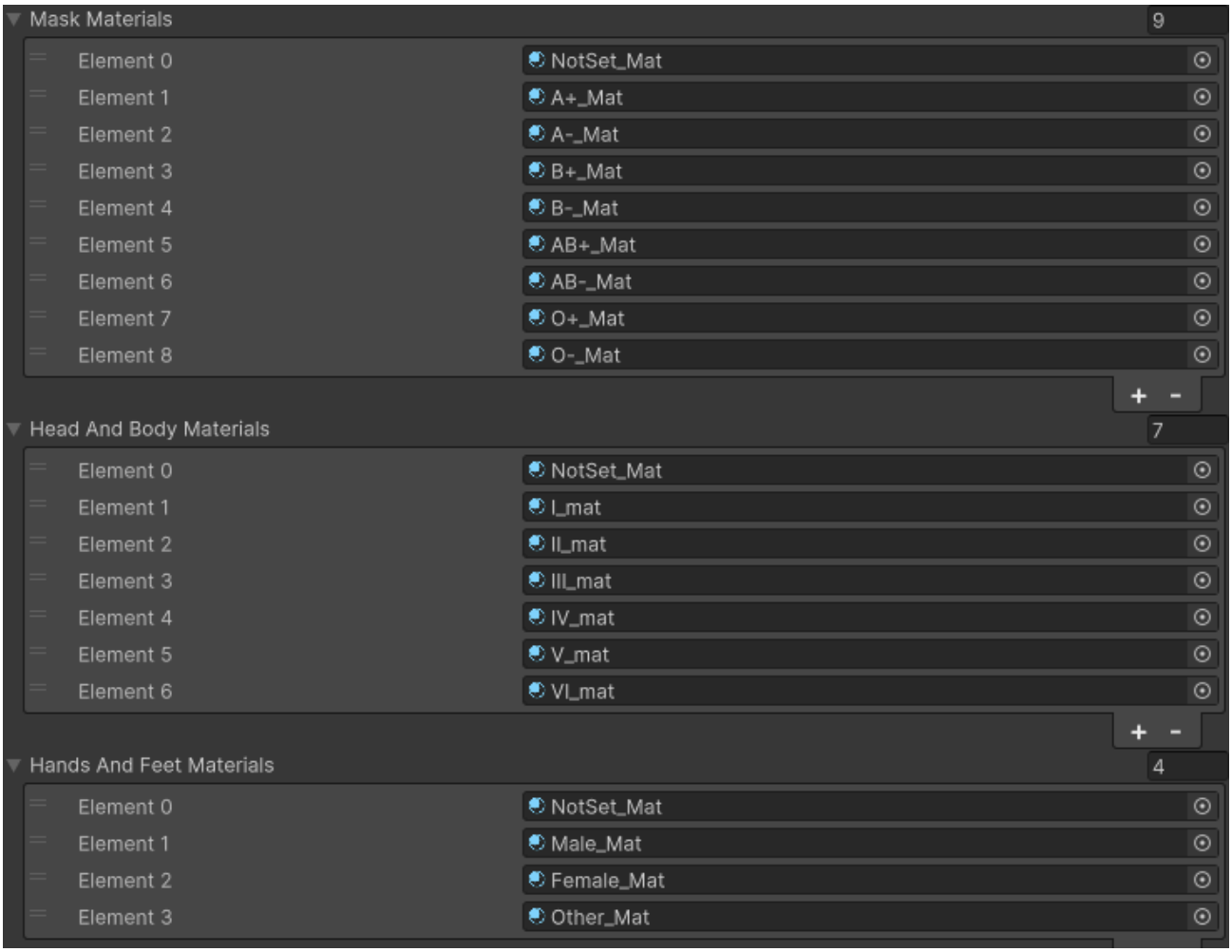

Figure 11: Character color mapping

With the completion of 3D modeling and texturing, the focus now shifts to the final phase of design, which involves animation. Rigging is the initial step in this process, where a humanoid skeleton is incorporated within the 3D model. This ensures that the bones of the model behave appropriately, facilitating subsequent animations. Utilizing Mixamo [23], a platform known for its animation services, various animations are integrated. The integration is configured to dynamically trigger animations based on the user's health data and the context within the application. This adaptive animation system allows the avatar to respond contextually to different situations, contributing to a more immersive and engaging user experience (Figure 12).

