Neuro-Bloom - Learning Disability Screening & Therapy Platform

Prof. Zarina Begum Mundargi
Vishwakrama Institute of Technology, Pune, India
zarinabegam.mundargi@vit.edu

Avishkar Ghodke
Vishwakrama Institute of Technology, Pune, India
avishkar.ghodke23@vit.edu

Jineshwari Bagul
Vishwakrama Institute of Technology, Pune, India
jineshwari.bagul23@vit.edu

Anuj Gosavi
Vishwakrama Institute of Technology, Pune, India
anuj.gosavi23@vit.edu

Devang Deshpande
Vishwakrama Institute of Technology, Pune, India
atul.deshpande23@vit.edu

Hardik Rokde
Vishwakrama Institute of Technology, Pune, India
hardik.rokde23@vit.edu

Abstract—In this project, we introduce an interactive game-based approach to the initial diagnosis of learning disabilities in children. The system is particularly designed for four types of learning disabilities, namely, Dyslexia, Attention Deficit Hyperactivity Disorder (ADHD), Dyscalculia, and Dysgraphia, and is targeted towards children between the age group of 6 to 17 years. A detailed set of four separate games has been designed in order to identify the behavioral characteristics of these disorders through interactive and fun-based play.

Designed for direct use by students within the educational setting, the system serves as a pre-screening tool, hence reducing the amount of intervention by parents or teachers. Every game has been specially designed to evaluate corresponding cognitive and behavioral markers, yielding important information about the learning problems of students. This approach is intended to optimize the accessibility, engagement, and data-driven aspects of the first screening phase for education professionals.

Preliminary evaluations of the four games have demonstrated promising levels of accuracy in identifying patterns related to specific learning disabilities. The Dyslexia machine learning model exhibited an accuracy rate of 94%, whereas the ADHDNet achieved an accuracy of 91.7%, along with a baseline model accuracy of 84.3%. The accuracy for Dysgraphia varied between 60% and 80% across different epochs.

Keywords—learning disability, ADHD, Dyslexia, Dysgraphia, Dyscalculia, behavioral patterns, engaging gameplay, specially designed games, promising accuracy, early detection.

I. Introduction

Many children worldwide are affected by learning disabilities, impacting their academic progress and overall development. Early identification and intervention are crucial for effective management of these conditions. However, these disabilities often go undetected due to a lack of awareness, knowledge, and resources.

This research aims to develop a game-based screening platform to identify children aged 6 to 17 exhibiting behavioral patterns linked to common learning disabilities. The innovation involves four interactive games that require no supervision from parents or teachers. These games monitor responses for primary detection of learning disabilities.

The project's goal is to bridge the gap between early signs of learning disabilities and timely professional diagnosis by providing a user-friendly tool for initial screening. By analyzing behavior during gameplay, the system supports educators and caregivers in recognizing potential concerns and pursuing further assessment if needed.

II. Literature Survey

[1] This document discusses the role of Information and Communication Technology (ICT) as a tool for the screening of students with specific learning disabilities. [2] The paper addresses the enhancement of technology for teaching in lectures, tailored for school going students potentially having learning disabilities, providing a comprehensive analysis. [3] This study represents a critical review of the existing scientific literature regarding the application of ICT, Virtual Reality, multimedia, music, and their effectiveness for children facing special learning challenges. [4] The paper encapsulates the author's insights into the difficulties encountered by children with reading and learning disabilities as they embark on their reading journey, alongside research focused on early identification and intervention strategies. [5] This paper explores issues related to the diagnosis and assessment of kids with learning disabilities in India's context. [6] It examines the identification of microdeletion syndromes in patients with intellectual disabilities through the use of molecular genetic testing. [7] The investigation measures adherence within a controlled and randomized trial of a complex intervention aimed at supporting self-regulation for adults having learning disabilities and type 2 diabetes. [8] This study focuses on the co-creation of innovative tools in collaboration with individuals who have intellectual disabilities. [9] The exploration of the invisible aspects of learning disabilities remains a critical area, particularly concerning identification and assessment in the context of India, as mentioned in related scholarly works.

