Ellie's Adventures: A gamified application to enhance Communication, Emotional, Cognitive and Motor skills in children with autism

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Project Proposal Report

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Declaration

I declare that this is my own work, and this proposal does not incorporate without acknowledgement any material previously submitted for a degree or diploma in any other university or Institute of higher learning and to the best of my knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgement is made in the text.

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Signature of the Supervisor Date

(Dr. Kalpani Manathunga)

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Abstract

Children with Autism Spectrum Disorder (ASD) often struggle with cognitive and verbal communication, affecting their ability to understand abstract concepts and language. Thus, in this study, an application is proposed to enhance these skills via two games. The first game, “Identify Suitable Objects by Understanding the Given Sentence,” employs GPT-2 for the generation of the sentence and uses SpaCy and WordNet for keywords’ extraction and adapts the complexity of the sentence according to the child’s performance. The second game, “Building Shapes Using Blocks,” deals with the cognitive domain by launching blocks where children are supposed to build shapes with high accuracy; accuracy is determined with EfficientNet.

It includes a 3D avatar for feedback, which has been made adjustable; it has a sensory-friendly look and feel and has end-to-end security features like Google confidential computing and multi-tenant encrypted storage. It has both a free version and a paid ‘Pro’ subscription, which would allow for further improvements. It also fills the gaps in the existing approaches while also being highly generalizable as a solution to improve on the communication development of children with ASD.

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List of Abbreviations

Abbreviation	Description
ASD	Autism Spectrum Disorder
CNN	Convolutional Neural Network
ABA	Applied Behavior Analysis
Gen AI	Generative Artificial Intelligence
LSTM	Long Short-Term Memory
ML	Machine Learning
RNN	Recurrent Neural Network
LLM	Large Language Model
UI	User Interface
UX	User Experience

Introduction

1.1 Background & Literature survey

Autism Spectrum Disorder (ASD) is a complex neurodevelopmental condition that significantly impacts social communication and is often characterized by repetitive behaviors and restricted interests [1]. While the exact cause of ASD remains unknown and there is currently no medical cure, various specialized educational and therapeutic behavioral interventions have been shown to be effective in enhancing skills and reducing challenging behaviors in children with autism [2]. There are several treatments and therapies available for autism, which include Applied Behavior Analysis (ABA), Speech Therapy, Occupational Therapy, Medication, Social Skills Training, and Cognitive Behavioral Therapy [15]. Addressing these difficulties is crucial for improving their overall well-being and fostering better social engagement.

The study found a high rate of uneven cognitive development in children with ASD. Discrepancies between verbal and nonverbal abilities were significantly higher in children with ASD compared to the normative [4]. Linguists specializing in receptive language describe it as the ability to respond nonverbally to spoken language stimuli; essentially, it refers to the capacity to recognize objects and follow directions. Typically, the initial signs of word comprehension in children appear around nine months of age. Research [10, 11] indicates that comprehension precedes production, as children are unable to produce words they do not understand. In the context of autism, a delay in receptive language is a significant aspect of communication impairment. Cognitive profiles in children with ASD suggest that they often have greater difficulties with language comprehension compared to language production, more so than children with other developmental delays [12, 13].

Additionally, children with autism often have difficulties in understanding written language. They may struggle to visualize the correct image in their minds when reading a sentence, which causes them to take more time to grasp a concept from written text [5].

Previous research has highlighted the effectiveness of technology-assisted methods in enhancing receptive language skills in autistic children. Studies referenced in [21, 22, 23] found that nine

autistic children acquired more vocabulary through computer-based interventions than traditional behavioral programs, primarily because these children were more attentive and motivated during the technological interventions. However, these studies were conducted in school or clinic settings using conventional computers that required a mouse for interaction. This method may not be suitable for many preschool children with ASD, who often experience motor skills deficits that make it difficult to use a computer mouse. The advent of touch-screen devices, such as smartphones and tablets, addresses this challenge. These devices are particularly appealing to autistic children, making them an ideal tool for supporting parent-mediated interventions at home.

Using technology in interventions for autism is not new. A number of recent studies [16,17,18,19,20] have reviewed previous works on technology-based interventions for autism. However, there are only a few research-based mobile applications [24,25] that focus on helping autistic children develop receptive language. Developing learning applications for children with autism is a challenging task, requiring an understanding of the characteristics of these children that impact the way they learn. In this section, we discuss some of these characteristics related to receptive language.

Overselectivity

Overselectivity is a common challenge when teaching autistic children. It refers to a narrow focus of attention exhibited by autistic children, where they "respond to only part of a relevant cue, or even to a minor, often irrelevant feature of the environment, without learning about the other relevant portions of that environment" [9]. For example, when teaching autistic children vocabulary using images, the child might focus on a specific detail in the image while ignoring other features. As a result, they may struggle to identify the required vocabulary as the number of vocabulary items grows, due to the overlap of features across different images [8].

Generalization

Generalization in language acquisition is the ability to learn a concept and its related vocabulary from an example or set of examples, and then use that knowledge in different settings and situations. Autistic individuals often have difficulties generalizing acquired vocabulary to other contexts [6]. For example, according to [7], after teaching an autistic child the word "car" using

an image of a specific car, the child might be able to recognize and point to that image successfully when hearing the word "car." However, the child might not be able to recognize the same car in a different image, identify different types of cars, or generalize the concept beyond the image to a real car. To address this challenge, multiple exemplars of the same concept should be presented to help the autistic child understand the relevant features of a stimulus. For instance, using different images of "car" can improve the child's understanding of the word.