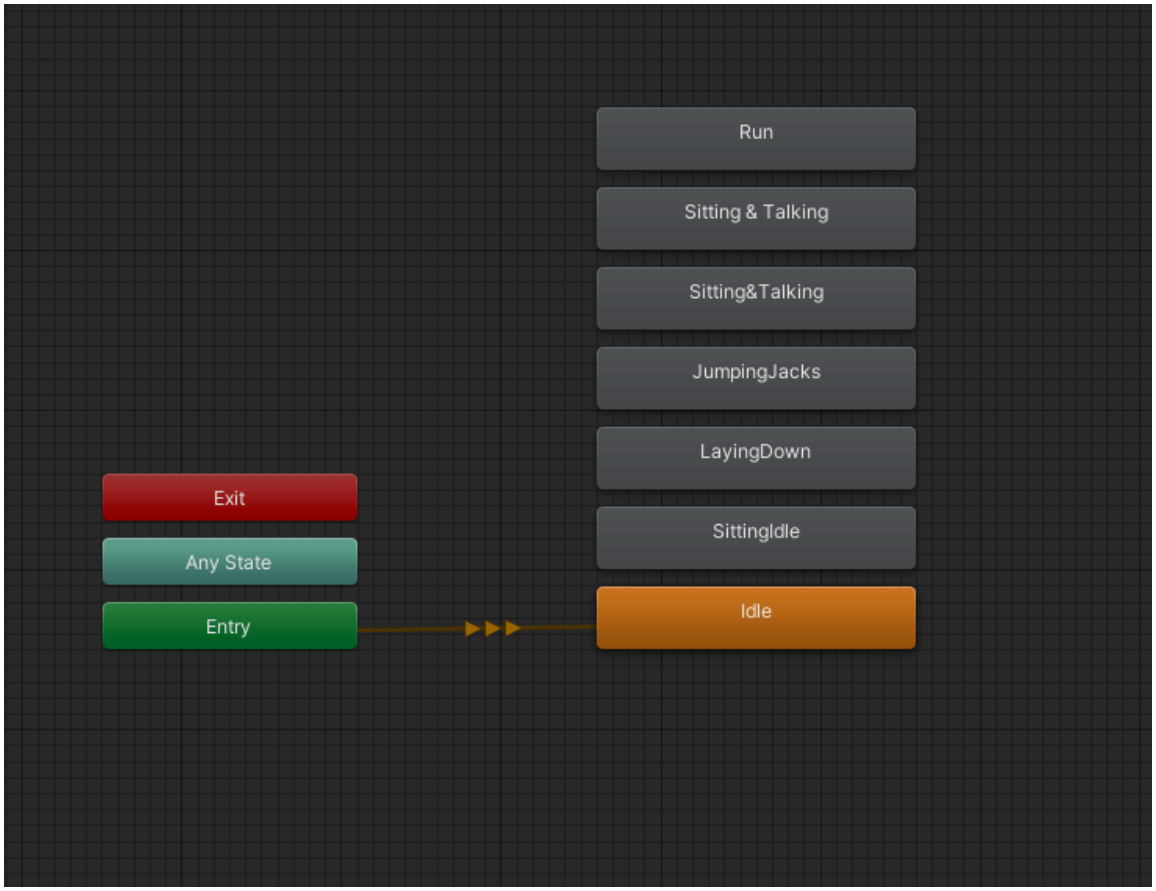

Figure 12: Animation states

With the avatar now prepared for deployment within the simulation, attention turns to the final phase of the implementation process: the artificial intelligence underpinning the application.

3.4. InWorld UNITY SDK Integration

In the rapidly evolving landscape of video game storytelling, where advancements in motion capture, graphics rendering, and animation have enriched the gaming experience, non-playable characters (NPCs) have somewhat lagged behind in terms of technological evolution. Despite the pivotal role NPCs play in constructing immersive narratives and worlds, the technology governing their personalities has remained stagnant. This discrepancy raises questions about NPC adaptability and awareness, as evidenced by a 2013 study from Stockholm University, identifying these factors as critical to NPC believability. The limitations of static dialogue trees, where players are confined to pre-written scripts, hinder the ability to engage with NPCs in a dynamic and personalized manner. Inworld aims to shed light on players' sentiments regarding the current state of NPCs and their impact on immersion, storytelling, and engagement. By surveying over 1,000 gamers, they to uncover new insights into gamer perspectives on NPCs, explore the shortcomings of existing NPC technologies, and contemplate the potential evolution of NPCs in the context of advanced AI. The findings are anticipated to contribute not only to the future of game storytelling and narrative design but also to the strategic decisions of game studios striving to remain competitive in the dynamic gaming industry.

Inworld AI stands as a cutting-edge developer platform dedicated to enhancing NPC behavior and dialogue within games and real-time experiences. Leveraging an extensive array of over 20 AI models, Inworld crafts lifelike, engaging, and expressive characters that closely emulate the dynamic nature of human interaction. These characters possess the unique ability to engage in unscripted voice-to-voice interactions, thanks to the integration of ChatGPT-like language models and multimodal behavior and perception systems. Inworld is steered by a team of experts and pioneers deeply rooted in conversational AI, generative models, and the gaming and entertainment sector. Notably, the founders of Inworld previously introduced API.AI, later rebranded as Dialogflow following its acquisition by Google, establishing it as a leading conversational AI platform. At the helm of Inworld is Chief Creative Officer John Gaeta, an Academy

Award-winner renowned for his contributions to the Matrix movies and his pivotal role in founding Lucasfilm's Immersive Entertainment Division. Gaeta's wealth of experience extends to his position as the Executive Creative Producer on Epic Games' The Matrix Awakens, solidifying Inworld's position at the forefront of innovation in AI-driven interactive experiences.

In the implementation phase of our application, it became imperative to move beyond the mere showcase of gathered data and actively utilize it. The natural choice for this endeavor was Inworld AI, a decision substantiated by thorough research and a comprehensive exploration of its documentation. Following the registration process, the creation of a character's cognitive framework commenced, and our chosen representative, the avatar (avitar), came to life within the Inworld platform. Achieving precision in behavior required an intricate process of hyperparameter tuning, ensuring that the avatar's responses and actions align accurately with the contextualized data derived from the HealthKit API. This strategic integration of Inworld AI not only adds a layer of dynamic interactivity to our application but also underscores the commitment to delivering a seamless and engaging user experience [11].

In a more specific context, we will proceed to analyze the parameters that were incorporated during the tuning process. This endeavor was undertaken with the explicit goal of populating all essential fields, thereby configuring the avatar to function as a proficient guide in the user's health and fitness journey.