III. Methodology

- The proposed methodology consists of a game-based diagnostic approach. The methodology is centered around the development and deployment of 4 distinct games, each tailored to specific learning disability, namely dyslexia, dysgraphia, dyscalculia, and ADHD. We have designed behavioral and cognitive pattern assessments for respective disorders. Each game targets specific key areas such as attention span, reading, number sense, and handwriting ability for each child's interaction. The games are designed to be easily accessible without parent or teacher supervision. Furthermore, this system is scaled as follows-

- In schools, all the children take the diagnostic test provided by us, targeting specific key features, aiming to detect early signs of learning disabilities.
- Students, based on the results of the test, are shortlisted.
- One-on-one interaction of shortlisted students happens with a clinically verified psychiatrist. Parents are informed the same.
- Therapy sessions, as per the verdict of the psychiatrist, are taken on our platform.

1. *Attention Deficit Hyperactivity Disorder (ADHD)*

Our platform offers three space-themed games designed for different age groups. These games identify behavioral patterns often linked to Attention Deficit Hyperactivity Disorder (ADHD), including inattention, impulsive behavior, and hyperactivity. These traits are key to clinical diagnosis and are measured through gameplay metrics. Each game gathers user interaction data, which is used in a machine learning model for predicting ADHD early. Moreover, these metrics give valuable information to clinicians who are monitoring the child's behavior.

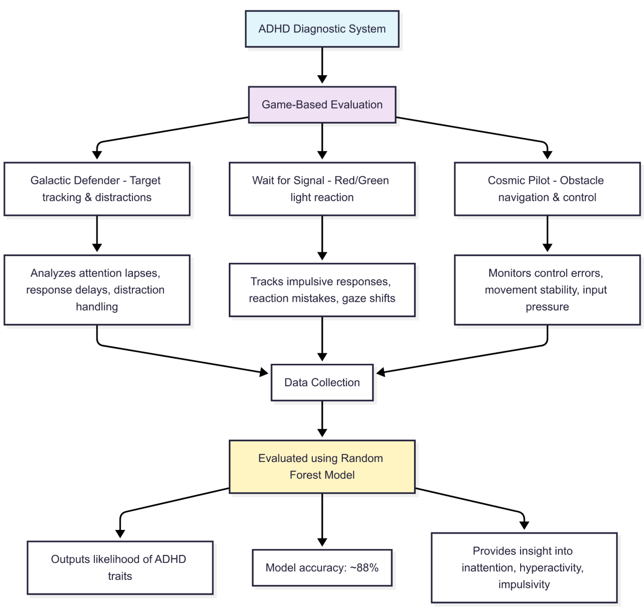

Fig 1: Working flow for ADHD detection

Game 1: Galactic Defender (Wack-a-Alien)

This game evaluates attention regulation and response consistency. Children are instructed to protect a space station by clicking on moving alien targets. At the same time, they must ignore unrelated visual distractions like stars and space debris.

Metrics captured include:

- Error Rate (sc_er): Missed or incorrect clicks on non-targets indicate potential inattention.
- Task Completion Time (sc_tct): Prolonged task duration may signal difficulties in sustained attention..
- Response Time Variability (sc_rtv): Inconsistent reaction times show impulsivity.
- Distracting Events (sc_de): Unnecessary or erratic clicks reflect hyperactive behavior.

These metrics reflect behaviors commonly seen in clinical attention tasks, such as the Continuous Performance Test. Children with ADHD often find it hard to maintain consistent response patterns and may show impulsive or hyperactive tendencies.

Game 2: Wait for Signal

The second game simulates a Go/No-Go task. Children must respond only when a green "GO" signal appears. They need to ignore red or blue lights, as well as times when there is no signal. This activity measures impulse control and visual attention.

