AR Communication Software for Children with Autism

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***Abstract*—This project details the complete development of a software solution for an Augmented Reality (AR) platform targeting the Meta Quest 3s headset, designed to support communication and self-expression for children with Autism Spectrum Disorder (ASD). The system creates an interactive, customizable environment allowing caregivers to tailor content to a child's unique needs. The final system includes three distinct therapeutic/educational activities: Object Identifier, Sentence Builder, and Emotion Explorer. Additionally, a companion web application was designed and developed to allow clinicians to visualize performance data exported from the headset. This report details the rationale, objectives, final implementation, and integration of the AR software and its web-based analytical tool.**

***Keywords*— Autism Spectrum Disorder, Augmented Reality, Assistive Technology, Communication, Human-Computer Interaction, Prototyping, ASD, AR.**

I. Introduction

Autism Spectrum Disorder (ASD) is a neurodevelopmental disorder that affects the communication, social interaction, and behaviors [1] of adults and children. Many children with ASD struggle with conventional communication methods, which makes it difficult for them to express their needs and emotions effectively. Although various assistive technologies exist, they often lack flexibility, fail to sustain engagement, or are not tailored to the unique needs of autistic children. Augmented Reality (AR) presents a promising advancement in assistive communication tools, offering a more interactive and adaptable solution.

This project focuses on developing a software-based communication solution tailored for an AR system. Our goal is to provide an engaging, interactive, customizable software that can be tailored to the individual needs of the child. The use of AR allows for digital overlays in the user's physical environment, which in turn offers a multi-sensory experience that can promote understanding and interaction. By emphasizing visual support, contextual clues, and interactive elements, the system aims to supplement or enhance the communication pathways that children with ASD find most accessible.

II. Problem Statement

Children who face communication challenges – such as those on the autism spectrum – often encounter impairments in social interactions, and communication [2]. Which can hinder their participation in social and educational contexts. Existing tools are often limited in customization and sometimes fail to sustain user engagement due to lack of interactivity. This gap underscores the need for a more responsive and immersive communication tool.

An augmented reality-based software offers a promising solution by introducing dynamic visuals and auditory stimuli that enhance communication without overwhelming the user. The ability to adapt to individual preferences while encouraging interaction in a real-world context makes AR an ideal medium for this application. A flexible, user-friendly system tailored to individual learning profiles has the potential to improve expressive capabilities and social confidence.

III. Project Objectives

For this project, our current objectives are:

- Develop a functional AR communication software.
- Allow for caregiver-driven customization of content and interface settings.
- Allow for emotion recognition.
- Design the user interface with accessibility and engagement as top priorities.
- Gather user feedback during development to ensure the system evolves to meet real-world needs.

IV. Project Methodology

Our project adopts a waterfall model with prototyping. This approach offers us a structured development process with built-in opportunities for iterative testing and refinement. Key stages include:

- **Requirement Gathering:** Consultation with specialists, therapists, end-users, to come up with a list of necessary requirements.
- **System Design:** Development of wireframes, and program design.
- **Prototype Creation:** Building early versions of the software for internal evaluation.
- **Evaluation:** User testing sessions with educators and therapy professionals.
- **Implementation:** Iterative enhancements leading to a stable, deployable prototype.

V. Structure Diagram

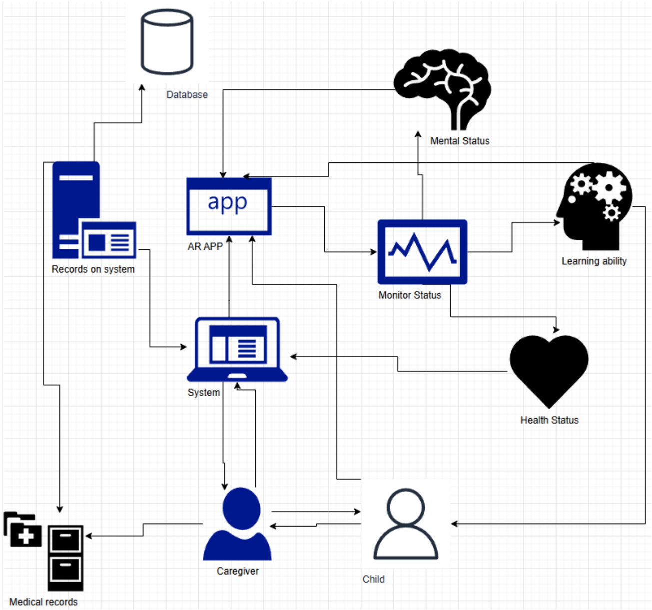

Figure 1: Structure Diagram of Our Project.

When designing our project, our vision is for pediatricians and healthcare professionals to systematically analyze and study the communication patterns and behavior in children with autism. The structure of this project uses an application as a tool for better understanding and appropriate communication. Certified medical practitioners utilize the application to track developmental progress across cognitive, emotional, and educational domains. The child using the app through the Augmented Reality (AR) headset will be able to immerse himself/herself in activities to help them understand and communicate in an efficient way. Every piece of information will be stored in the system with a database which only medical professionals will have access to.

VI. System Design

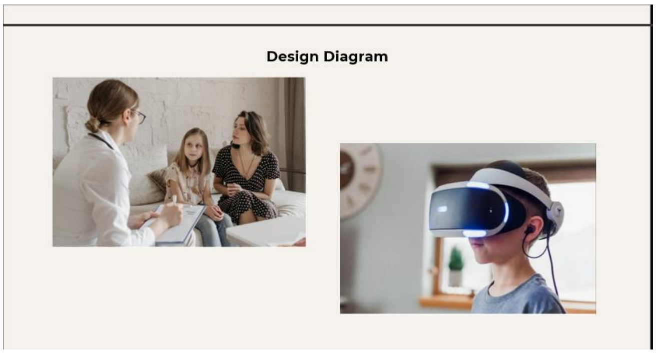

Figure 2: Design Diagram of Our Project.