Reinforcement

In traditional therapy, reinforcement is a fundamental part of behavioral intervention in autism therapy. It simply means rewarding the child when they successfully complete a task in order to strengthen that behavior. In digital interventions, rewards are crucial for autistic children to help them overcome sensory demands and distractions, and to motivate them to complete learning tasks. Digital rewards can include static smiley or silly faces, thumbs up, texts, music, a parent's recorded voice, animated words, fireworks, etc. It has been found that these children may have different preferences, so the system should be personalized to fit each child's needs [8].

To conclude the background and literature review, it is evident that while traditional therapies have shown significant benefits in addressing the cognitive and verbal communication challenges faced by children with ASD, the integration of technology offers new avenues for enhancing these skills. The advancements in mobile and tablet devices, alongside the development of personalized and adaptive learning applications, present promising solutions for improving the learning experience of autistic children. However, the design and implementation of these tools require a deep understanding of the unique learning characteristics of children with autism. By combining the insights from traditional therapeutic approaches with innovative technological solutions, there is a strong potential to create more effective and accessible interventions that can better support the development of cognitive and verbal communication skills in children with ASD.

1.2 Research Gap

The existing research addresses various aspects of improving cognitive and verbal communication skills for autistic children. However, gaps remain in integrating advanced technologies and adapting interventions across diverse cultural contexts. While some studies provide guidelines for serious games or tablet-based applications, they do not fully explore long-term effectiveness, cross-cultural adaptability, or the cognitive benefits of incorporating specific game elements. Furthermore, no research consolidates these elements into a comprehensive system that utilizes both advanced evaluation methods and culturally relevant content. The following studies have individually addressed parts of this issue, but none offer a unified approach to enhancing cognitive and verbal skills through innovative and adaptable solutions.

Recently published research “A” presents a comprehensive set of guidelines for designing effective serious games aimed at the treatment and intervention of ASD [26]. The guidelines are grounded in an in-depth analysis of the unique needs and characteristics of individuals with Autism, emphasizing the use of specific parameters and content, such as puzzles and interactive elements, to cater to the specific needs of autistic children. While this study offers valuable insights, particularly for the Indian context, it does not address the long-term effectiveness and scalability of these games across diverse cultural settings. Moreover, the study overlooks the integration of advanced technologies, such as artificial intelligence or virtual reality, which could significantly enhance the therapeutic impact of these games. These gaps highlight the need for further research to explore the cross-cultural applicability and technological advancements that could improve the efficacy of serious games for autistic children.

The study on research “B” reports on the development of a tablet-based application designed to support parent-mediated interventions aimed at enhancing receptive language skills in autistic children from Arabic-speaking families [8]. By addressing autism-related learning challenges, the application leverages technology to provide a culturally relevant and accessible platform for language learning. Despite its focus on the specific needs of Arab autistic children, the study does not fully explore how Faheem performs across different Arabic dialects or its potential adaptability to other languages and cultural contexts. Additionally, while the application excels in delivering

language learning content, the study misses an opportunity to investigate the cognitive benefits of incorporating shape-building games or advanced evaluation methods for assessing children's performance, which could further enhance its educational value.

The research paper “C” on the European project "Intelligent Serious Games for Social and Cognitive Competence" explores the development of serious games designed to enhance the social and cognitive competence of children with learning difficulties [27]. The project utilizes interactive mobile games and 3D simulations to create an engaging and efficient educational environment, focusing on teaching essential life skills such as social interaction, basic cognitive abilities, and work skills. These games aim to make learning more attractive and playful, thereby supporting the social integration and personal development of these children and youth. However, while the project successfully meets the needs of children with mild learning difficulties, it does not extend its scope to those with more severe disabilities or consider the adaptability of the games to other types of learning challenges. Moreover, the paper does not provide a detailed exploration of advanced methods for evaluating tasks like shape-building or for creating game content that could further enrich the educational experience. These omissions highlight areas where further research could expand the applicability and effectiveness of serious games for a broader range of learning difficulties.

The following figure 1.1 presents a tabularized format summarizing the key aspects of the research and identified gaps related to improving cognitive and verbal communication skills for autistic children.

SYSTEM	Writing and sentence structure exercise	Identify the accuracy of written letters	Usage of generative AI to predict more words	Gamified approach to improve verbal communications	Track hours & pain points to monitor progress
RESEARCH A	✓	✗	✗	✓	✗
RESEARCH B	✗	✗	✗	✓	✓
RESEARCH C	✗	✓	✗	✓	✗
PROPOSED SYSTEM	✓	✓	✓	✓	✓

Figure 1: Research gap analysis

Given the gaps in current research on improving cognitive and verbal communication skills for autistic children, this study proposes the development of an integrated application designed to address these deficiencies. The proposed system will incorporate advanced technologies such as artificial intelligence and interactive elements to enhance both cognitive and verbal skills. Unlike existing solutions, our application will offer adaptability across different cultural contexts and languages, as well as incorporate sophisticated evaluation methods for better assessment of progress. By combining these features, the application aims to provide a comprehensive, scalable tool for supporting autistic children's communication development, bridging the gaps identified in current research and improving overall effectiveness.