Key metrics include:

- False Positives (wfs_fpr): Pressing the spacebar on incorrect signals shows impulsivity.
- Premature Responses (wfs_prc): Reacting before any signal appears also shows poor control over impulses.
- Gaze Shifts (wfs_gs): Simulated eye-tracking tracks attention shifts; frequent gaze changes indicate distractibility.
- Reaction Time (wfs_rt): The speed of correct responses reflects attention and processing speed.
- Playtime Duration: Very long interaction time may relate to poor focus or distraction.

This task is similar to tests used in clinical settings to evaluate executive functioning and attention control, which are important issues for people with ADHD.

Game 3: Cosmic Pilot

Cosmic Pilot challenges players to control a spaceship in a changing environment full of obstacles and directional cues. The child navigates using the arrow keys and must avoid collisions while keeping the target aligned. A unique aspect of this game is an energy bar that needs to be filled before the player can shoot at the chosen targets. This design requires the child to show patience and timing, which helps improve impulse control and planning skills. The game lasts about three minutes and is meant to assess motor regulation and precision.

Metrics collected include:

- Control Failures (ft_cf): Errors in navigation or a lack of appropriate responses show a lapse in attention.
- Mean Movement Variability (ft_mmv): Inconsistent movement patterns indicate difficulties with sustained attention.
- Excessive Input Intensity (ft_eii): Overuse or strong inputs might signal hyperactivity.
- Target Precision (ft_tp): Low accuracy in target alignment points to impulsivity and poor planning.

This game offers insights into how cognitive and motor functions work together and how behavior is controlled. These insights relate to visual tracking and motor coordination tests often used in ADHD evaluations.

*2. **Dysgraphia***

Dysgraphia is a **learning disability** that affects fine motor skills and a child's ability to produce legible and coherent written language. **Symptoms may include inconsistent handwriting, irregular spacing, spelling difficulties, and challenges in organizing ideas on paper**. Often, these issues are overlooked during the early stages of a child's education, which can lead to long-term academic challenges and decreased self-esteem.

To address this issue, a **gamified dysgraphia** screening tool has been developed. This tool features an interactive front-end interface combined with a powerful backend powered by **deep learning and generative AI**. The module is designed to provide a non-invasive, child-centered initial screening that can be easily implemented in school environments without requiring clinical settings or specialized oversight.

2.2.1 Game Design and Workflow

The game is front-end based around a **historical** narrative theme, being suitable for children in the age group 7 to 14 years old

. Upon launching the game:

- The child is prompted to **enter their name and age**.
- A brief, age-appropriate paragraph based on a historical event is displayed on screen.
- The user is then asked to **copy the paragraph in their handwriting** under a fixed time constraint.
- After completion, the child **uploads an image of their handwriting** via the platform.

2.2.2 Model Architecture and Technical Workflow

The uploaded image is processed through a **deep learning pipeline** built using **TensorFlow** and **Keras** libraries. The steps include:

- **Preprocessing**: All images are normalized to a pixel range of [0,1] and resized to 224×224 pixels.
- **CNN**: A Convolutional Neural Network (CNN) was created with the following layers:
    1. Three convolutional layers (ReLU activation).
    2. Two layers for max-pooling.
    3. Dropout layers to prevent overfitting.
    4. Fully connected dense layers leading to a sigmoid output for binary classification.