The project employs a streamlined, user-centric design to ensure accessibility for its intended users (families and clinicians). We have the family visit their licensed medical doctor to have an evaluation of how the child interacts or communicates with other people. Following this evaluation, the next step is to gradually introduce the child to AR so that they can get accustomed to the platform. During this time, the doctor will be connected to a computer using the app to compile the data for analysis.

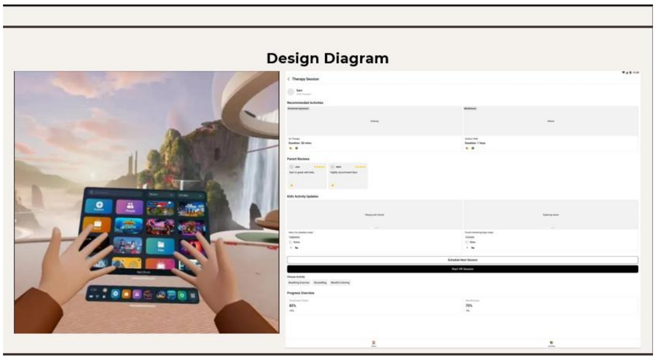

Figure 3: Wire Frames of Our Project.

The Augmented Reality headset incorporates a customizable menu of gamified activities, allowing the child to select various therapeutic modules aligned with their preferences. Each of the activities is designed to automatically transmit performance metrics (e.g., completion rates, response patterns) to the healthcare professionals' portal for behavioral assessment. The application, synchronized across AR hardware and clinical workstations, features role-specific profiles for medical practitioners. These profiles provide a centralized dashboard for progress tracking, adaptive goal setting, and session scheduling, enabling doctors to efficiently manage caseloads across multiple patients.

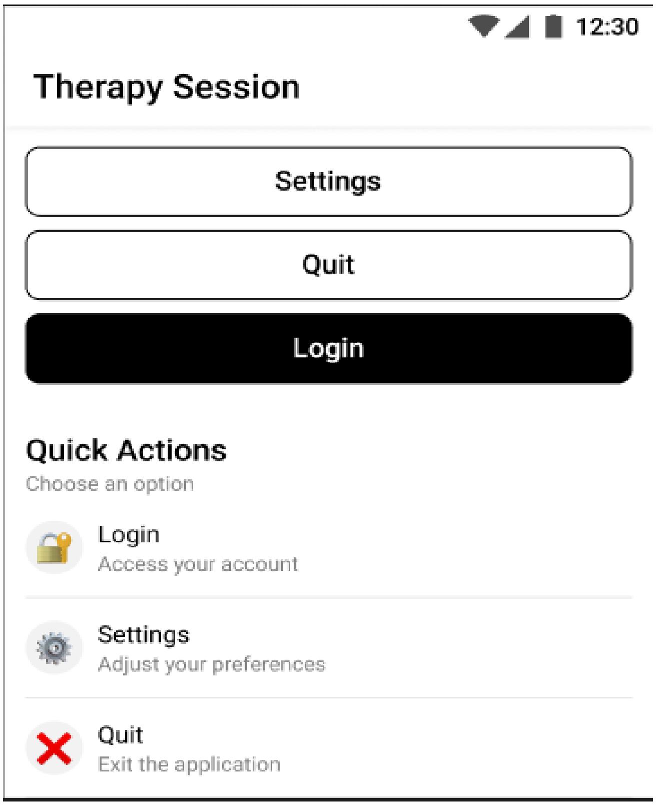

Figure 4: Login Screen for the Therapist.

A visualized concept for the project is to have a log in for the therapist/caregiver. In here, they can modify the activities for each session and have a clear progress of how the child has been during the session. They can also start sessions with activities if the child has any trouble choosing an activity.

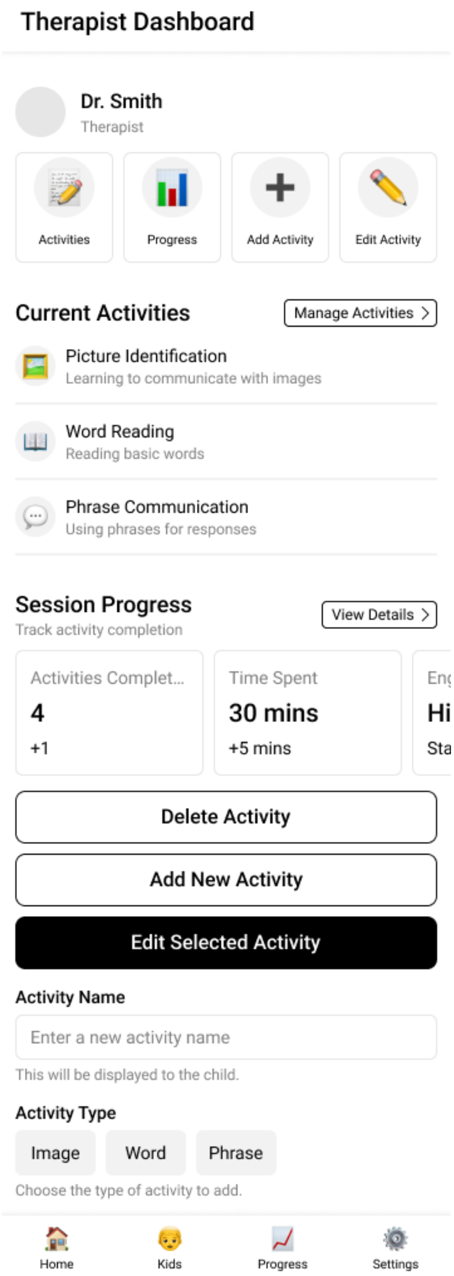

Figure 5: Menu Screen for the Therapist

This menu has access to all the content that can be personalized for the therapist/caregiver will use to have steady progress with the child. In here, we have information such as the doctor's name, the activities that will be implemented during the session and a progress to keep track of any communication that the child has learned.