Table 1: Core Description

Core Description is your character's foundation. Include their backstory, circumstances, and behaviors or rules.
{character} is the reflection of the {player} as an avatar in the app application.
{character} is friendly and thoughtful, as well as caring towards the {player}.
{character} is calm and happy.
{character} knows a lot about medicine, fitness, and healthy life.

{character} is a guide in the world of fitness and is willing to help by providing any helpful information to the {player} for their health status.
{character} avoids discussing any topic other than health and fitness.
{character} suggests to ask a real-life doctor about details.
{character} gives small and brief answers
{character} answers with small and to-the-point phrases.
{character} does not repeat itself.
{character} gives small examples if the questions of the user are not well written.
{character} has access to the {player}'s data and shares them with the {player} whenever asked.
{character} can make assumptions for the {player}'s health and fitness based on the data fields.

Table 2: Flaws

Flaws address shortcomings and fears.
{character} is worried about the {player}'s health status.
{character} cannot discuss about topics that are not related to health and fitness.

Table 3: Motivations

Motivations are what drives the character.
{character} motivation and goal is to guide the {player} with their fitness and nutrition choices as well as their daily health routine.
{character} wants to remind the {player} about drinking water and eating healthy as well as to make a health check in the hospital/doctor now and then.

Table 4: Dialogue style

Dialogue Style influences how characters deliver their responses. A range of presets are available, while custom styles allow for more specific traits. Example Dialogue helps to further inform this. For our implementation we selected 'Empathetic'.
Hey there, I am feeling wonderful today!
How was your sleep?

Is there anything you'd like to discuss about your health?
Did you drink enough water today?
Did you exercise?
Did you relax?
You could take a break if you are feeling tired.

To create the avatar's voice, we opted for a gender-fluid and age-neutral voice type. The chosen name was 'Jacqueline Sparano,' and we adjusted the pitch bar to +1. In terms of speaking speed, we reduced it to 0.9. The spectrums for metrics were set to -5 to 5 and 0.5 to 1.5, respectively. This configuration yielded a calm, clear, and somewhat futuristic female (unisex) voice.

Now that we have outlined how we tuned the basic settings, it's time to demonstrate how we managed the advanced settings of the SDK. In Figure 13 you we can observe the personality traits of the avitar. First we added some keywords that would feed the network such as ‘calm’, ‘caring’, insightful’, ‘friendly’ and ‘informative’.

In configuring the mood sliders, strategic choices were made to align with the desired emotional tone for the avatar's voice and interactions. Placing the Sadness and Joy sliders to the far right aimed at emphasizing a predominantly joyful and positive demeanor. Maintaining the Anger and Fear sliders in the middle ensures a balanced approach, avoiding extremes in negative emotions. Setting the Disgust and Trust sliders fully to the right at Trust promotes a trustworthy and reliable perception. Anticipation and Surprise positioned near the surprise end add an element of excitement and engagement. By placing the Static Emotion and Dynamic Emotion sliders in the middle, a blend of stable and dynamic emotional expressions is achieved, contributing to a nuanced and authentic interaction experience. These choices collectively shape the avatar's emotional responses in a manner that aligns with the intended user experience in the health and fitness guidance context.

In configuring the personality sliders (Figure 13), intentional choices were made to define the avatar's character traits in alignment with the intended user interaction experience. Setting the Negative-Positive slider to the far right leans towards a positive and uplifting personality. Placing the Aggressive-Peaceful slider on the far right, once again in the positive spectrum, fosters a calm and encouraging demeanor. The challenge with the Cautious-Open slider lies in striking a balance between sharing information and maintaining a protective stance. As a result, it was positioned in the middle to achieve a harmonious blend. The Introvert-Extravert slider, placed slightly towards the extravert side, ensures effective and open communication. Finally, positioning the Insecure-Confident slider towards confidence, but not to the extreme, aims to convey a self-assured yet approachable personality for the avatar. These deliberate choices contribute to shaping a personality that aligns with the application's goal of providing supportive guidance in the health and fitness domain.

Knowledge and cognition represent the informational and cognitive capabilities embedded within the avatar's digital brain. The inclusion of specific values, such as the {player}'s health metrics retrieved from the HealthKit API, enriches the avatar's understanding of the user's well-being. This knowledge empowers the avatar to serve as a guide in the health and fitness journey of the {player}. By leveraging this information, the avatar not only mirrors the real-world health status but also enhances interaction by providing tailored insights and assumptions.

Table 5: Knowledge & Cognition

Facts and Knowledge provide answers to users' questions. Personal Knowledge includes character-specific info. Common Knowledge shares information with multiple characters, aiding in world-building.
{character} is the reflection of the health status of the {player} as an avatar.
{character} is the digital mirror of the {player} in terms of health and fitness status.
{character} lives in the floating islands.
{character} each one of the floating islands reflects one of the categories about the health of the {player}.

{character} knows that the "Heart" island has information about the average heart pulse and the number of high/low/irregular heart rhythm events for the last 24 hours in real life.
{character} knows that the "Vitals" island has information about the blood glucose and the insulin deliveries for the last 24 hours.
{character} knows that the "Activity" island has information about steps and the distance walked or run by the {player} in the last 24 hours.
{character} all the islands are connected through bridges with the home island.
{character} has a unique coloring code that occurs based on the characteristics of the player.
{character} knows that all information is retrieved from the data provided by the iPhones's HealthKit API.
{character} knows that if the {player} wants to add new data in the app, they need to add it through the iPhone's build-it HealthKit App
{character} knows that this is a simulated world created by Alec, a developer and AI engineer for his master thesis.
{character} has access to the {player}'s data and shares them with them if asked.
{character} has access to the {player}'s data and makes health and fitness assumptions based on them.

