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Research Article

A Coding Schema-Based Mobile System for Children With ASD in Mauritania

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Abstract: Children with Autism Spectrum Disorders (ASD) in many African countries face persistent barriers, including limited diagnostic awareness, scarce specialized resources, and the absence of educational interventions adapted to local contexts. In Mauritania, these challenges are exacerbated by the extreme centralization of autism services, with only two care centers available nationwide. Unlike existing ASD interventions that rely on imported pedagogical models and generic digital tools, this study introduces a context-aware, data-driven educational approach grounded in real classroom practices. We propose a coding schema derived from video annotation of educational sessions conducted with autistic children in Mauritania. This schema serves as the foundation for designing six culturally and linguistically adapted pedagogical scenarios, explicitly targeting cognitive, social, and communicative skills. The scenarios are operationalized through an interactive mobile application, enabling scalable access to structured and personalized learning activities beyond specialized centers. Experimental deployment and qualitative observations indicate improved engagement, task completion, and interaction behaviors among participating children. The proposed framework demonstrates how locally grounded observational data can be transformed into effective digital interventions, offering a replicable model for ASD education in low-resource and underrepresented contexts.

Keywords: Autism in Africa, Educational Scenarios, Coding Schema, Mobile System, Gamification

Introduction

In Africa, autistic children are often grouped under the broader category of intellectual disability (Bakare & Munir, 2011). In many countries in the region, autism is still viewed through the lens of supernatural beliefs or witchcraft (Abubakar et al., 2016). This perception leads to social stigmatization and systematic exclusion, placing these children in vulnerable situations (Mpaka et al., 2016). Generally, few specialized facilities are dedicated to their care. Consequently, most of these children do not receive the necessary support and services, resulting in inadequate assistance (Mukau Ebwel, 2023).

A few figures illustrate the scale of the phenomenon across the region. A facility-based study in Mali observed a prevalence of 4.5% among 2,343 individuals referred for neurodevelopmental concerns (Sangare et al., 2020). In Senegal, a survey documented a prevalence rate of 1.8%, a figure close to the global average of one in 160 children (Der Dieye et al., 2022). Nevertheless, comprehensive epidemiological data remain exceedingly scarce across much of West and North Africa, underscoring the need for more systematic research and surveillance in the region.

This work is part of an initiative to improve the education and inclusion of children with ASD in developing countries such as Mauritania. The goal is to provide a digital solution that helps these children acquire necessary life skills while taking local cultural and linguistic nuances into account.

The subject of autism in Mauritania remains largely underexplored and inadequately addressed. Currently, only two specialized centers provide services for children with Autism Spectrum Disorder (ASD). The first, the Center for the Training and Promotion of Children with Disabilities, is a public institution that currently serves 107 children, including 26 girls, under the supervision of 15 specialized educators. The second facility, the Zayed Center for Autistic Children, benefits from foreign funding and offers more advanced resources and equipment. However, its services remain inaccessible to the majority of Mauritanian families due to prohibitively high costs.

At both centers, children are taught fundamental skills such as attention, autonomy, language, expression, and preschool skills. Assessments take place regularly, on a weekly or monthly basis. The program largely follows the principles of Picture Exchange Communication System (PECS) (Bondy & Frost, 2001), a proven method for reinforcing appropriate behaviors and reducing problem behaviors. The aim is to foster autonomy and social integration.

Despite the challenges posed by autism, children with ASD can make significant progress if they receive the right support. This includes early intervention, personalized education, targeted therapy, and a supportive environment that encourages autonomy and social skill development.

This article proposes a solution based on a coding schema derived through video annotation of real educational sessions. The solution aims to facilitate the monitoring, evaluation, and improvement of skill acquisition in autistic children.

Related Work

In this section, we examine six research studies that led to the development of mobile educational systems designed to enhance the language and cognitive abilities of children with autism. We provide a brief summary of each study and present a comparative analysis in two tables. Table 1 highlights general aspects, while Table 2 focuses on technical details.

Background Work

Lima et al. (2019) developed a three-module system. The first module consists of finger puppets fitted with RFID tags. The second module is a hand puppet with an integrated RFID tag reader and an ESP12-E NodeMCU microcontroller. The third module identifies the selected finger puppet, displaying the corresponding visual representation and playing the associated sounds. Autistic children are presented with a set of finger puppets on a table. When a child picks up a puppet and brings it close to the hand puppet, the embedded reader scans the RFID tag and sends the data to the third module via Wi-Fi. The third module identifies the puppet and displays its image on a projection screen, triggering the relevant sound effects and animations. For instance, if a child selects the frog puppet, the system will display an image of a frog, play the sound of a frog croaking, and animate a jumping motion.

de Mira Gobbo et al. (2021) developed a game to promote literacy among children with autism. The game uses pictograms that represent daily activities. There are six levels of increasing difficulty, ranging from identifying shapes to writing words that correspond to images, including object identification, letter recognition, syllable construction, and word-image associations.

The main objective of Deveau et al. (2022) was to accurately classify children as either autistic or neurotypical. To this end, the authors employed three machine learning models: linear regression, decision trees, and SVM. Their game is based on a playful activity in which a parent holds a smartphone against their forehead, displaying a prompt or image that the child must act out, similar to a charades game. Then, the parent tries to guess the emotion or action that the child is miming. After each 90-second game session, the parent and child can review the sequence together. To validate an answer, the parent tilts the phone forward for a correct guess and backward for an incorrect one before moving on to the next prompt.