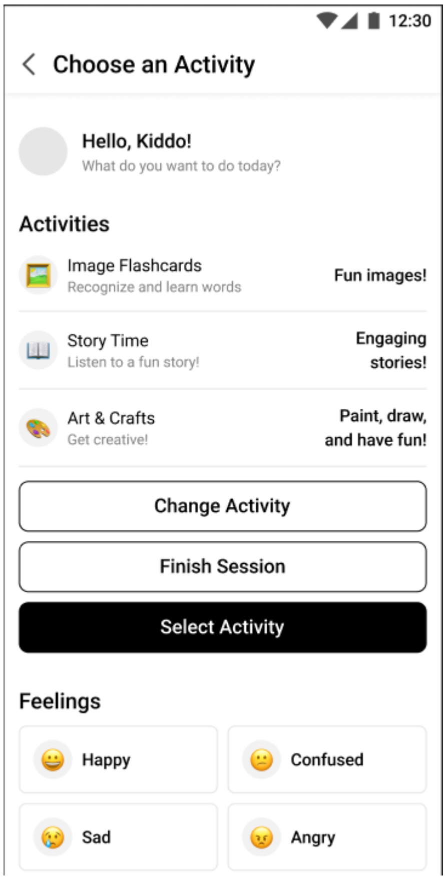

Figure 6: Menu Screen for Children.

This menu has more restrictions since it is for a child and to not overwhelm them with too much information. This simple menu has the child's name, the activity they want to partake in and a feelings option to express how they are currently during the session.

VII. Functional Requirements

Our current functional requirements for the project are as follows:

- AR (Augmented Reality) Overlay with Symbols:
  - These visual symbols will help the child who has difficulty trying to communicate.
- User Interface with AR Elements:
  - Since we do not know how the child will react to complete immersion, the layout and interface will be displayed in the real world.
- Customizable Content:
  - Dynamic library of games or activities for the child to participate in and interact with the doctor for better communication.
- Reward System:
  - Implementation of rewards for completing simple exercises.
- Motivational System:
  - Promote the child for good engagement.
- Basic Text-to-Speech System:
  - For better communication skills, we have a text-to-speech system so the child can also learn.
- Progress Tracking System:

- Useful for the licensed professional to maintain a curriculum with the child and keep steady progress.
- Emotion Recognition Assistant:
  - To maintain the safety of the child and have a safe environment and to keep the child at ease.
- Visual Setting Customization:
  - Adjust brightness, sounds and animations to accommodate the child wearing the headset.
- Voice Recognition and Commands:
  - Implement for an interaction through voice commands.
- Multi-language Support:
  - Create new ways of learning using different languages.
- Alert System:
  - Allow professionals to act if the child is under any kind of stress.
- Offline Functionality:
  - To maintain integrity and confidentiality, we will develop some parts with offline capabilities to keep information of patients secure.

VIII. Non-Functional Requirements

Our current non-functional requirements for the project are as follows:

- System Usability:
  - Make the system easy for both the medical professional and the child to use.
- Performance:
  - The system should always run smoothly and not cause any disturbance during the therapy session.
- Portability:
  - For cases where the child needs to be attended to in a different setting, have a way to keep data and take it to where the session will occur.
- Scalability:
  - Implement a database for keeping more patients.
- Availability:
  - The system should be ready at any time of the day.
- Security:
  - Access to confidential information should be given to medical professionals and the creators of the system.
- Maintainability:
  - Maintain updates for the software to prevent any intrusions and keep the software running without any problems.

IX. Cyclomatic Complexity

To evaluate the complexity of our system, we conducted a cyclomatic complexity analysis on the main functional modules of the software. Our system diagram includes major modules such as the AR activity interface, text-to-speech communication module, and progress tracking system. After analyzing the complete module structure and their control paths, the total cyclomatic complexity was calculated to be twelve, this indicates a moderate level of complexity. The result reflects our design intention to maintain simplicity and usability, particularly considering our target users. The cyclomatic complexity evaluation was supported using GitHub Copilot, an AI-based assistant, which helped in structuring the control flow analysis and refining the module logic [18].