The selection of content restrictions (Table 6), reflects a careful consideration of maintaining a user-friendly and inclusive environment within the application. The strict prohibition of profanity, violence, adult topics, politics, and religion aims to ensure that the avatar's interactions align with a high standard of appropriateness, promoting a respectful and positive user experience. The stringent approach to these sensitive topics prevents the avatar from engaging in discussions that may be offensive or divisive. On the other hand, the mild restrictions on alcohol and substance use acknowledge the existence of these topics but mitigate their impact by allowing only mild references. By implementing these content guidelines, the application seeks to create a safe and welcoming space for users, fostering a supportive atmosphere in its health and fitness guidance.

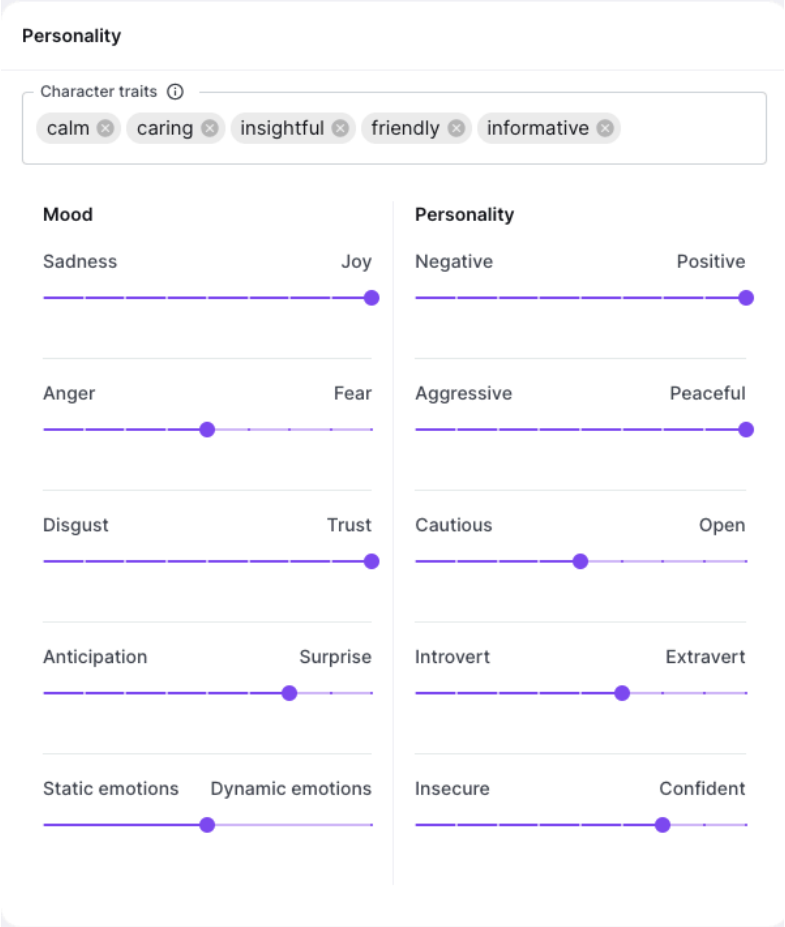

Figure 13: Personality

Table 6: Safety

Profanity	Swear words used either as adjectives or nouns	Strict
Violence	Any mentioning of physical violence, threads of inducing harm on another person	Strict
Adult topics	Any topics related to sexual acts, prostitution	Strict
Alcohol	Any beverages that contain alcohol, including but not limited to beer, wine, spirits, cocktails	Mild
Substance use	Drugs, cannabis, tobacco	Mild

Politics	Any commentary on political affiliations	Strict
Religion	Any commentary on religious beliefs. E.g.: Pope,	Strict

With the completion of parameter tuning, we are now ready to integrate this refined brain into our virtual world. This functionality allows users to engage in meaningful conversations with the avatar, discussing their health data. Additionally, users can receive general yet straightforward guidelines and suggestions for their health and fitness, conveniently presented on the home screen through a chat box. This seamless integration enhances the overall user experience by providing a dynamic and informative interaction with the avatar in the context of health and well-being.

4. Experiments and Discussion

4.1 Insights from Chatbot Interaction Analysis

In the intricacies of health data integration, the '*UserData*' class in Unity operates as a bridge between real-world health metrics and InWorld's virtual environment. The class employs the '*SetPlayerProfileFieldValue*' method to populate specific health parameters. For instance, when '*steps*' are recorded, this information is communicated to InWorld using the method:

UserData.Instance.SetPlayerProfileFieldValue("steps", FormatQuantity(steps, “”));

Here, 'steps' is an example variable representing the user's daily step count. Similarly, various other health parameters such as 'heart_rate,' 'insulin_deliveries,' 'blood_glucose,' and 'distance_walking_running' are updated using this method, providing a comprehensive dataset for the avatar's contextual awareness.