The model training was done on a custom-labeled dataset split into 80% training and 20% testing. **Binary cross-entropy** loss function and **Adam optimizers were brought into use**. Over **30 epochs**, the model achieved:

- **Training accuracy**: 81.2%
- **Validation accuracy**: 78.4%
- **Precision**: 0.77
- **Recall**: 0.81
- **F1 Score**: 0.79

To improve prediction confidence and generalization across diverse handwriting styles, an **ensemble strategy** was used that includes:

- **ResNet50** and **MobileNetV2**: Both pre-trained on ImageNet and fine-tuned on our dataset for feature extraction
- The predictions from CNN, ResNet50, and MobileNetV2 were combined using **soft voting**, yielding an overall accuracy of **82.7%**

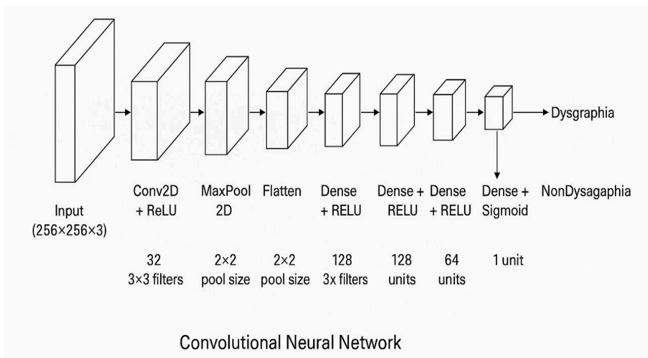

Fig 2: CNN used for Dysgraphia diagnosis based on handwriting images

2.2.3 Clinical Alignment and Feature Interpretation

The following handwriting features were identified as significant indicators of dysgraphia:

Feature Extracted	Clinical Indicator	Model Role
Irregular stroke pressure	Fine motor instability	CNN image analysis
Uneven character spacing	Visual-motor coordination issue	MobileNet + ResNet features
Inconsistent letter formation	Poor memory-to-motor execution mapping	GAN similarity analysis

Table 1: Clinical Alignment and Feature Interpretation

The following image demonstrates the use of machine learning to identify, predict, and conclude the possibility of dysgraphia in the child, which is essential for the early detection and further diagnosis.

*3. **Dyslexia***

Dyslexia is the learning disorder responsible for hampering a person's ability to read, write, spell, and decode words despite having the intelligence to do so. A person having this disorder has difficulty in processing phonemes, which makes recognizing and manipulating sounds in words difficult.

Based on the study of recent research papers on Dyslexia, significant features were selected to be calculated for dyslexia prediction. Keeping that in mind, we developed 5 games:

1. **Bubble Bay**: This helps in enhancing orthographic awareness because it enables children to practice letter recognition and thereby distinguish between very similar-looking letters, such as n/h and b/d, which are mirror image orientations of each other.

   Utility: Dyslexic individuals often struggle with processing and recognizing letter forms, especially those that are mirrored or rotationally similar.

   This game targets a core visual perceptual difficulty associated with dyslexia.

2. **Word Reef**: This game helps provide lexical decision-making by requiring children to identify correctly spelled words from a collection of visually similar distractors. This helps in assessing visual word form recognition and error detection.

   Utility: Dyslexia often impairs the ability to recognize appropriate word forms and differentiate between the ones that are visually confusing and phonetically similar words.

   This system, in conclusion, can infer difficulty with word-level decoding.

3. **Memory Cove**: This gamified experience targets working memory capacity, which is a cognitive domain often impaired by dyslexic individuals

   Utility: Working memory is closely related to reading fluency and comprehension. Dyslexic children often have limited verbal and visual working memory, which affects their ability to decode and retain language patterns.

   This system indirectly measures cognitive load handling and sequential recall.

4. **Spell Shore**: Focuses on making phoneme-grapheme mapping and spelling skills better, thus training phonological awareness and orthographic precision.

   Utility: Spelling errors in dyslexic children are often systematic, which can be inferred from the phonological processing deficits underlying them.

   This game simultaneously provides a method to reinforce correct association.

5. **Sentence Sea**: Helps in enhancing syntactic awareness by enabling children to arrange jumbled words into correct grammatical sentences, thus improving understanding of how a sentence is structured.

   Utility: Dyslexia may also impair comprehension and syntactic processing, especially in more complex reading tasks.