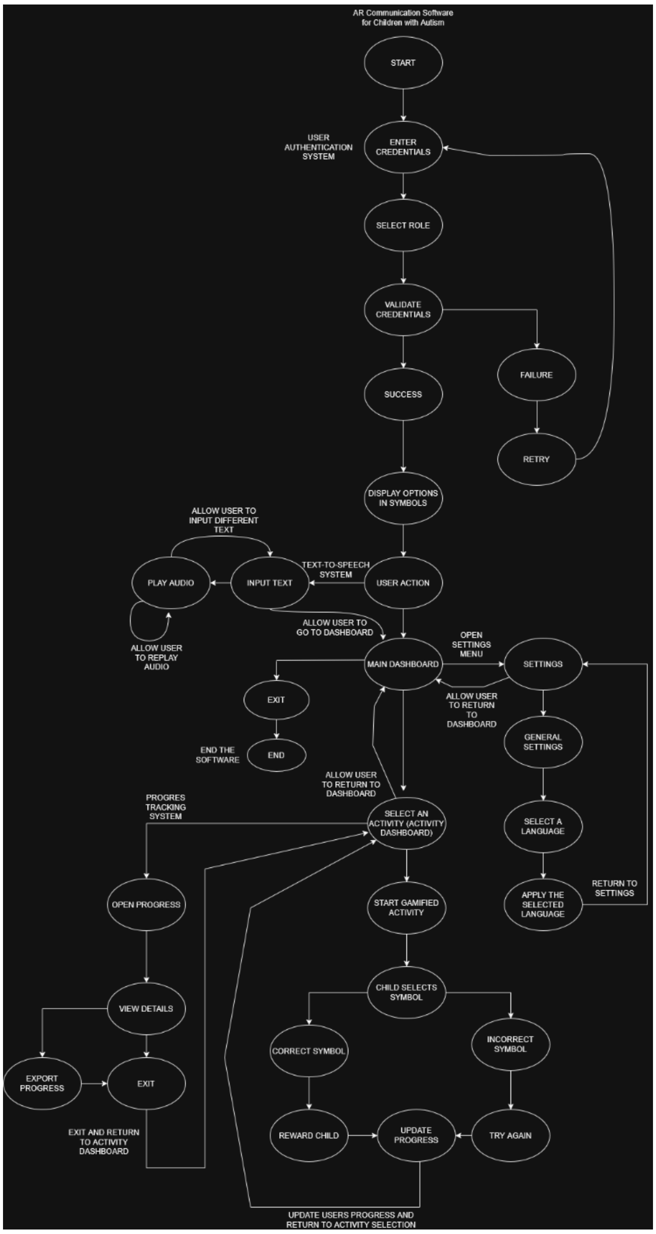

Figure 7: Cyclomatic Complexity Graph.

X. Application Implementation

This section details the concrete development and implementation progress achieved during the Capstone II phase, focusing on the system architecture, database development, and the completion of the first educational activity.

A. Core Application Infrastructure

The core application, developed in Unity Engine using C#, is a standalone APK application targeting the Meta Quest 3s headset.

- **Account Administration Panels**: Fully functional sign-up and login panels have been developed to manage the creation and administration of user accounts. These panels are the main interaction that the user will be able to do as soon as the application is started.

Figure 4: Authentication Panels.

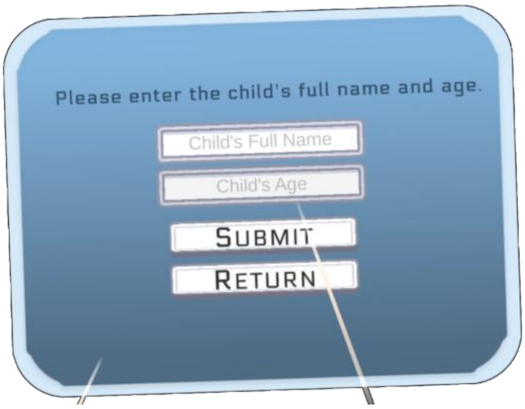

Figure 5: Sign Up Panel.

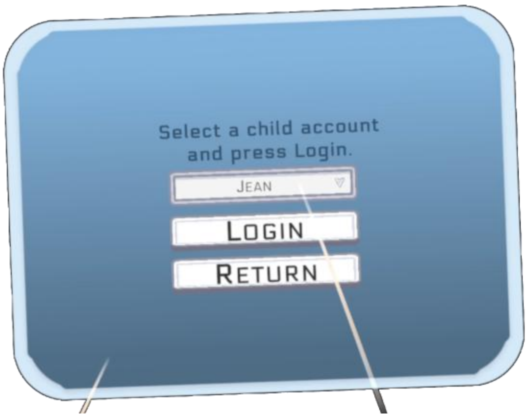

Figure 6: Log-in Panel.

- **Dashboard Development**: The entire main user dashboard is complete, providing centralized navigation to key sections: Activities, My Profile, Export Data, Settings, Help / About, and Logout. Currently, the Activities and Settings submenus are the menus that have been fully developed with their intended purpose implemented. The other selections which lead to the other submenus must be developed. The icons used to facilitate with navigation were generated with the assistance of Gemini Pro (a generative AI designed by Google) [19].

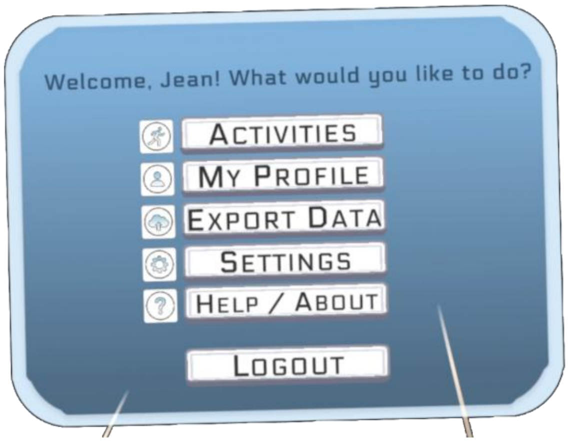

Figure 7: Main Dashboard of The Application.

Figure 8: Activities Selection Submenu.

Figure 9: Settings Submenu.

The settings menu will serve as the hub for anything related to the applications settings. Currently we have implemented sound effects when the user selects/clicks on a button, thus we have developed an audio volume setting in which stores the preference based on the account that is logged into the application.

B. *Object Identification Activity*

We have developed and fully implemented the first activity called "Object Identification".

- **Purpose**: The purpose of this activity is to aid the child in identifying everyday objects in a safe, controlled AR environment. This activity is meant to expand their vocabulary and object knowledge.
- **Mechanism**: The activity presents two AR-rendered objects (left and right) with a textual prompt on the top of the screen (e.g., "Select the kitchen chair."), requiring user selection.
- **Data Integration**: This activity is fully integrated with the database, successfully creating and logging accurate entries in the database tables.

Figure 10: Object Identification Activity Selection.

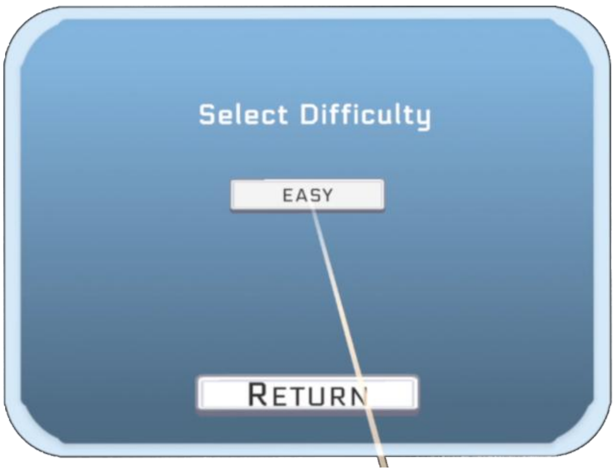

Figure 11: Difficulty Selection for The Activity.