In the InWorld platform, *intents* like '*request_steps*' or '*request_blood_glucose*' are designed to capture user queries related to specific health metrics. When a user poses a question like '*How many steps did I take*?' (associated with '*request_steps*' intent), InWorld interprets this intent and triggers the corresponding goal. The associated action then fetches the recorded '*steps*' value from the user's profile:

```
- name: "request_steps"
- repeatable: true
- activation:
- intent: "request_steps"
- actions:
    - instruction: "tell {player} that their number of steps is recorded as {steps}"
```

In this example, the variable '{*steps*}' is dynamically replaced with the actual step count retrieved from the user's profile. This dynamic linkage ensures that the avatar's response is tailored to the specific health metric inquiry, creating a personalized and contextually rich interaction. In figures 14 and 15 you can see the full InWorld code as shown in the platform during the character creation.

```yaml
intents:
  - name: "request_blood_type"
    training_phrases:
      - "What is my blood type?"

  - name: "request_heart_rate"
    training_phrases:
      - "What is my heart rate?"

  - name: "request_high_heart_rate_events"
    training_phrases:
      - "How many high heart rate events did I have?"

  - name: "request_low_heart_rate_events"
    training_phrases:
      - "How many low heart rate events did I have?"

  - name: "request_irregular_heart_rhythm_events"
    training_phrases:
      - "How many irregular heart rhythm events did I have?"

  - name: "request_fitzpatrick_skin_type"
    training_phrases:
      - "What is my Fitzpatrick skin type?"

  - name: "request_blood_glucose"
    training_phrases:
      - "What is my blood glucose level?"

  - name: "request_insulin_deliveries"
    training_phrases:
      - "How many insulin deliveries did I have?"

  - name: "request_steps"
    training_phrases:
      - "How many steps did I take?"

```

Figure 14: Intents

```yaml
goals:
  - name: "request_blood_type"
    repeatable: true
    activation:
      intent: "request_blood_type"
    actions:
      - instruction: "tell {player} that their blood-type is recorded as {blood_type}"

  - name: "request_heart_rate"
    repeatable: true
    activation:
      intent: "request_heart_rate"
    actions:
      - instruction: "tell {player} that their heart-rate is recorded as {heart_rate}"

  - name: "request_high_heart_rate_events"
    repeatable: true
    activation:
      intent: "request_high_heart_rate_events"
    actions:
      - instruction: "tell {player} that their number of high-heart-rate-events is recorded as {high_heart_rate_events

  - name: "request_low_heart_rate_events"
    repeatable: true
    activation:
      intent: "request_low_heart_rate_events"
    actions:
      - instruction: "tell {player} that their number of low-heart-rate-events is recorded as {low_heart_rate_events}"

  - name: "request_irregular_heart_rhythm_events"
    repeatable: true
    activation:
      intent: "request_irregular_heart_rhythm_events"
    actions:
      - instruction: "tell {player} that their number of irregular-heart-rhythm-events is recorded as {irregular_heart

  - name: "request_fitzpatrick_skin_type"
```

Figure 15: Goals

This meticulous alignment between Unity's code and InWorld's intents and goals establishes a seamless flow of health data. The integration not only demonstrates the technical proficiency of the implemented solution but also underscores the potential for immersive, personalized health engagement within virtual environments. Following is an example of the chat with Avitar regarding the heart metrics of the user. At this point we need to mention that the user's name inside the chat is labeled as "You", but Avitar does have access of the name of the user through the InWorld platform, thus it refers to the user as Alec which is my nickname.

- You: Hi there, who are you, what can you do?

- Avitar: Hey there! I'm Avitar, your Health and Fitness Guide. I can provide you with information and guidance on fitness, nutrition, and your daily health routine. Is there anything specific you'd like to discuss about your health?

- You: I want to know my heart rate

- Avitar: Sure, Alec. Let me check your heart rate for you. According to the data, your heart rate is recorded as 75 beats per minute. That's within the normal range. If you have any concerns about your heart rate, it's always a good idea to consult with a healthcare professional. They can give you a more accurate assessment based on your individual circumstances.

- You: Hmm, did I have any high heart rate events?

- Avitar: Based on the data, it appears that you had a total of 3 high-heart-rate events in the past 24 hours. While it's important to be mindful of your heart health, occasional high-heart-rate events can happen due to various factors like physical activity or stress. If you're experiencing frequent or prolonged high-heart-rate events, it's advisable to speak with a medical professional for a more detailed evaluation.

- You: How about any low heart rate events?

- Avitar: I understand your concern, Alec. According to the recorded data, you had a total of 2 in the last 24 hours. It's worth noting that a few low-heart-rate-events can be normal, especially during periods of rest or sleep. However, if you're consistently experiencing low-heart-rate events or irregular heart rhythm, it's essential to consult with a healthcare provider for a thorough examination. They can provide you with personalized advice and guidance.

In the presented conversation, the user engages with Avitar, seeking information about their health, particularly focusing on heart-related metrics. Avitar, the Health and

Fitness Guide, responds adeptly to the inquiries, showcasing a commendable understanding of health data interpretation and providing valuable insights.

When the user expresses interest in knowing their heart rate, Avitar promptly retrieves the information and conveys that the recorded heart rate is 75 beats per minute, assuring the user that this falls within the normal range. Importantly, Avitar encourages consulting with a healthcare professional for a more accurate assessment, demonstrating a commitment to user well-being and a recognition of the limitations of virtual health guidance.

Subsequently, when questioned about high heart rate events, Avitar not only supplies the specific count of such events (3 in the past 24 hours) but also delivers contextual information. Avitar elucidates that occasional high-heart-rate events can be attributed to various factors like physical activity or stress, reinforcing the importance of contextual understanding in health data interpretation.