   This game, in conclusion, evaluates a child's ability to mentally organize language**.**

Overall, this system consists of early identification of the disability in a very friendly and interactive manner, making it a non-invasive testing framework. The model is supported by data-driven insights to identify patterns aligned with clinical symptoms.

4. Dyscalculia

Dyscalculia is a learning disability that specifically impairs a child's ability to understand and manipulate numbers, recognize patterns, and apply basic math concepts. It often manifests as difficulties in number sense, sequencing, symbolic representation, spatial reasoning, and time management — despite average or above-average intelligence.

To address this, our screening platform offers a suite of gamified, age-tailored assessments under a unified **"Math Adventure"** theme. These include:

- **Dot Counting Game** (ages 6–7): Tests subitizing skills — the ability to perceive quantities without counting.
- **Number Comparison Game** (ages 8–9): Assesses understanding of magnitude and quantity

relationships.

- **Pattern Completion Game** (ages 8–9): Detects logical reasoning and sequencing ability.

- **Symbol Confusion Game** (ages 10–12): Evaluates the child's ability to distinguish mathematical symbols.

- **Place Value Puzzle** (ages 9–11): Tests comprehension of numerical structure and place value understanding.

- **Basic Word Problem Game** (ages 8–10): Applies mathematical reasoning to real-life situations.

- **Conversational Math Game** (ages 8–12): Simulates dialogue-based problem-solving to evaluate real-time math cognition.

- **Clock Reading Game** (ages 9–12): Assesses time interpretation skills using analog clocks

These games are embedded in a **candy land-themed environment** to reduce test anxiety and improve engagement. Each interaction is monitored and analyzed by a **Large Language Model (LLM)**, which evaluates not only correct answers but the **child's reasoning process**, error patterns, and consistency. This holistic approach enables early, low-pressure detection of dyscalculia-related symptoms, making the experience both effective and enjoyable.

IV. Experimental Results and Impact

The proposed system was tested with specifically designed games representing various learning scenarios. The results display the system's effectiveness in detecting the behavioral indicators of learning disabilities. The proposed system highlights the value of using interactive, colorful gameplay thoughtfully designed for children of the specified target group.