- **Difficulty Selection**: The activity features a difficulty selection screen in which the user will be able to select the activities difficulty. Currently the Object Identification activity features an "Easy" difficulty but there will be more difficulties implemented into the activity.

Figure 12: Start Pop-Up for The Activity.

- **Start Pop-Up**: Once the user selects the difficulty the activity scene will load, and a popup panel will appear prompting the user to get into a safe and open environment before starting the activity. This is because the activity relies on assets that will spawn in the environment, and they will need to be in an open space.

Figure 13: Object Identification Activity in Action.

Once the user selects the "Start" button the activity session will start. They are shown two objects and a text prompt with the task that they must complete (**Note**: the background of the activity is black because this screenshot was taken with the Meta Quest 3s headset connected to the computer and connected to Unity Engine, currently Unity Engine does not support passthrough therefore the background won't show the real world as AR should and instead shows a black background).

- **Pause Menu**: The activity features a fully functional pause menu that allows the user to either "Continue" the activity or "Exit" the activity. If the user selects the "Exit" button, then they will be taken to the activity selection menu.

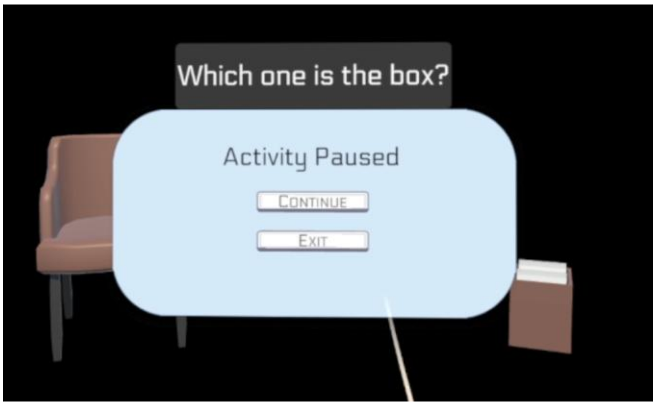

Figure 14: Activity Pause Menu.

- **Activity Completion**: When the activity is successfully completed and all tasks were done. The user is then shown a pop-up panel that tells them that the activity was completed, and it shows them the score that they received.

Figure 15: Activity Completion Pop-up.

C. *Sentence Builder Activity*

Following the completion of the Object Identification activity, we implemented the Sentence Builder activity. This activity is designed to target grammatical structure and sentence comprehension.

- **Activity Flow:** The user is presented with a text prompt displaying an incomplete sentence (e.g., “The cat is on the __”). The user must examine the AR environment and select the correct object that completes the sentence both grammatically and contextually.
- **Purpose:** This activity builds upon the vocabulary learned in the previous module by requiring the user to understand how words fit together to form coherent thoughts.

Figure 16: Sentence Builder Activity.

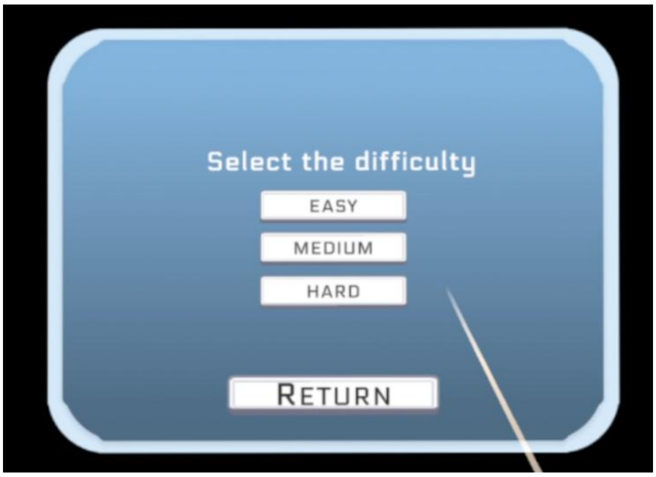

Figure 17: Difficulty Selection.

During the development of the Sentence Builder activity, we integrated fully all the proposed difficulties into this activity and into the other activities as well. All these difficulties use the ActivityConfigPreset table in the database which holds all difficulty presets.

Figure 18: Sentence Builder Activity in Action.

D. *Emotion Explorer Activity*

The third and final activity implemented is the Emotion Explorer activity. Unlike the previous modules, this activity is meant to be used as an assessment tool with no right or wrong answers designed strictly for evaluation.

- **Activity Flow:** The user is prompted with a scenario in text, accompanied by a related visual object for clarity. Below the object, four interactive emotion buttons are displayed representing specific emotional states: Happy, Sad, Neutral, and Mad.

- **Interaction:** The user must select the emoticon that best represents how they would feel, or how a person in the scenario would feel.
- **Clinical Value:** This assessment activity allows therapists to evaluate the child's emotional recognition skills and social causality. The specific emotion selected is logged in the database for the therapist to review later to see how the child processes situations.

Figure 19: Emotion Explorer Activity.

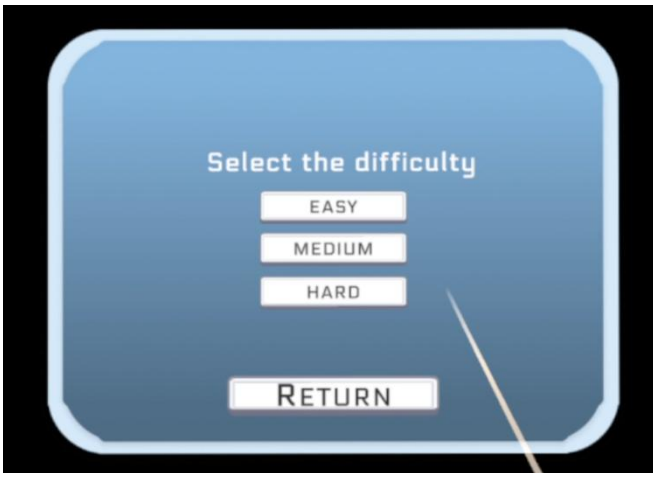

Figure 20: Difficulty Selection.