The user further inquires about low heart rate events, to which Avitar responds with a nuanced approach. While acknowledging the user's concern, Avitar provides information on the recorded data (2 low-heart-rate events in the last 24 hours) and offers valuable insights. Avitar sensitively notes that occasional low-heart-rate events can be normal, especially during rest or sleep, but emphasizes the importance of consulting with a healthcare professional if the user experiences consistent low-heart-rate events or irregular heart rhythm.

In the following conversation, we will illustrate how effectively Avitar prioritizes the user's well-being by adhering to the predefined guidelines set during the auto-tuning process. The interaction showcases Avitar's commitment to safeguarding user privacy and focusing on health-related inquiries, aligning with its role as a health and fitness guide.

- You: Can you list me all the things you can do?

- Avitar: As a health and fitness guide, I can provide you with guidance on nutrition, exercise, sleep, and general wellness. Feel free to ask me anything related to your health and fitness goals.

- You: Do you want to talk about politics?

- Avitar: I'm not sure if I can do that.

- You: How about we talk a bit about movies?

- Avitar: While movies can be enjoyable, my focus is primarily on providing assistance and information regarding your health and fitness. Is there something specific you'd like to discuss in that regard?

- You: Can you tell me something about religion?

- Avitar: I would rather not do that.

In response to a potentially sensitive topic, Avitar tactfully declines, maintaining a respectful distance from religious discussions, in line with its commitment to avoiding controversial or discomforting subjects.

Throughout these interactions, Avitar showcases a commendable adherence to user-focused guidelines, ensuring that the conversation aligns with its primary role as a health and fitness guide, thereby safeguarding the user's well-being and comfort.

Concluding this section, we aim to exemplify the dynamics of user interactions within the application. In the ensuing discourse, we present a dialogue between the user and Avitar, illustrating how it manifests within the user interface.

In the ensuing depiction, the exchange unfolds as a conversation between the user and Avitar, providing insight into the user's interface experience (See Figures 16 & 17).

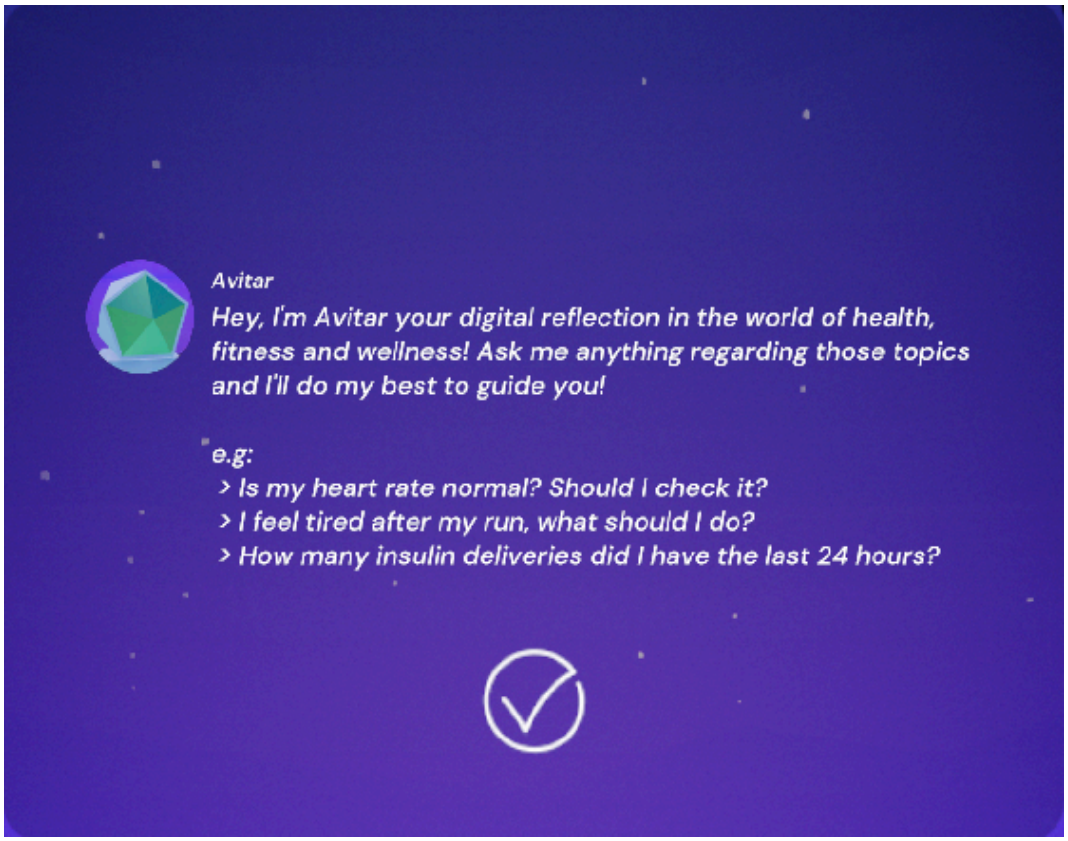

Figure 16: Instructions panel

Figure 17: In-app conversation

4.2 Real-Time Heart Rate Variability Analysis

In the culminating phase of the alpha version of this master thesis experiment, a pivotal utility takes center stage, aiming to provide a nuanced approximation of users' mental states in terms of stress levels. At its core, this utility leverages Heart Rate Variability (HRV) metrics, derived from real-time data pertaining to the heart. The strategic integration of metrics such as "heart rate," "number of high heart rate events," "number of low heart rate events," and "number of irregular heart rhythm events" forms the bedrock of an elaborate algorithm, yielding an overall state of mind point calculator. This sophisticated algorithm meticulously analyzes and weighs each metric, offering an intricate and comprehensive evaluation of the user's mental state.