The results achieved have been displayed as follows-

1 **Dyslexia:**

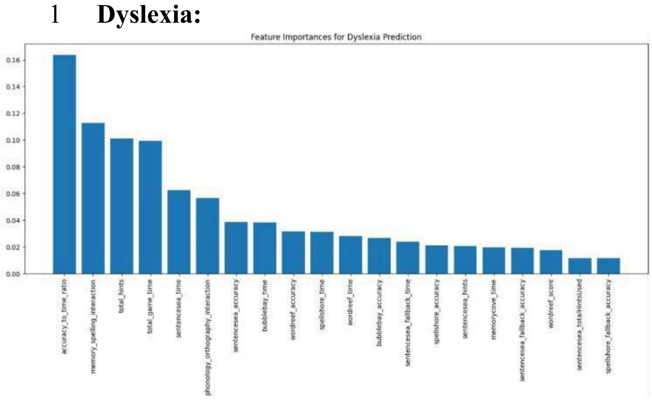

Fig 3: Feature importance for dyslexia prediction

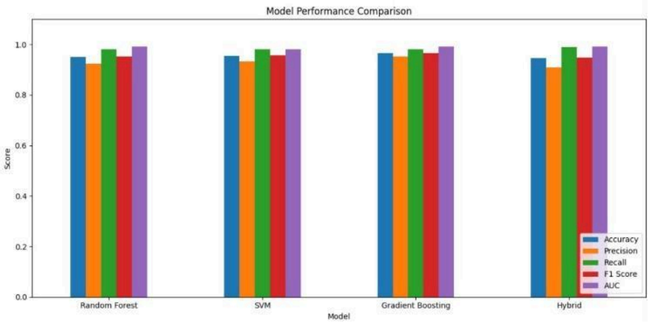

Fig 4: Model Performance Comparison

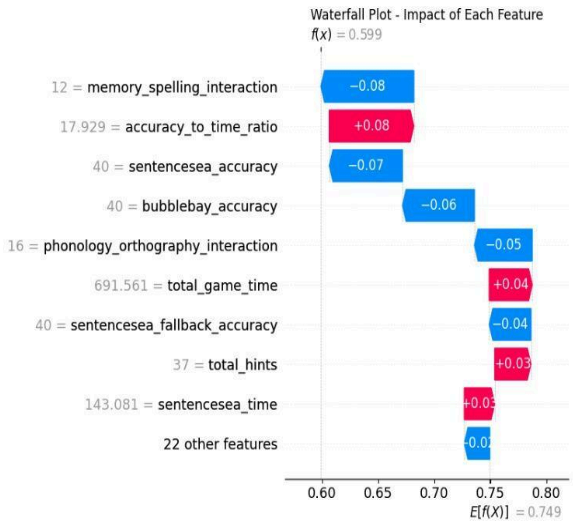

Fig 5: Impact analysis of each feature

Classification Report:

	precision	recall	f1-score	support
0	0.99	0.90	0.94	100
1	0.91	0.99	0.95	100
accuracy			0.94	200
macro avg	0.95	0.95	0.94	200
weighted avg	0.95	0.94	0.94	200

Fig 6: Classification Report

These graphs demonstrate the various parameters used in the machine learning models, the features, and the performance, respectively.

2 **Attention Deficit Hyperactivity Disorder(ADHD):**

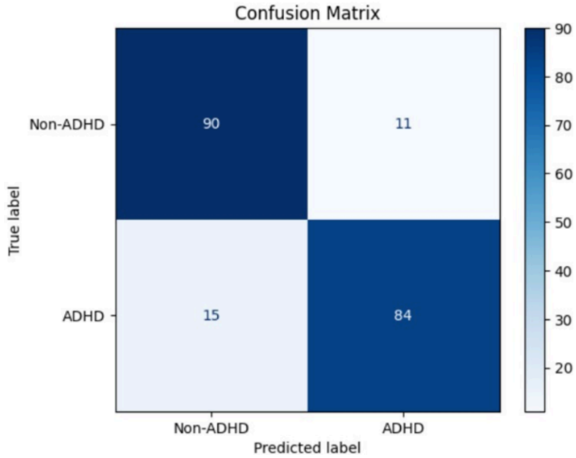

Fig 7: Confusion Matrix

Metric	ADHDNet	Baseline Model
Accuracy	91.7	84.3
Precision	90.5	82.2
Recall	93.0	85.1
F1-Score	91.7	83.6
AUC	0.942	0.876

Fig 8: Evaluation Metrics Comparison

3 **Dysgraphia**

```
model.summary()

Model: "sequential"
┌──────────────────────────────┬──────────────────────┬────────────┐
│ Layer (type)                 │ Output Shape         │    Param # │
├──────────────────────────────┼──────────────────────┼────────────┤
│ conv2d (Conv2D)              │ (None, 254, 254, 32) │        896 │
│ max_pooling2d (MaxPooling2D) │ (None, 127, 127, 32) │          0 │
│ conv2d_1 (Conv2D)            │ (None, 125, 125, 64) │     18,496 │
│ max_pooling2d_1 (MaxPooling2D) │ (None, 62, 62, 64) │          0 │
│ conv2d_2 (Conv2D)            │ (None, 60, 60, 128)  │     73,856 │
│ max_pooling2d_2 (MaxPooling2D) │ (None, 30, 30, 128) │         0 │
│ flatten (Flatten)            │ (None, 115200)       │          0 │
│ dense (Dense)                │ (None, 128)          │ 14,745,728 │
│ dense_1 (Dense)              │ (None, 64)           │      8,256 │
│ dense_2 (Dense)              │ (None, 1)            │         65 │
└──────────────────────────────┴──────────────────────┴────────────┘
Total params: 14,847,297 (56.64 MB)
Trainable params: 14,847,297 (56.64 MB)
Non-trainable params: 0 (0.00 B)
```

