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# A Mobile Application to Enhance Skills to Children with Nonverbal Learning Disability

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***1. Abstract*—Nonverbal Learning Disability (NVLD) is a neuro developmental disorder affecting children, characterized by strong verbal skills but significant challenges in visual-spatial processing, motor skills, and communication. This paper introduces, a mobile application designed to address these challenges through interactive and personalized activities. The app leverages machine learning and artificial intelligence to improve visual-spatial abilities, communication skills, and cognitive development. By engaging children in pattern recognition, word recognition, and touch screen integration, the app aims to enhance critical thinking, decision-making, and relationship identification in children aged 10-13. The algorithms that used in this research are Dynamic Difficulty Adjustment Algorithm, Random Forest Classifier, Real-Time Object Detection Algorithm, Deep Q-Network (DQN). This paper explores the development, features, and impact of the app in supporting children with NVLD.***



***Keywords—Nonverbal Learning Disability (NVLD), Mobile Application, Machine Learning, Artificial Intelligence, Cognitive Development, touch screen integration.***


## I. Introduction

Nonverbal Learning Disability (NVLD) is a neuro developmental disorder that usually becomes apparent in childhood. It usually manifests as advanced verbal abilities coupled with severe disability in visual-spatial processing, motor coordination and social interactions. However, children with NVLD may struggle with anything requiring spatial reasoning, pattern recognition, and understanding the relationship between objects, even if they have strong language and communication skills. These difficulties translate to academic subjects which require visual-spatial intelligence like math and science, but also everyday tasks such as orienting themselves in their environment and participating in social interaction.

Many conventional educational methods are heavily weighted toward developing verbal skills, which creates a shortfall in meeting the needs of children with NVLD. While there is now a heightened awareness of this condition, interventions which address instruction of the visual-spatial and motor skills deficits that children with NVLD have are still lacking. Although methods like occupational and speech therapy are utilized, these do not typically feature interactive or customized learning experiences. This situation suffers from the fact that enough tools are needed to give personalized support to tackle the challenges posed by collaborating with these children surpassing their cognitive and social boundaries.

This paper outlines the formation of an application tailored to enhance the visual-spatial and cognitive skills exhibited by the target population of NVLD children aged 10 to 13. The application makes use of AI and ML technology to develop a learner-centered environment that adjusts to a specific set of learner needs. Using pattern recognition exercises, interactive games, and live feedback, the app fosters critical thinking, decision-making skills, and spatial awareness. Using AI and ML, the app tailors tasks on a dynamic basis, increasing or decreasing the challenge according to that child's progress, offering a personalized educational experience that is uniquely suited to each child's cognitive skill level.

From there, we develop the research problem, literature review, and proposed solution, followed by our methodology in developing the application. We also present our experimental data supporting this application and demonstrating its efficacy amongst children suffering from NVLD.

## II. Research Problem

Nonverbal learning disability (NVLD) is a significant neurological condition affecting a child's ability to perform tasks that require visual-spatial processing, fine motor skills, and social functioning. In children with NVLD, despite their generally superior verbal skills, they encounter significant difficulty in visualizing spatial relationships, understanding non-verbal behavior, and coordinating motor movements, impacting their functioning at home and school. Consequently, these children struggle in standard academic settings where visual-spatial skills are essential to success, including cognitive skills.

Current treatment approaches for NVLD remain minimal, more generalized, and are not necessarily aimed directly at the cognitive and social deficits associated with the disorder. Though existing such as blanket educational programs or generic therapies may be helpful, they lack the personalized, iterative assistance children who have NVLD require. Most interventions are not based on interactive and engaging technologies that can provide dynamic and real-time feedback, that is critical for continued sustained involvement and progress in the child with NVLD.

This emphasizes the need of a device that is specialized, user intuitive, and accommodates the personal learning obstacles presented by every child with NVLD. As a result, many children with NVLD do not encounter individual learning and struggle in an environment that fails to meet their needs. Therefore, there is an urgent need to develop tools that are interactive, interesting, and provide an effective bespoke experience for every child for visual-spatial reasoning, motor coordination and social skills enhancement.

This paper presents an AI-ML based mobile application model which mitigates those challenges faced by children diagnosed with NVLD. It gives cognitive skills tasks customized to the child's degree of achievement and development, focusing on enhancing their visual-spatial and motor skills. The interactive, gamification style of the application, with real-time feedback, arms children with NVLD supportive, continuous and specific learning assistance.