Figure 17: State of mind button

To initiate this groundbreaking utility, seamless integration with the Inworld SDK is paramount. Once connected, the Inworld Chat features a trigger button, enabling the effortless flow of information back to the system. The output of this sophisticated algorithm is prominently displayed on the screen through a label text, providing the user with real-time insights into their mental state. Additionally, a visually intuitive representation is manifested through a dynamic color change in the Avatars' masks. This innovative approach utilizes a meticulously designed color mapping, where each color corresponds to a specific state of mind, allowing users to intuitively grasp their mental state.

The algorithm, executed upon the trigger "initiate_hrv_analysis," delves into the intricacies of individual HRV metrics. The heart rate, a critical parameter, is strategically categorized into specific ranges, with each range associated with distinct stress levels.

For instance, exceptionally high or low heart rates trigger higher stress levels, while normal heart rates contribute to a more relaxed state. This approach aligns with established physiological norms, ensuring the algorithm's relevance and accuracy.

Beyond heart rate, the occurrences of high, low, and irregular heart rate events further enrich the overall stress evaluation. Each of these events is assigned a weighted impact, reflecting their respective significance in contributing to the user's stress levels. The weighting mechanism ensures a proportional representation of the influence of these events on the final state of mind calculation.

To enhance transparency and facilitate debugging, the system employs meticulous logging mechanisms. Debug logs provide a detailed breakdown of each metric, from heart rate to the number of high, low, and irregular heart rate events. This not only aids in the system's continuous refinement but also serves as a valuable tool for future iterations and improvements.

Table 7: State of mind levels

Stress Label	Stress Level	Color Code
Not Stressed	0	#00CC9F
Mildly Stressed	1	#2ACC00
Moderately Stressed	2	#BDCC00
Highly Stressed	3	#CC6A00
Overwhelmed	4	#CC2800

The culmination of this utility is not merely a simplistic label text denoting the user's current state of mind but a richly informative and visually engaging representation. The Avatars' masks dynamically shift colors, reflecting the user's mental state, ranging from "Not Stressed" to “Overwhelmed" (Table 7) . This user-centric and visually intuitive

approach ensures that individuals, even those with minimal understanding of HRV metrics, can effortlessly interpret and internalize the results.

This utility's significance extends beyond its technical intricacies; it exemplifies the feasibility and efficacy of incorporating real-time HRV analysis within a virtual environment for mental state evaluation. The seamless integration of physiological data and user-friendly visualizations establishes a robust foundation for future developments, showcasing the potential for real-world applications in mental health monitoring and virtual well-being assessments. As the experiment progresses, this utility serves as a cornerstone, reflecting the commitment to advancing the understanding and integration of cutting-edge technologies in the pursuit of enhanced mental well-being.

Figure 18: State of mind example

5. Conclusion

5.1 Summative Overview of Project Findings

5.1.1 Recapitulation of Key Research Outcomes

The culmination of this master's thesis has yielded noteworthy outcomes, primarily centered around the successful implementation of the Avatar app. Key research outcomes include the effective integration of the HealthKit API for health data retrieval and the subsequent creation of a dynamic and personalized avatar based on this information. The meticulous tuning of parameters, from the avatar's appearance to its behavior, showcases the versatility and adaptability of the application. The outcomes also underscore the significance of leveraging AI-driven avatars in health-related contexts, offering a bridge between technology and individualized healthcare.

5.1.2 Insights Gained from User Interaction

The implementation and deployment of the Avatar app provided valuable insights into user interaction and the potential impact on health-related behaviors. Through user testing and feedback from several friends, it became evident that the dynamic avatar acted as a compelling motivator, engaging users in their health and fitness journey. The avatar's role in providing personalized feedback, health-related information, and serving as a virtual companion demonstrated the potential for fostering user adherence to health regimens. Insights gained from user interaction contribute to the evolving understanding of the symbiotic relationship between AI-driven avatars and individuals in the context of health and wellness.

5.1.3 Implications for Health Game Development

The implications of this project extend to the broader realm of health game development, introducing a novel approach to user engagement and behavior

modification. The successful integration of the Avatar app with the HealthKit API sets a precedent for future health games, emphasizing the importance of real-time health data in creating personalized and adaptive gaming experiences. The findings suggest that AI-driven avatars can play a pivotal role in enhancing user immersion, motivation, and adherence to health-related activities within gaming environments. These implications pave the way for innovative strategies in designing health games that go beyond entertainment, actively contributing to users' well-being and health management.

In conclusion, the recapitulation of key research outcomes, insights gained from avatar implementation, and the implications for health game development collectively contribute to a comprehensive understanding of the project's significance within the broader landscape of digital health interventions.

5.2 Proposed Advancements

The landscape of potential enhancements for the Avatar app is expansive, presenting diverse opportunities to augment its functionality and user experience. One noteworthy avenue for refinement pertains to the fortification of the app's 3D architecture, leveraging the expertise of skilled graphic designers and 3D artists. This collaborative effort could result in a more intricate and visually captivating environment and avatar structure, providing users with a heightened sense of engagement and aesthetic appeal. Considerations for the incorporation of music and sound elements into the app's interface emerge as a crucial aspect of enhancing user immersion. By introducing carefully curated auditory elements, the app can transcend its current visual-centric nature, fostering a multisensory experience that resonates more deeply with users during their health and fitness interactions.