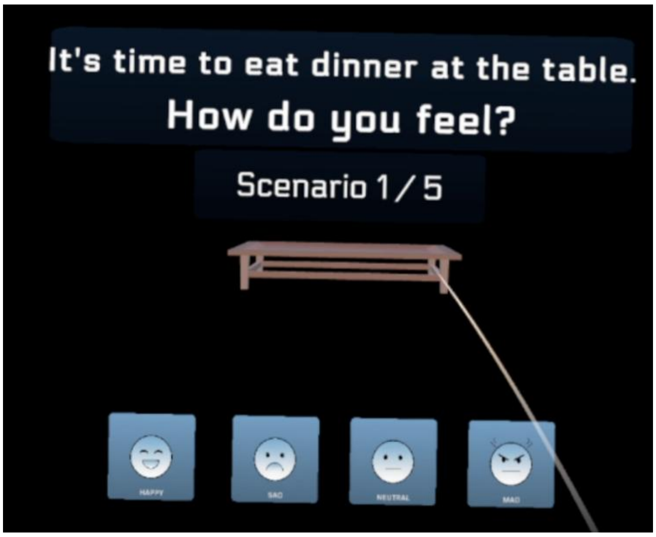

Figure 21: Emotion Explorer in Action.

E. Menu Systems and Data Export

After the activities were developed, we then fully implemented the remaining user interface menus to ensure complete user experience and data portability.

1. **My Profile**: The "My Profile" menu is now fully functional. Upon access, it displays a dynamic welcome message personalized to the currently logged-in user.
   a. **Statistics:** The profile displays aggregate data, including the total number of sessions played and total hours of playtime.
   b. **Milestones:** The system tracks achievements. When a user interacts with a completed milestone, a pop-up panel appears detailing the specific achievement and the date/time it was earned.

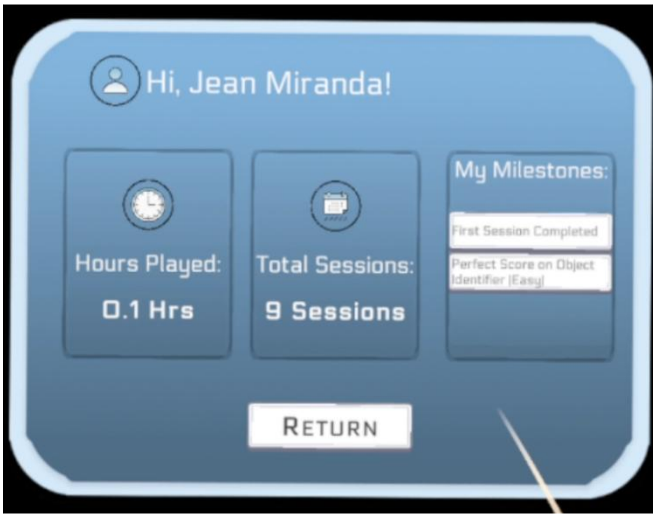

Figure 22: My Profile Menu.

Figure 23: Milestone Pop-Up.

2. **Export Data (JSON Integration):** To bridge the gap between the standalone headset and the clinician's workstation, we implemented a data export function.
    a. **Definition:** JSON (JavaScript Object Notation) is a standard text-based format for representing structured data based on JavaScript object syntax.
    b. **Functionality:** When selected, this function queries the local SQLite database and generates a JSON file containing all session logs and response data. This file is stored on the headset and is ready to be exported by connecting the device to a computer via USB.

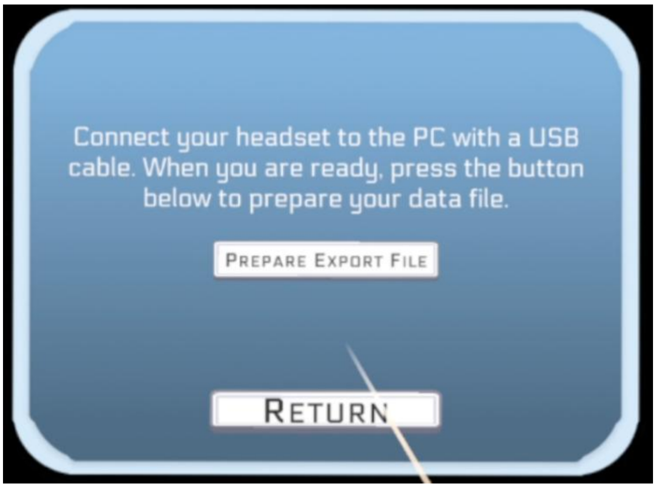

Figure 24: Export Menu.

Figure 25: JSON File Generated.

3. **Help / About:** The Help/About menu has been implemented featuring icon-based navigation. This section provides the user with essential tutorials and information regarding the application and credits.

Figure 26: Help / About Menu.

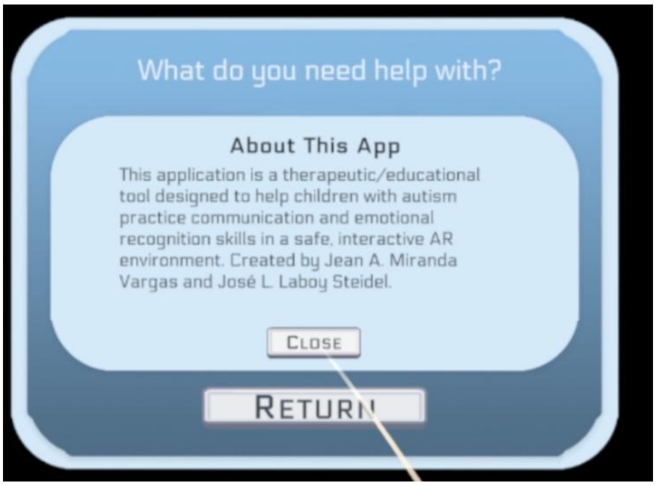

Figure 27: Example Pop-Up for Help.