1.3 Research Problem

Children with Autism Spectrum Disorder (ASD) experience significant differences in the development of their cognitive abilities, including thinking, language, behavior, and social skills [30]. A prominent challenge among these children is their poor comprehension of abstract concepts, which is a common cognitive problem [31]. Research indicates that children with ASD often struggle to grasp abstract ideas and concepts, impacting their overall understanding and communication skills [31].

The global prevalence of ASD has risen from 0.62% in 2012 to 1.0% in 2021, highlighting the growing need for effective interventions [28]. In Sri Lanka, the only study exploring autism prevalence found that red-flag signs of autism were present in 7.4% of children, with 1.07% of children aged 18 to 14 months diagnosed with autism [29]. This underscores the importance of addressing the unique challenges faced by children with ASD, especially in early learning stages.

Children with ASD often face difficulties in social interaction and communication, which affect every aspect of their lives. Identifying their learning styles and tailoring educational approaches to their needs is crucial during their early developmental stages. Reading comprehension poses a significant challenge for these children, as they may be able to recognize words but struggle to understand their meaning within a text [32, 33].

Research has shown that while children with ASD often demonstrate strong word recognition skills, they lack the corresponding ability to construct meaning from text [33]. For instance, they may read a sentence aloud but fail to understand its actual meaning due to poor comprehension. This difficulty stems from their inability to form mental images or establish relationships between words and their referents in real-world scenarios [31]. Consequently, children with ASD may experience significant barriers to learning and communication, as they struggle to interpret text accurately.

During a recent visit to the ‘Ceylonsteps’ child therapy center, it was observed that parents often bring their children for therapy after school. Each child is assigned several therapists who work on improving their skills based on their specific difficulties. However, not all parents have the

capability or resources to take their children to therapy centers regularly. This limitation highlights the need for accessible and effective interventions that can be implemented at home or in school settings to support children with ASD.

The challenges faced by children with ASD, particularly in cognitive and verbal communication, underscore the need for interventions that can enhance their ability to comprehend and relate to abstract concepts. Such interventions are crucial for improving their overall communication and learning outcomes, as well as their ability to identify and differentiate things and solve real-world problems effectively.

2. Objective

2.1 Main Objectives

The primary goal of this research is to develop a practical technological solution that enhances cognitive and verbal communication skills in children with ASD. This will be achieved through a gamified application that offers therapeutic exercises as interactive games, all designed to support "therapy at home" under parental supervision.

1. **Verbal Communication Game:** This game enhances verbal skills by having children identify objects based on a given sentence, improving their comprehension of language and its connection to real-world objects.
2. **Cognitive Development Game:** This game focuses on building cognitive skills by guiding children to create shapes using blocks, fostering pattern recognition, spatial awareness, and problem-solving.

2.2 Specific Objectives

The main objective is achieved through a set of targeted sub-objectives designed to enhance cognitive and verbal communication skills effectively.

2.2.1 Developing Interactive Games for Verbal Communication

Create games that help children identify objects from given sentences or form sentences from objects to boost verbal skills. The system will use **NLP** (**SpaCy, WordNet**) to extract keywords, categorize them, and generate relevant images for easier interaction. The game will adapt to increasing complexity as the child progresses, with a **CNN** model ensuring accurate object identification and sentence formation. This keeps the content engaging and age appropriate.

2.2.2 Designing series of games for Cognitive Development

Develop games using blocks of various shapes and colors to enhance cognitive skills and problem-solving. Starting with shape identification, the games advance to color matching, construction, and puzzle solving. Children will build structures by dragging and dropping shapes, with accuracy assessed by a **CNN** model like **EfficientNet**. The system provides feedback and adjusts difficulty based on the child's performance, promoting growth in shape recognition, spatial awareness, and problem-solving.

2.2.3 Identifying and Analyzing Difficulties (Child's Pain Point)

Implement a system to detect and evaluate where children face challenges during activities. By analyzing patterns of errors and difficulties collected through the interactive games, the system will provide insights into the child's specific pain points, aiding in understanding and addressing their individual needs.

2.2.4 Utilizing Generative AI for Adaptive Learning:

Integrate Generative AI to dynamically create and suggest new words and sentences based on the child's performance and areas of difficulty. This will help in customizing learning material and adjusting the difficulty level to support the child's ongoing improvement. This will leverage large language models (**LLMs**) to tailor content effectively.

2.2.5 Enhancing Engagement with a 3D Avatar

Create a 3D avatar using Unity to guide the child interactively, providing personalized feedback, encouragement, and clear instructions. The avatar will offer instant results and constructive feedback, making the learning process engaging and supportive while maintaining motivation and focus.

2.2.6 Incorporate Positive and Negative Reinforcement

Implement a reinforcement system with rewards and praise for correct responses to encourage engagement, and constructive feedback for mistakes to guide improvement. This balanced approach supports motivation and skill development by providing both encouragement and corrective guidance.

2.2.7 Training EfficientNet for Shape Accuracy

Train the EfficientNet model to evaluate and compare the shapes created by the child against predefined target shapes. EfficientNet, known for its efficiency and accuracy in image classification, will be employed to analyze the child’s shapes, identifying matches or discrepancies with the target shapes. The model will be fine-tuned to handle variations in shape complexity, orientation, and size, ensuring precise and reliable performance in assessing shape-building activities. This approach leverages EfficientNet's advanced convolutional architecture to deliver high accuracy in shape recognition and evaluation.