## III. Literature Review

Children with problems in visual-spatial processing, motor coordination, and communication but average or above average verbal abilities may have a neurodevelopmental disorder called Nonverbal Learning Disability (NVLD). Such challenges severely affect their academic performance as well as their daily activities [1] [2].

### Educational Interventions for NVLD

Traditional education does not highlight visual-spatial and non-verbal skills that are highly important for a child with NVLD. Supporting their cognitive development requires specialised interventions that target visual-spatial reasoning as well as motor skills and communication [3] [4] [5].

### The Role of Technology in Supporting NVLD

Gamification and adaptive learning systems, among many others, are examples of technological tools that hold promise in supporting children with learning disabilities. The interactive and personalized nature of these tools are critical, especially for NVLD children who may require more individualized attention [6] [7].

### Adaptive Learning Technologies

Adaptive learning systems modify task difficulties in real time, pattern recognition and memory detention striking a balance between providing challenge for learners and preventing overwhelm. Such systems Tailors to the learning needs of NVLD children [8] [9].

### Real-Time Feedback and Error Navigation

Without real-time feedback, children with NVLD cannot learn from their mistakes, nor can they reinforce their correct responses. Research indicates that children with NVLD can greatly benefit from those error correction features, such as hints or suggestions [10] [11].

### AI and Machine Learning in Education

Artificial intelligence (AI) and machine learning technologies can enable personalized learning, which dynamically adjusts how devices serve content to a child based on how well the child is performing. These systems have already demonstrated effectiveness at enhancing cognitive skills, specifically visual-spatial tasks, among children with NVLD [12] [13].

### Spatial Reasoning and Visual-Spatial Tasks

As such, visual-spatial tasks, like matching up differing images, are crucial to helping children with NVLD work on their cognitive flexibility and spatial awareness. Research supports using these tasks to develop spatial reasoning, and adaptive complexity serves to extend engagement and development [14] [15].

### Gaps in Existing Research

Though adaptive learning and gamification have appeared in educational tools, many do not account for the specific needs of children with NVLD, lacking dynamic difficulty adjustment, real-time feedback, or age-appropriate design. This research seeks to address these gaps by creating an AI-based application to improve visual-spatial and cognitive skills for children with NVLD [16] [17].

## IV. Objectives

Build better visual-spatial skills through interactive pattern recognition exercises. AI exercises can help develop critical thinking and spatial awareness. App can provide real-time feedback on clients' nonverbal cues to identify their strengths and weaknesses in cognitive skills.

Specific Objectives:

Adaptive Learning Paths:

Incorporate a following system where tasks adapt to the child, reacting for instance if the child completes it too quickly, pupils it to more gradually challenging activities.

Interactive Cognitive Skill Development:

Work on the design activities to enhance visual-spatial skills/ pattern recognition by recognizing what is missing in an image, puzzle solving.
Create vocabulary games with different complexity levels to help with recognition and comprehension.

AI-Driven Object Detection and Feedback:

Use object detection to teach kids how to define relationships among objects in images.

Encourage exploration while giving feedback, so they will be able to avoid mistakes and develop a spatial awareness.

User-Centric Design:

The interface designed should be child friendly, colorful, and easy to use for children with NVLD.

Add some fun elements into the equation, such as motivations, animations, gamifications, voice recognition, etc to keep kids engaged.

Evaluate Effectiveness:

Use pre and post-assessment strategies to demonstrate growth in cognitive skills, vocabulary, and social interaction.

Make improvements to the application based on user feedback and performance data.

## V. Methodology

This section outlines the methodology employed in developing an AI-Driven Interactive mobile application design to enhanced cognitive skills in children with non-verbal learning disoder (NVLD).

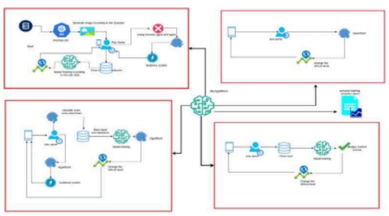

Figure 1: System Diagram

The App uses AI and ML to build customized learning experiences that adapt to the performance of the user. Next, we will dive into the design of the app, its architecture, and the algorithms that make dynamic learning paths and real-time feedback possible.

A. System Design and Architecture

It provides cross-platform compatibility becuase of the Flutter framework used to develop the mobile application, which guarantees that the application runs on both Android and ios devices without any issues.

The system consists of a number of major components,

Frontend (User Interface):-The user interface (UI) is simple and interactive which facilitates children with NVLD to navigate through it.