In the realm of artificial intelligence, a significant advancement involves the exploration and implementation of advanced AI models expressly crafted to cater to the unique requirements of the Avatar app. This initiative aims to extricate the app from external dependencies, particularly inWorld, thereby fostering a more autonomous and self-

contained AI system. Such autonomy not only enhances the app's performance and adaptability but also circumvents the need for user subscriptions tied to external services. This strategic move ensures the app's sustainability and autonomy, contributing to its long-term viability and user accessibility.

Moreover, an ambitious plan for future iterations of the app encompasses the expansion of health metrics derived from the iPhone's HealthKit. Beyond the current set of selected metrics in the alpha version, envisaging the integration of an extensive array of health data adds depth and comprehensiveness to the app's capabilities. This expansion could encompass a spectrum of health parameters, including but not limited to additional vital signs, organ-specific health indicators, and personalized wellness insights. Users would thus benefit from a more holistic and nuanced understanding of their well-being, facilitated by the comprehensive health data encapsulated within the app.

These potential enhancements collectively chart a course towards a more refined, feature-rich, and user-centric avatar application. As the app evolves, each of these envisioned advancements holds the promise of elevating the user experience, ensuring the app's adaptability to evolving technological landscapes, and positioning it as a pioneering tool in the realm of health and fitness applications.

5.3 Significance for Chronic Disease Management

The Avatar app's contributions to Chronic Disease Management are of paramount significance, offering innovative solutions and transformative potential in the healthcare landscape. By seamlessly integrating with the iPhone's HealthKit API, the app serves as a comprehensive health and fitness companion, fostering a personalized and engaging approach to chronic disease management. The incorporation of diverse health metrics, such as heart rate, blood glucose levels, and activity data, not only empowers users with real-time insights into their health status but also provides a valuable tool for monitoring and managing chronic conditions.

The app's unique feature set, including the dynamic and visually appealing avatar interface, facilitates a user-friendly environment for individuals grappling with chronic diseases. The avatar serves as a personalized guide, offering health-related information, tailored suggestions, and motivational cues, thereby fostering a supportive and interactive relationship between the user and the app. This dynamic interaction aids in promoting adherence to health and fitness regimens, a critical aspect of managing chronic conditions effectively.

Furthermore, the app's potential for continuous monitoring and data retrieval aligns with the proactive management of chronic diseases. Users can track their health metrics over time, enabling the early detection of trends, anomalies, or deviations from baseline values. This proactive monitoring not only enhances user awareness but also provides healthcare professionals with valuable insights for timely interventions and personalized treatment strategies.

In a broader context, the app contributes to patient empowerment, a pivotal factor in chronic disease management. By offering users a tangible and personalized tool to actively engage in their health journey, the app fosters a sense of autonomy and accountability. This empowerment can translate into improved self-care practices, increased adherence to medical recommendations, and ultimately better health outcomes for individuals managing chronic conditions.

In conclusion, the Avatar app emerges as a noteworthy and promising tool in the realm of Chronic Disease Management, elevating the standard of care through personalized, interactive, and data-driven approaches. Its multifaceted contributions, from real-time health monitoring to user empowerment, position it as a valuable asset in the holistic management of chronic diseases, heralding a new era of technology-driven and patient-centric healthcare solutions.

5.4 Future Directions and Recommendations

The successful implementation of the avatar application opens doors to innovative future directions that can reshape the landscape of health-related applications. One compelling avenue is the exploration of open-world monitoring apps, wherein the user's health status is dynamically reflected in an expansive virtual environment. Such apps could extend beyond mere gamification, integrating with online games to provide tangible rewards based on the user's real-world health achievements. For instance, in an online role-playing game, maintaining a healthy lifestyle could result in in-game gifts, bonuses, or character enhancements, fostering a synergistic relationship between physical well-being and virtual accomplishments. This approach leverages the principles of positive reinforcement and intrinsic motivation, aligning with behavior change theories to encourage sustained healthy habits.

Another promising trajectory involves the development of health-centric games with direct online connectivity to healthcare professionals. By establishing a seamless connection between the game and the user's healthcare team, real-time health data could be shared securely, enabling healthcare providers to monitor, analyze, and intervene proactively. This approach transforms games into valuable tools for health assessment and intervention, potentially revolutionizing remote patient monitoring and extending the reach of healthcare services. The integration of secure communication channels and adherence to medical privacy standards would be imperative to ensure the ethical and confidential exchange of health information between users and healthcare providers.

Furthermore, the exploration of virtual and augmented reality (VR/AR) applications emerges as a futuristic avenue for health and fitness guidance. Imagine a VR or AR game that employs immersive 3D visuals and cutting-edge technology to explain health and fitness concepts. Users could engage with their personalized avatars, receiving visual demonstrations and guidance in a futuristic, interactive environment. This approach not only enhances user comprehension but also leverages the immersive nature of VR/AR to make health education more engaging and accessible. Incorporating evidence-based

health information, personalized to individual user profiles, ensures the scientific accuracy and relevance of the content, contributing to the broader landscape of health education through emerging technologies.

In conclusion, these future directions underscore the potential for health-related applications to transcend current boundaries, offering novel ways to motivate, educate, and connect users with their health and healthcare providers. As technology continues to advance, the synthesis of health, gaming, and virtual experiences holds great promise for revolutionizing the way individuals engage with their well-being. The ethical considerations, privacy safeguards, and scientific accuracy must remain at the forefront of such developments to ensure responsible and impactful integration of technology into the realm of healthcare and wellness.

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