3. Methodology

The proposed solution for enhancing cognitive and verbal communication skills in children with autism features two interactive games guided by a customizable 3D avatar. **Game 1**, "Identify Suitable Objects by Understanding the Given Sentence," involves the avatar presenting simple sentences to the child, who must identify or select objects that match the sentence. As the child advances, the game adjusts sentence complexity using NLP techniques to generate relevant images, ensuring appropriate challenges based on the child's progress. **Game 2**, "Building Shapes Using Blocks," requires the child to construct shapes using various blocks, with their creations evaluated against target designs using **EfficientNet**. The 3D avatar provides instant feedback, encouragement, and adjusts the difficulty based on the child's performance. The system identifies areas where the child struggles and adapts the games to offer additional practice and support, creating an engaging and supportive environment for skill development.

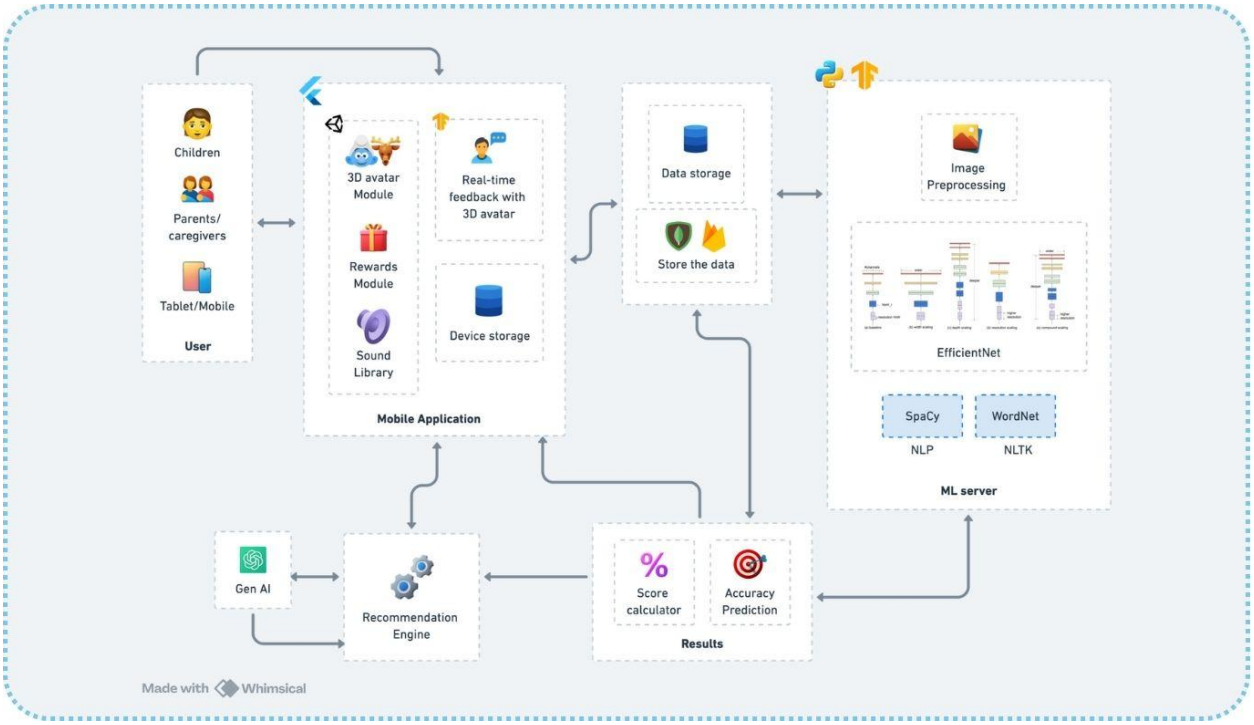

Figure 2 : System Architecture Diagram

The proposed system diagram outlines the methodology for enhancing cognitive and verbal communication skills in children with autism through a hybrid mobile application developed using Flutter and Flames. The application features two primary games: **Game 1** focuses on improving verbal communication by having the child identify suitable objects based on given sentences, while **Game 2** aims to enhance cognitive development through shape-building activities with blocks.

Initially, parents or caregivers will set up the child's basic information to determine their current level. The child will then engage with the games according to their needs. In **Game 1**, the child will choose the correct object by reading and understanding sentences generated by fine-tuning or using an existing language model like GPT-2 from Hugging Face. SpaCy will be used to extract keywords from these sentences, which will then be categorized using WordNet. Additional keywords will be generated for each category to provide mixed answers, with object images sourced from the COCO dataset.

If the child selects the correct object, the game will advance to a higher level, and the child's progress will be reflected in their score, which will be stored in MongoDB. As the child progresses, GPT-2 will generate increasingly challenging sentences. Incorrect selections will trigger additional tasks based on positive reinforcement strategies.

Feedback will be provided through a 3D avatar named **Ellie**, developed using Unity, which will offer encouragement and guidance. The system's backend will be managed using Node.js, ensuring smooth operation and data handling throughout the child's learning journey.

In Game 2, the focus is on building shapes using various objects. The child will be presented with a set of shapes, such as circles, rectangles, triangles, and squares, and tasked with constructing a shape based on given instructions. Developed using Flutter and Flames, the game is designed to align with the child's cognitive level, considering their problem-solving abilities and thought processes.