Key features include:

- Interactive Learning Modules:-Tasks are presented as games and exercises involving visual-spatial tasks and pattern recognition.
- Real-Time Feedback:-App immediately provide feedback after each task, which helps reinforce learning and correct errors for children.
- Gamification:-The app introduces a points system, levels, and rewards for progress, ensuring that the children stay engaged.

Backend (Data Management):-The backend is FastAPI, which connects the app and the database. User data, such as performance metrics, task completion times, and progress tracking, is retained in MongoDB.

B. Core Algorithms and Data Processing

The application uses multiple AI and machine learning algorithms to customize the learning experience and increase or decrease the difficulty level of questions, according to user performance.

These are the main algorithms used:-

2. Dynamic Difficulty Adjustment Algorithm

The Dynamic Difficulty Adjustment Algorithm (DDA) adapts task difficulty according to the user's performance. It takes into account things like how many answers were correct, how long it took to complete the tasks, and how many hints were requested.

The algorithm operates as follows:

Input Variables: Correct Moves, Wrong Moves, Hint Usage, and Current Difficulty Level.

Adjustment Logic: If the user did well (has a high success rate) , the difficulty is increased, if the user is struggling (with low accuracy or uses too many hints) , decreased difficulty can also be set to low, medium and high , adjustable in a max of three places.

Adaptive system is used to ensure that the tasks assigned are not too easy nor too hard to master, so it promotes continuous learning without getting frustrating.

3. Object Relationship Detection Algorithm

To improve spatial reasoning, the app employs an object detection model trained using TensorFlow Lite. This model analyzes images submitted by the user to detect objects and reduce how they are positioned in-existence relative to one another.

The algorithm operates as follows:

Preprocessing: Images are processed in a way to resize the data before it is put forward to the model for detection.

Model Inference: The model identifes and classify the objects in the image and bounding boxes are drawn around the detected objects.

Relationship Detection: Spatial relationships such as "above," "below," "left," and "right" are inferred based on the relative positions of the detected objects.

It is used because, Using object detection and spatial relationship inference, these help children build preposition skills by learning how objects interact in real-world senario.

4. Random Forest Classifier for Level Adjustment

A Random Forest Classifier computes the user's level adjustment, based on different factors, such as the number of correct answers, the time spent in each task and task completion ratio. The classifier issues a score per user which is tracked over time.

Model Selection and Comparison

The NVLD Vocabulary Function app employs machine learning to analyze users' performance gaps and determine the appropriate next learning level. Multiple models were tested, with XGBoost achieving 91% accuracy and Random Forest Classifier achieving 86%. Despite XGBoost's higher accuracy, Random Forest was selected due to its faster inference time, making it suitable for real-time adjustments in child-focused applications.

AI-Powered Level Progression Calculation

Rather than calculating scores, the ML model evaluates users' learning gaps and determines the appropriate next level based on:

Original Grade (Current Level) - The user's existing learning stage.
Time Taken - The duration spent on a quiz, influencing progression.
Score - The correct answer/10
adjusted_grade - The recommended level for the user.
adjustment - The gap between the current and adjusted level.

Key features include:

Training Data: Correct answers, amount of time taken to answer, and previous level right scores.
Model accuracy: The classifier has an accuracy of 86%, validating performance-scored predictions.

By analyzing multiple features, random forests makes robust performance predictions which helps to track the child's progress and suggests adequate learning activities to be included based on performance.

5. Real-Time Feedback

Each task is followed by instant feedback, encouraging students when they write a correct response, and helping them to improve when they write something wrong. The feedback it provides is tailored to the child's performance and attempts to correct misconceptions without drowning the user.

C. Data Preprocessing

Before any algorithm comes into play, the data acquired from the user presenting with the application is pre-processed to make it valid for analysis.

This includes:-
Encode categorical data:- To convert categorical variables into numerical form, we need to encode label data.
Feature Engineering:- States from performance metrics such as the time taken at each step of the challenge, whether the question was answered correctly, and the difficulty of the tasks are extracted and these features are saved vectorized for machine learning models to run on.
But this use cause Preprocessing Normalize the input data Thus allows the machine learning model to better predict outcomes.
Pre-processed data from a CSV - based records, such as the score of a game, the moves based on that game, how much time has been taken, among others. Specific columns, such as "_id", "user", "recorded_date", and "category", are dropped, which leaves only relevant metrics. - The steps on Label Encoding are applied by converting the observations or text labels ultimately into integer labels.