F. Database Schema and Logic

The standalone application features a fully localized SQLite database utilizing a Unity Engine plugin called **SQLite4Unity3D**. This plugin allows us to safely implement our database in the application completely localized without the need for the application being connected to the internet. The following tables constitute the current schema:

Table Name	***Function/Data Stored***
ActivityConfigPreset	Holds difficulty settings and activity parameters to prevent hard-coding difficulty logic in multiple scripts.
ActivityResponse	Stores every individual response detail from the activity, including the item presented, the child's selection, and the time taken to answer each item.
ActivitySession	Stores high-level session metadata: session start/end time, total duration (in seconds), and the total amount of items presented during that session.
ChildAccount	Stores basic child profile information (full name, age).
ProgressMilestone	Designed to store achievement data and track milestones achieved by the child for motivational purposes.

Table 1: Database Tables.

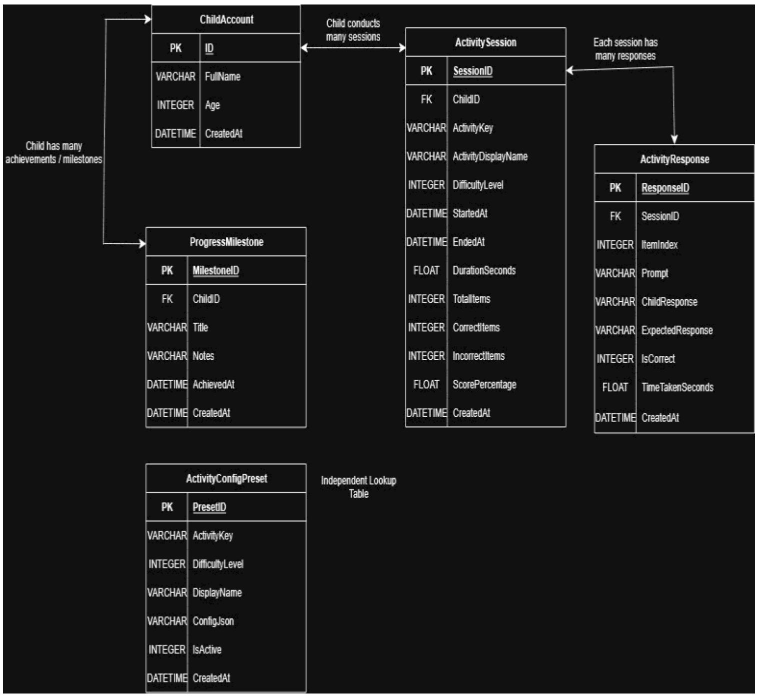

Figure 28: Database Diagram.

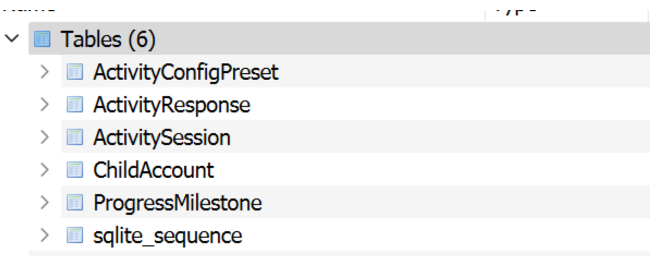

Figure 29: Database Tables in DB Browser (SQLite).

All database tables outlined in the schema are now fully implemented and operational. The system successfully records and inserts granular data for all three activities (Object Identification, Sentence Builder, and Emotion Explorer). This includes high-level session metadata as well as specific user responses, ensuring comprehensive tracking is performed reliably upon session start, pause, exit, and activity completion.

XI. Companion Web Application

To visualize the data exported from the headset, we developed a simple companion web application.

A. Technology Stack

- **XAMPP:** The web application was built using the XAMPP stack, it is a free and open-source cross-platform web server solution package consisting of Apache, MariaDB, and interpreters for scripts written in PHP and Perl.
- **Database Structure:** The web system utilizes two primary MySQL tables: a 'users' table for clinician authentication and a 'patients' table to map imported data to specific patients.

B. Functionality

The web application allows the clinician to upload the JSON file generated by the AR headset. The system parses this file and visualizes the information in a user-friendly dashboard. Clinicians can view charts detailing the child's progress. This tool is essential for making informed diagnoses and planning future therapy sessions based on empirical data.

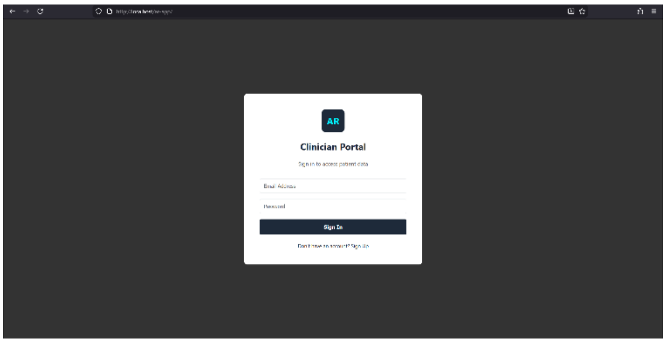

Figure 30: Web Application Login / Signup Page.