The game starts with basic levels tailored to the child's cognitive development. At these levels, the child will identify, drag, and drop basic objects to categorize them. A rule-based system will assign

scores for these early tasks (levels 1-3). As the game progresses to more complex levels, the child will be given a keyword and a reference image. The child must understand the keyword, select the appropriate shapes from the options, and use them to build the target shape.

Once the child completes a task, the built shape is captured as an image. EfficientNet, a CNN architecture, will then be used to assess and compare the accuracy of the built shape against the target image. EfficientNet performs feature extraction and segmentation on both images, allowing for a precise comparison of shape alignment and accuracy. Based on the accuracy score, feedback will be provided, and the child's level will be adjusted accordingly. This approach ensures that tasks remain challenging and engaging while adapting to the child's evolving skills.

Summary of technologies, techniques, architectures and algorithms used for the classification of Building shapes using object is shown in the table (Table 3.1) below.

Table 1 : Technologies, techniques, and algorithms used.

Technologies	Flutter, Python, TensorFlow, VS Code, MongoDB, Node Js, Firebase, Figma, Unity, Flames
Techniques	Feature Extraction and Segmentation, Data Augmentation, Data Pre-processing
Algorithms	CNN, EfficientNet, Spacy, NLTK's WordNet, Gen AI

3.1 Software solution

Customization and Personalized UI/UX

Customization and ambiguous UI and UX to different users are crucial factors that make an application addressing the needs of children with autism. It helps the children to be comfortable when they are inter viewing with the software thus they can take their own preferred color on the interface. Interaction design allows for better interaction with the user and keeps the child interested in learning; it is favorable to make the process as enjoyable as possible so that a child

could get the most out of it. This approach also provide parents and therapist with tools to add on the security of the platform based on the cognitive and verbal communication of the child.

Sensory-Friendly Design

Sensory-friendly design is a concept that seeks to eliminate anything that may cause increased sensitivity among; this is particularly so for children with autism. This involves regarding certain factors such as colors, noise, and condition that elicit and overload the senses. They seek to minimize on interferences so that children are in a position to concentrate on the specific activities that are set for them. Thus, the elements of sensory integration are useful and could make the application interesting for children without avoiding their overstimulation.

Google Confidential Computing

Google Confidential Computing is a security technology that means the data will be encrypted the moment it will be inside the cloud to be processed by the cloud. Such is important especially dealing with sensitive information especially in the applications that deals with the children information. Despite the substantive information it processes, which includes data on the details of cognitive or verbal communication development, the application can ensure that client data is sealed to third parties, earning the user's trust and compliance with data protection laws.

Multi-Tenant Encrypted Storage

Multi-tenant encrypted storage entails a system of storage in which several users or tenants store data securely in the same storage system but none of the tenants can access the other tenant's data and in the process has the data encrypted. This is especially crucial in a system developed to cater for childhood autism, since it provides a safe and effective way of handling data unique to individual children, possibly belonging to different families, or attending different therapy centers. With an encrypted storage technology in place, the system will be able to protect information, and data integrity and confidentiality for all the users of the system will be upheld.

Layered Client-Server Architecture

Layers client-server architecture is a structural model where application process is divided into several layers, for instance, presentation layer, application layer and data layer. Due to such a split, the software is easier to scale, maintain, and make more flexible. In case of applying to children with autism, this architecture provides a proper interaction between the client – the interface of the application and the server, where data processing takes place. It also allows multiple users and big amounts of data, this will make the system to run smooth and fast for the users.

Deploy as a Distributed System

Hosting the application as a distributed system will also being the result of which will implies the use of many servers or machines rather than one server host. It improves the characteristics of the system such as stability and capacity as well as efficiency. For a platform intended for working on the child's language development abilities and speech of the child with autism, structures the application as a distributed system guarantees that it can process major volumes of the data as well as users, which means that the application will remain smooth as the number of users increases. This also results in improved fault tolerance in a way that there is little or no space for downtime and thus, no interruptions.

Unit Testing for Flutter Using flutter_test

Usability testing is an imperative stage of the development cycle, that guarantees the proper performance of the specific elements of the developed application. By employing **'flutter_test'**, application developers are in a position to test their Flutter applications to ensure that every line of the code will function as required. This is even more crucial especially in an education context, where reliability of the Application is a key aspect in the child's learning and development specifically in his communicative language development. thereby ensuring that the application is developed in a stable and reliable state, this is so because unit tests enable one to identify and fix bugs at source and therefore eliminating the chances of them reoccurring.

Linting Code Using Tools Such as Dart Linting for Flutter and PyLint for Python

Linting is a process of checking code for issues, syntax errors, semantic errors or violations of coding standard. Linters are helpful tools like Dart Lint for Flutter and PyLint for python which

helps the developers to maintain the good quality of the code and also helps with identifying the issues. For instance in a project designed to teach children with autism more on cognitive and verbal communication skills, the use of linting tools helps make the codes as clean and efficient as possible, therefore reducing errors. This benefits in making the software more reliable and sustainable since the attributes that have been adjusted are those that are fundamental to the usage of the software.

3.1.2 Commercialization

In developing and commercializing the application, two subscription plans are offered to cater to different user needs: There are two kinds of levels namely the FREE and PREMIUM. The free version of the application enables users to work with the basic set of options practically, including real-time feedback that can be given with certain limitations, thus letting families start the cooperation with the application free of charge. This plan is suitable to those who are using the site for the first time and those who have not yet deposited any money in their accounts.