Fig 9: parameters and their values

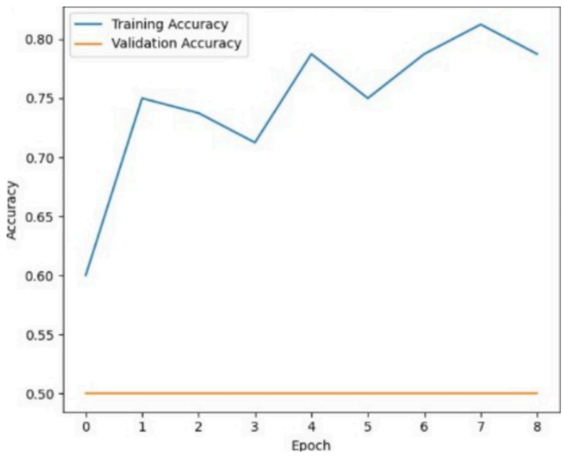

Fig 10: Training accuracy and validation accuracy using epoch

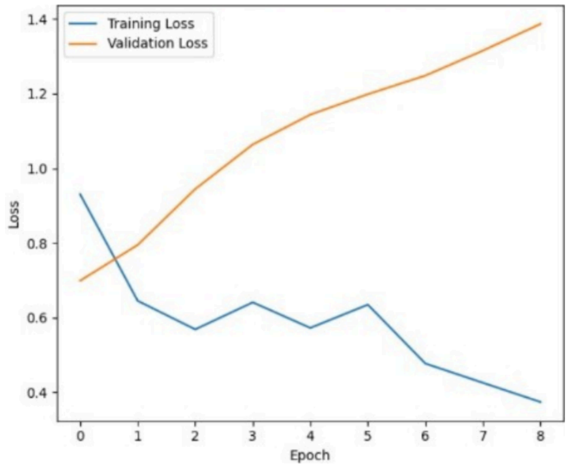

Fig 11: Training loss and validation loss using epoch

V. CONCLUSION AND FUTURE SCOPE

A. Conclusion

The project aims to identify learning disabilities in children early through interactive game-based screening tools. Separate games designed for dyslexia, ADHD, dyscalculia, and dysgraphia allow observation of associated behavioral patterns and serve as primary assessment tools requiring minimal supervision. These engaging games can be used in various schools and provide valuable insights into learning capabilities.

This approach detects early warning signs without a clinical setting, facilitating timely professional intervention. While the current implementation shows usability, further research will help to improve diagnostic accuracy and adapt the games over diverse educational and cultural contexts.

B. Future Scope

Building on the current capabilities, several enhancements can be thought of, to further improve this system's functionality and applicability:

- **Integration with school systems**: The games can be used across various educational boards by taking their inputs, thereby integrating the games with the school curriculum.
- **Age group support**: By extending the games to age groups under 6 and adolescent learners, who may face challenges with these particular learning disabilities.
- **Technology-specific algorithm**: The Implementation of Machine learning algorithms can be implemented to identify patterns that may be missed by these games.

- **More personalized gameplay**: Allowing users to get a more comprehensive and dynamic user score, which is personalized.
- **Incorporating neuro-adaptive feedback**: Enhancing accuracy of diagnostics by monitoring stress indicators, attention shifts, and visual scanning behaviour during gameplay.
- **Extension of system-based architecture**: We can extend the architecture to study neuroscience, child psychology, and linguistics, which provides a detailed analysis of the relationship between gameplay behaviour and neural learning pathways.

By implementing these improvements, the system can evolve into a more versatile and robust solution, capable of meeting the growing demands for a high-quality learning disability identification system, which may potentially help in the early detection of the disabilities, leading to a better life.