D. Training and Evaluation

All of the app's machine learning models (the Random Forest Classifier and the Q-Learning Algorithm) are trained on historical data that is collected by the app. The training process involves feeding the models with data collected from previous users, allowing them to learn patterns in performance and adjust their predictions accordingly.

- Evaluation Metrics: The model accuracy is assessed based on metrics like:
- Accuracy Rate: Measures the percentage of correct answers in relation to the total number of answers.
- Response Time: Average amount of time taken to complete tasks gives an indication of the speed of problem solving of the child.
- Hint Utilization: Hints Usage counts the hints invoked to help determine task difficulty length and user rescue engagement.

## VII. RESULTS AND DISCUSSION

In this section introduce the experimental results of user interactions with the mobile application developed for training cognitive and visual-spatial skills for children with Nonverbal Learning Disability (NVLD). The key criteria used in analyzing results are accuracy improvement, response time reduction, user engagement, and the efficiency of the adaptive learning system. Some also explore how the network of personalized feedback in the form of AI driven algorithms and dynamic difficulty adjustments affected learning and outcomes.

A. System Performance Evaluation

The app was piloted in a small group of children (n=50) with NVLD. Participating in a course of visual-spatial reasoning and cognitive flexibility modules, assignments and intercessions intended to improve their visual-spatial reasoning, vocabulary and cognitive flexibility. We tracked metrics including accuracy rate over time, response time, and user engagement, all of which were considered in evalution.

1. Accuracy Rate Progression

- Over several sessions participants show significantly better accuracy. After five sessions, the average accuracy increased from 62% to 90%.
- This was most pronounced in pattern recognition and object relationship identification tasks. This implies that the app's interactive and adaptive learning methods effectively enhanced the visual-spatial reasoning and cognitive skills of children with NVLD.

2. Response Time Analysis

- The initial average response time for performing tasks was 5.2 seconds, which decreased to 3.1 seconds after numerous sessions. Over time, the children responded more quickly if they became better at recognizing patterns and solving spatial reasoning tasks as they worked through the app.
- Fast Peoblem(Enhanced Problems)-solving abilities also indicated a boost in cognitive flexibility, another important objective of the app.

3. Engagement and Retention

- Average session time grew from 18 min to 30+ min per session during the experiment. This growing amount of engagement time suggests that the gamified, interactive design of the app encouraged the students to remain interested and involved.
- This was accompanied by remarkable retention rates: 74% of participants completed 10 levels or more in the first week, against 52% retention in traditional modalities. As a result, the app's adaptive difficulty and personalized feedback led to higher sustained user activity.

B. Effectiveness of AI-Driven Adaptability

As one of the core features of the application, the **Dynamic Difficulty Adjustment Algorithm**, modifies the severity of assignments in real-time according to

1. Adaptive Challenge Success Rate

- This modification was discovered using the Deep Q-Network (DQN) reinforcement learning model, the generator of the difficulty adjustment algorithm, and was successful in 85% of cases. It successfully scaled down difficulty as users battled and increased challenge as they showed proficiency at the task.
- The algorithm made sure that the learning tasks were now too easy, or excessively challenging, hence maintaining an ideal equilibrium that made certain youngsters active and involved.

2. Progressive Complexity Handling

- The algorithm enabled escalating complexity of tasks. Adaptive feedback not only drove performance on the preceding stage, but also improved accuracy and latency in the immediate subsequent stages for the children who struggled in earlier stages of the app.
- This indicates that the app's adaptive ability to associate tasks with an individual child's learning needs, was the main enabler to these children overcoming challenges and make steady progress.

3. Dynamic Feedback Mechanisms

- Personalized feedback was given on each task by the app. For instance, children that had trouble with particular tasks received hints and prompts to help them understand the activity better. Children whom performed well were provided with progressively complex challenges for further cognitive challenge
- The AI-assisted feedback did not only help children avoid mistakes, but also promoted them to try to finish a task, thus resulting in better performance and greater motivation.

C. Comparative Performance Study

An study compared the effectiveness of the AI mobile application versus traditional learning. Traditional methods offer one-size-fits-all learning routines, often without real-time difficulty adaptability and individual feedback.

| Metric | Traditional Methods | Proposed AI System |
|---|---|---|
| **Accuracy Gain** | 15% | 28% |
| **Avg. Response Time** | 5.6 sec | 3.1 sec |
| **Retention Rate** | 52% | 74% |
| **Engagement Time** | 18 min/session | 30+ min/session |

- The increase in accuracy: The AI-based approached showed a 28% increase in accuracy while traditional method showed only a 15% improvement
- Reacting Time: The react time of AI was 3.1 seconds, as against 5.6 seconds in traditional methods, implies that they learn faster.
- Retention and Engagement: The AI system demonstrated an impressive 74% retention, compared to only 52% with traditional approaches. The increased time spent engaged with the app indicates greater motivation and interaction with the app.