On the other hand, there is the ability to hire a real account for LKR 4000 with full access to all the options of the application. This is especially important for providing differentiated feedback and for involving generative AI features to personalize the learning process with reference to the individual learning profile of each child. The second is for families and the therapy centres that would like a more advanced and exhaustive tool in helping the kids with ASD. Also, paying for the premium plan to be a member of this application will support the further enhancement and permanency of this application in the field of autism therapy.

This tiered pricing model not only opens up the possibility for users to choose what they want depending on their taste and preference for price point but it also helps with the sustainability of the application, and the possibility of continually developing the application with new features with reference to the feedback from the users and technological advancement.

4. Project Requirements and Design

4.1 Functional requirements

i The system should be capable of assessing and identifying the child's cognitive and verbal communication skills.

ii The system should automatically adjust difficulty levels based on the child's performance to ensure an appropriate challenge.

iii Based on identified difficulties, the system should suggest and generate new words or concepts tailored to the child's needs, supporting their cognitive and verbal development.

iv The games and exercises within the system should be concise and time-limited to avoid excessive screen time and encourage healthy engagement.

v The system should provide scores, feedback, and instructions through an interactive 3D avatar to enhance user experience and guidance.

4.2 Non-functional requirements

i. **User-Friendly**: The system should feature user-friendly and sensitive interfaces tailored to the needs of children with autism, ensuring ease of use and accessibility.

ii. **Reliability** - The system should not fail or get stuck at any time throughout the process. The users should feel secure and confident while using the application.

iii. **Data Protection**: All sensitive information must be securely protected, ensuring privacy and confidentiality for users. The system should adhere to best practices for data security and compliance with relevant regulations.

iv. **Reliability**: The system should consistently deliver accurate and correct output, building trust with users by ensuring dependable performance.

v. **Performance**: The system should operate efficiently and smoothly, providing fast results without failures or delays to maintain a positive user experience.

vi. **Availability**: The application should be accessible to all users in need and available for use at any time they prefer, providing flexibility and convenience.

4.3 System requirements

The purpose of software requirements is to define the necessary resources and tools that must be implemented for the proposed system to function effectively. The software specifications for this proposed component are as follows:

i. **VSCode (Visual Studio Code) IDE**: To implement and manage the code using Python, facilitating efficient development and debugging.
ii. **Flutter + Flame**s: To create a mobile game application that is interactive and engaging for users.
iii. **Keras**: To develop and analyze deep learning models that will be used for various cognitive and verbal communication tasks.
iv. **TensorFlow Libraries**: To analyze and process images, compare actual and target images, and calculate accuracy and scores for performance evaluation.
v. **Firebase**: For backend services, including data storage, user authentication, and real-time database management.

4.4 Personnel requirements

i. The mobile application will be developed specifically for children with autism who experience difficulties in cognitive and verbal communication. The application will feature interactive games designed to be used under parental supervision and with the consent of caregivers. The games aim to enhance comprehension and communication skills in a supportive and engaging manner. Data and resources required for the development and research of the application will be provided by the primary external supervisor, ensuring that all needs are met according to the project requirements