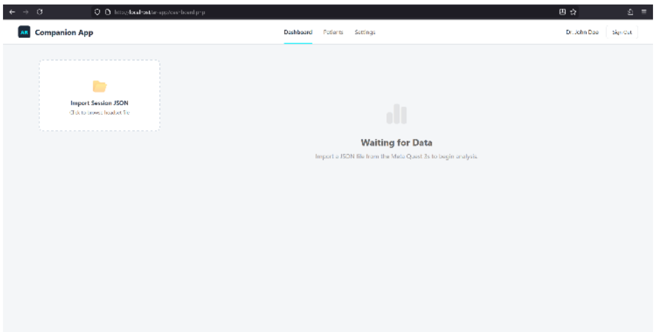

Figure 31: Web Dashboard.

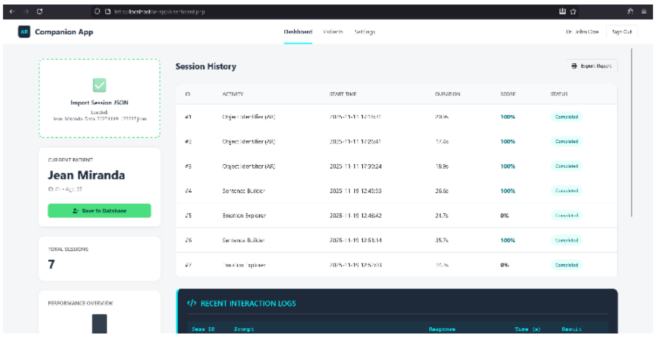

Figure 32: Web Dashboard after Importing JSON File.

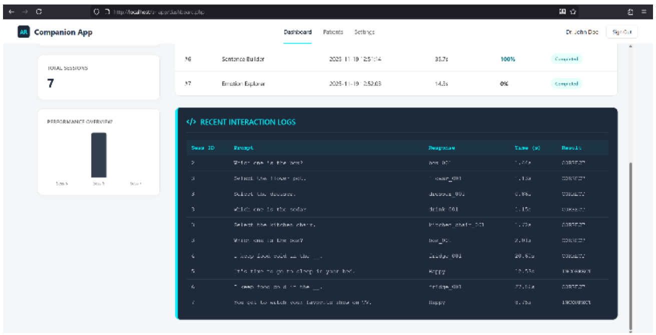

Figure 33: Continuation of JSON Visualization.

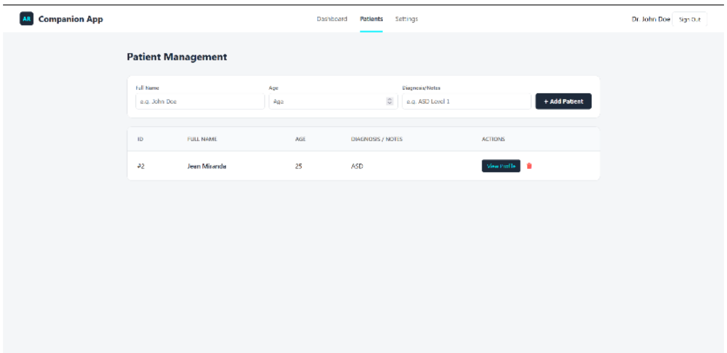

Figure 34: Patients Page.

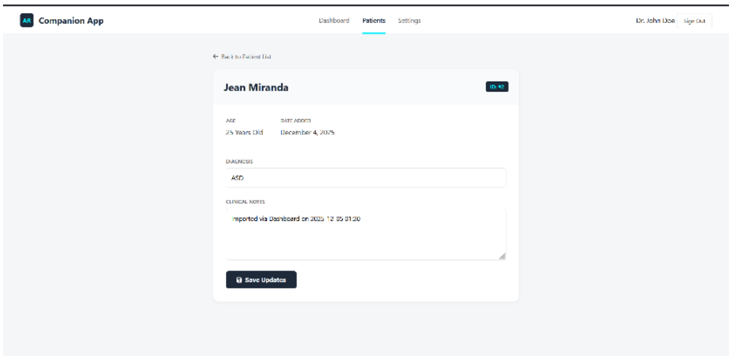

Figure 35: Patient Profile (Note: This is not an actual patient).

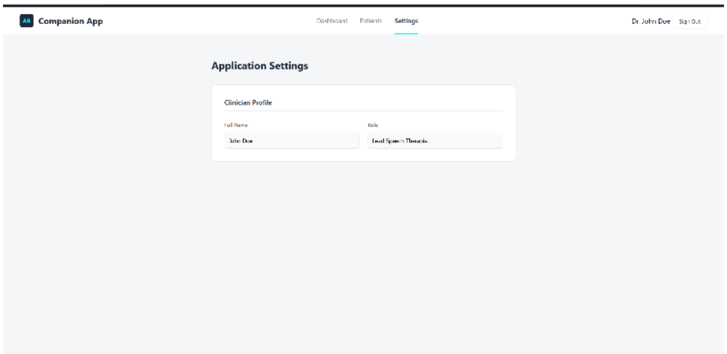

Figure 36: Settings Page.

XII. CONCLUSION

In conclusion, the Capstone II phase has concluded with the successful implementation of the project. We have achieved all our development goals. The project evolved from a single-activity prototype into a robust suite of three distinct activities, Object Identification, Sentence Builder, and Emotion Explorer, that collectively address vocabulary, grammar, and social-emotional skills.

The technical infrastructure proved sound; the SQLite database successfully manages complex relationships between user profiles, session logs, and specific activity responses. The "My Profile" and "Export Data" features successfully close the loop between the child's experience and the clinician's analysis. By integrating the standalone AR application with a custom-built companion web application via JSON data export, we have provided a seamless workflow for healthcare professionals to monitor patient progress.

This project demonstrates that Augmented Reality, when combined with accessible design and rigorous data tracking, is a viable and powerful tool for assisting children with Autism Spectrum Disorder. The software is stable, the user experience is optimized for the target demographics, and the analytical tools are ready for clinical deployment.

XIII. References

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