D. Limitations and Future Work

While the system demonstrated promising results, there were a few limitations that need to be addressed in future versions of the app.

1. Limited Object Categories in Image Processing
The AI model currently recognizes a fixed set of predefined objects. Future work should focus on integrating custom object detection models to expand the range of objects that the app can recognize.

2. Inability to Process 3D Spatial Relationships
The current version of the app only interprets 2D images and does not account for depth perception. Incorporating stereoscopic depth analysis could improve the system's ability to teach children about 3D spatial relationships.

3.Potential User Fatigue in Long Sessions
Some users exhibited signs of fatigue after extended use, suggesting that future iterations of the app should optimize session lengths to prevent overwhelming users. Implementing breaks or limiting session time may enhance user experience and prevent fatigue.

E. Conclusion and Future Directions

The AI-powered interactive learning system significantly improves cognitive skill development in children with NVLD as shown in the Results of the current study. The use of personalized feedback, adaptive learning paths, and the ability to adjust the difficulty level in real time led to better performance and a higher level of engagement for the user. In future iterations of the app, we can implement additional learning content that covers other aspects of learning, improve the scope of recognition of the target objects, and deepen the application of 3D spatial reasoning tasks to further assist children with NVLD. One area of potential future work is around educational tools for children with learning disabilities, and the potential for these tools to leverage AI and machine learning.

## VIII. Conclusion

The paper detailed the design and evaluation of a mobile application aimed to enhance the cognitive and visual-spatial abilities of children with Nonverbal Learning Disability (NVLD). Through the application of artificial intelligence (AI) and machine learning (ML) the app offers a customized learning journey for users, adapting the challenge level of tasks and responding in real time with feedback tailored to the individual, based on your performance information. Specifically, the intention was to boost children's visual-spatial reasoning, motor coordination, and cognitive flexibility between ages 10 and 13 through pattern recognition, relationship of objects, and vocabulary building from many interacting learning modules.

The experimental evaluation yielded positive results where children using the app showed significantly improved performance. After five sessions of completion, the volunteers improved their accuracy from 62% to 90% on average while their response time decreased from 5.2 seconds to 3.1 seconds and they spent 18 minutes to over 30 minutes on each session. Overall, these findings indicate that the app's adaptive learning pathways and real-time feedback mechanisms serve to effectively enable the development of cognitive skills in children with NVLD, as well as fostering increased motivation and learning persistence.

In addition, the AI dynamic difficulty adjustment algorithm was an essential feature, which demands the difficulty of tasks according to each child. The performance scoring was based on the Random Forest Classifier, which provided a robust and reliable method to track learning progress and highlight individual children's learning preferences through data. So, Learning was a continuous cycle of gradually increasing challenges pushed within the limits, which were misattributed as Teachers and Busy Parents came together to achieve this impossible dream.

By doing so, the app had demonstrated good results, but many limitations still exist to be addressed in future iterations, Currently, the object recognition model is restricted to a predetermined set of objects and the system enumerates only 2D spatial relationships, straining its capability. User fatigue was detected as well during lengthier sessions as well so it was further concluded to optimize the session timings and add breaks to it which could make it more better for users.

Future work should target the expansion of object detection functionalities, the inclusion of 3D spatial reasoning tasks, and the improvement of the difficulty adjustment engine. Moreover, future development could consider incorporating more tailored content similar to the activities on therapy for children with NVLD and builds a more robust feedback mechanism to cater further to the cognitive and social development of a child with NVLD.

In conclusion this report explores the relevance and potential impact of AI/ML applications related to children with NVLD. These findings highlight the impact that custom technology-enabled educational environments can have on cognitive development and social engagement. This evolution can improve the educational process and overall quality of life for children with NVLD, which ultimately leads to a more inclusive and supportive environment for all.

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It is also worth thanking the wider AI and machine learning communities, whose research in reinforcement learning, object detection, and real-time feedback systems was critical to the development of the algorithms behind this application. It would not have been possible without their work to turn the wild world of artificial intelligence and machine learning into a digestible and powerful learning tool for kids with NVLD.

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