4.5 Use Case Diagram

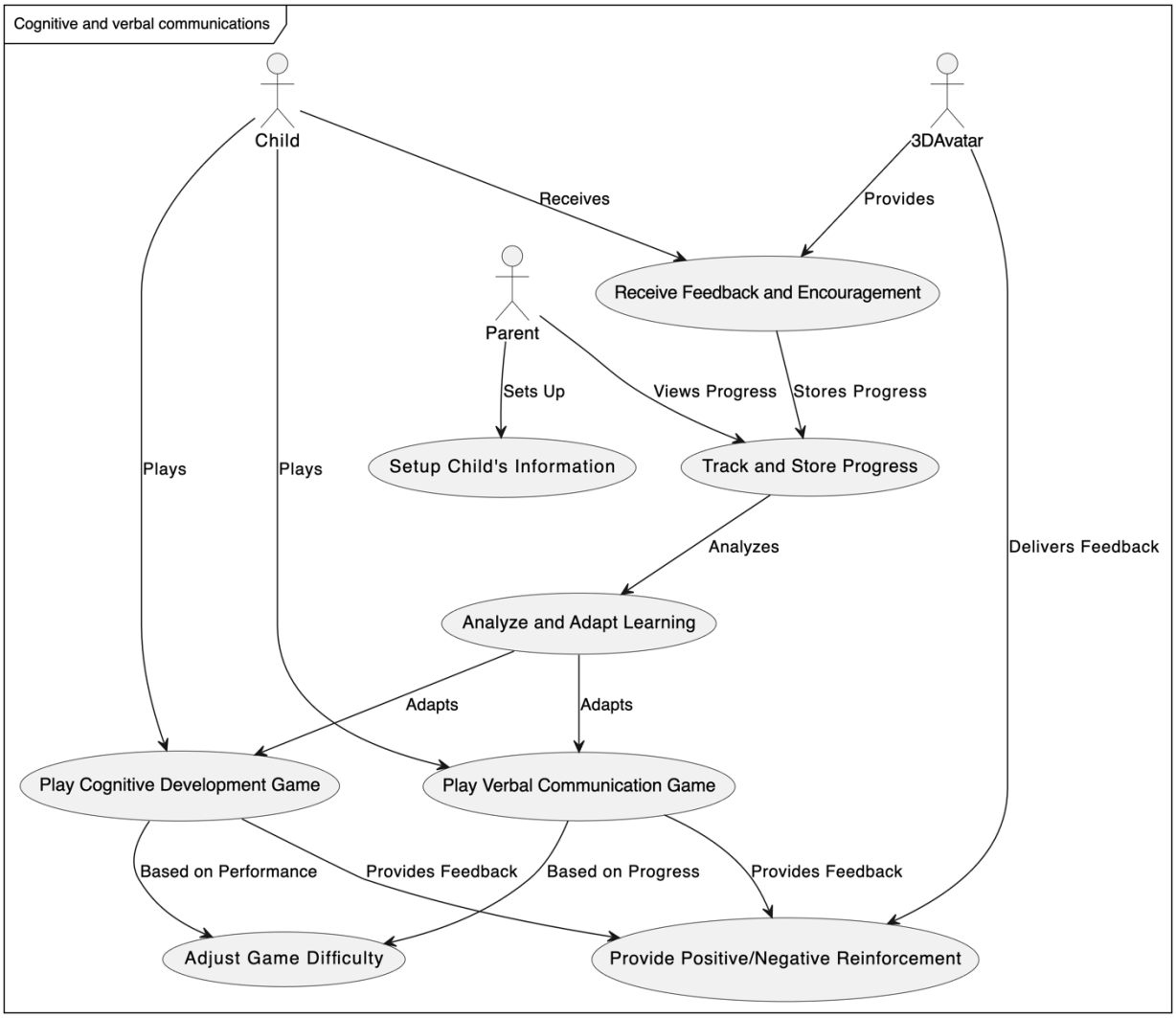

Figure 3 : High-level use case diagram

4.6 Tentative UI wireframes

The following UIs have been developed as initial drafts to be shown as a prototype when performing ethnographic field study at a renowned therapy center in Sri Lanka.

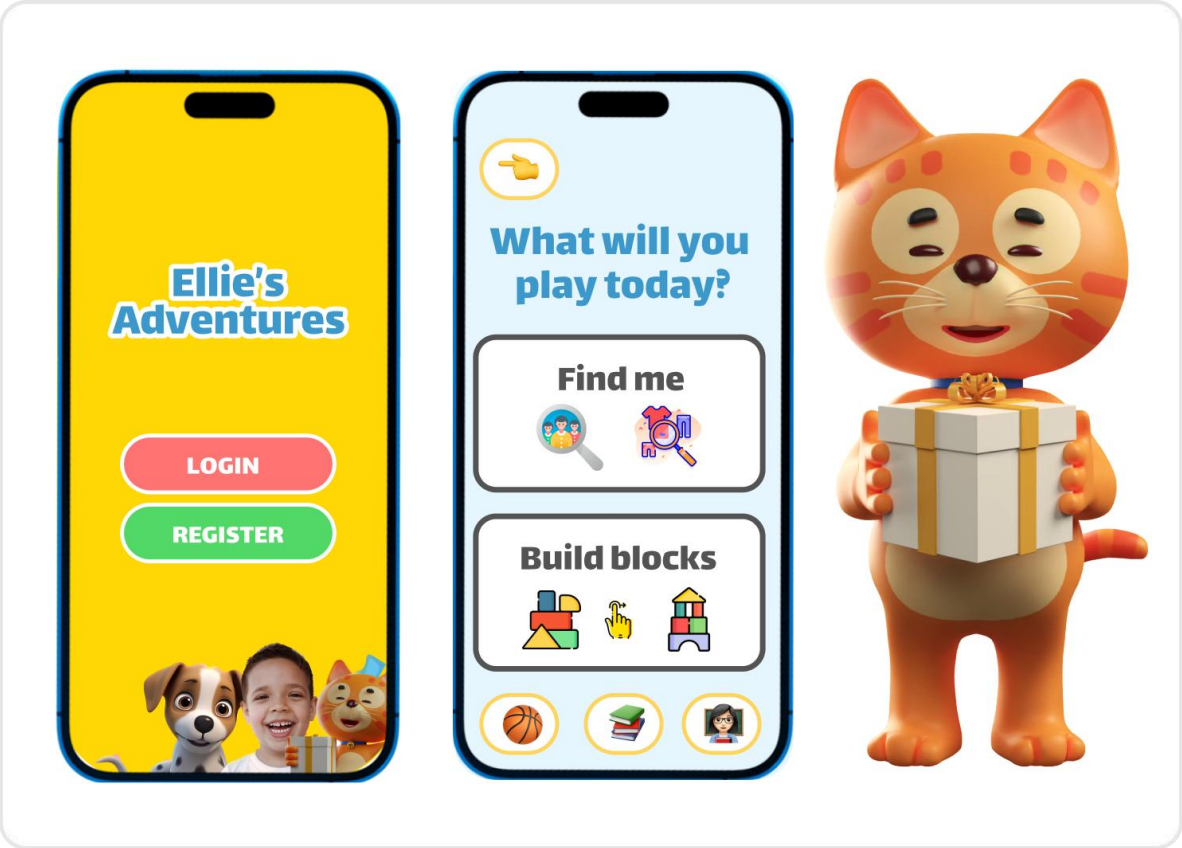

Figure 4 : Tentative UI wireframes

5. Gantt chart

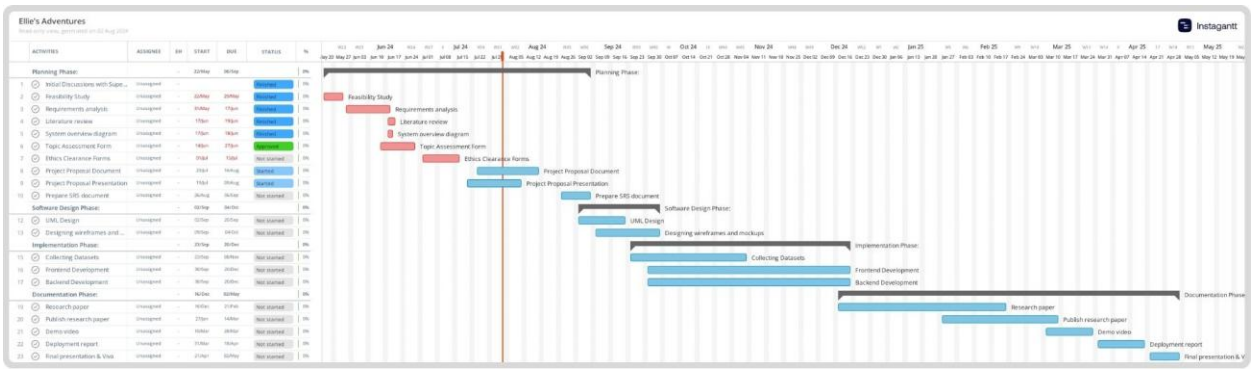

Figure 5 : Gantt chart

5.1 Work Breakdown Structure (WBS)

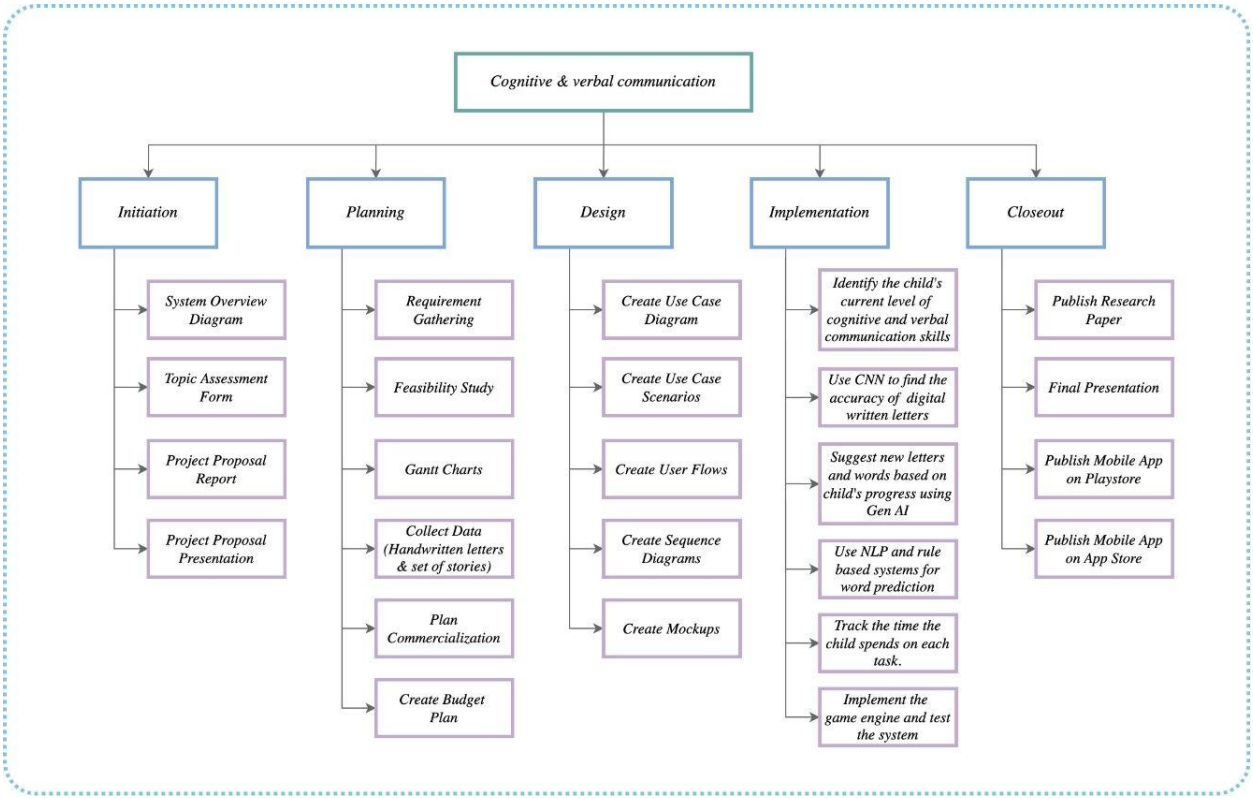

Figure 6 : Work Breakdown Chart

6. Budget and Budget Justification

The below table 6.1 depicts the overall budget of the entire proposed system

Table 2 : Expenses for the proposed system

Expenses	
Requirement	**Cost (Rs.)**
Travelling cost for data collection	30,000.00

Cost of Deployment to cloud	25,000.00
Cost of storage and database	7,000.00
ML model training and deployment	35,000.00
Cost of hosting in Play Store	8,000.00
Cost of hosting in App Store	33,000.00/Year

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