Popescu et al. (2022) proposed a solution composed of three main components: a mobile application called PandaSays, CNN models, and a humanoid robot (Alpha 1 Pro). The autistic child creates a drawing, which is sent to the CNN model to interpret and classify the emotion expressed. The classification result is then transmitted to the robot, which responds with an appropriate action (e.g., dancing, singing, etc.). The dataset used contains 1,279 drawings, categorized into five emotion classes: happy, sad, fear, insecure, and angry. These labels were provided by psychologists specialized in interpreting children's drawings. To train the models, the authors use transfer learning, leveraging pretrained weights from ImageNet.

Wali et al. (2023) developed a mobile application designed to improve communication and social skills among Arab children with autism. The system offers six interactive components: identifying images from albums, learning emotions, organizing daily routines, selecting meals, constructing sentences through drag-and-drop, and playing language games. These features aim to support language development, emotional expression, and daily organization using familiar visuals and audio in the child's native language.

Veerman et al. (2024) developed a game based on Broodies, which are fantastical creatures that symbolize emotions. The game is structured around eight levels, each of which lasts approximately 20 minutes. One level is designed for two players, either a parent and child or siblings, while the others can be played solo. Each level consists of three educational mini-games. The first game associates situations with emotions (e.g., sadness or frustration). The second game transforms negative thoughts into positive ones (e.g., "I'm alone" to "I can ask for help"). The third game identifies key elements in an illustration to reinforce observation skills.

Comparative Analysis

Table 1 provides a general overview organized into three main sections. The first section comprises two sub-

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criteria: the first sub-criterion offers a chronological perspective by presenting studies from different periods, while the second indicates the cultural context of the study population. The second section comprises three sub-criteria: the total number of children in each study, the age range of the autistic individuals (in years), and the number of autistic girls, reflecting female representation. The third section consists of a single criterion: the type of approach used to enhance communication and social interaction among autistic individuals.

Table 2 presents a technical comparison organized into three categories. The first category includes two sub-criteria. The first one indicates that the learning scenarios are extracted from videos created by specialists during capacity-building sessions for individuals with autism. The second sub-criterion corresponds to the ability to define a dynamic scenario by assigning a description to an image related to new knowledge that the individual with autism is expected to learn. The second category encompasses five sub-criteria. The first one distinguishes between applications that allow autistic users to create a personal account that can be tracked over time and applications where games are only accessible through an educator's account with no direct access for autistic individuals. The second sub-criterion relates to the application's ability to identify the user's level at the start based on a specialist-established questionnaire. The third sub-criterion specifies the number of levels offered by the game. The fourth sub-criterion indicates whether the application provides sub-levels. The fifth sub-criterion evaluates whether the application provides traceability of scenarios played by autistic individuals.

As Tables 1 and 2 show, our solution introduces significant improvements over existing work. It takes Arabic into account, a language which that largely underexplored in the context of autistic children. It also covers a larger population of 35 out of 100 and provides detailed, gender-specific data, including the number of autistic girls. Furthermore, it combines scenario extraction, generic scenarios, and all key gamification elements: identification, levels, and traceability.

Table 1: General overview of each game

Game	Overview		Sample			Approach
	Year	Language	Children	Age	Female	
Lima et al. (2019)	2019	Portuguese	12	6–12	0	NA
de Mira Gobbo et al. (2021)	2021	Spanish	28/44	2–15	NA	TEACCH
Deveau et al. (2022)	2022	English	28/44	3–12	9	NA
Popescu et al. (2022)	2022	English	NA	NA	NA	NA
Wali et al. (2023)	2023	Arabic	131	3–12	38	PECS
Veerman et al. (2024)	2024	Dutch	16	6–13	NA	NA
Ours	2025	Arabic	25/45	6–15	8	PECS

Table 2: Scenarios and gamification elements in each game

Game	Scenarios		Gamification			
	Extraction	Generic	Profile	Identification	Levels	Traceability
Lima et al. (2019)	✗	✗	✗	✗	NA	✗
de Mira Gobbo et al. (2021)	✓	✗	✓	✗	6	✗
Deveau et al. (2022)	✓	✗	✗	✓	NA	✗
Popescu et al. (2022)	✓	✗	✗	✗	NA	✓
Wali et al. (2023)	✓	✗	✓	✗	6	✗
Veerman et al. (2024)	✓	✗	✓	✗	8	✓
Ours	✓	✓	✓	✓	6	✓

Methods

This section presents the technical details of the proposed solution. First, we introduce the learning scenarios. Next, we describe the system's architecture.

Learning Scenarios

We used a coding scheme developed in a general learning context (Farouk et al., 2007). Using this scheme, we manually annotated 62 videos of educational sessions involving autistic children, obtained from the Zayed Center for Autistic Children and the Center for the Training and Promotion of Children with Disabilities. This observation phase enabled us to refine the coding scheme to better address the specific needs of autistic children by identifying new context-specific attributes and discard less relevant ones. Table 3 presents the updated version of the coding scheme.

The second step was to integrate the refined schema into the ANVIL tool (Kipp, 2012). The goal was to annotate videos more systematically and identify the attributes teachers use most frequently in their pedagogical interactions. Fig. 1 illustrates this process.

By cross-referencing the most frequent attributes (e.g., Ask to do, Encourage to respond, Imitate an action) with the pedagogical content of the sessions, we were able to group behaviors into typical situations, or

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learning scenarios. Each scenario corresponds to a specific educational objective and is supported by a coherent set of attributes derived from the coding scheme. Table 4 presents the six identified scenarios along with their main associated attributes.

Several meetings were held with special education experts from the Zayed Center for Autistic Children and the Center for the Training and Promotion of Children with Disabilities. These exchanges provided an opportunity to present and discuss the identified scenarios. The experts validated the scenarios, emphasizing their importance in developing fundamental skills and promoting the integration of autistic children into their daily environments. The experts also proposed levels of progression, associated scoring criteria, and target skills for each scenario, as shown in Table 5.

Table 3: Coding schema

Category	Sub-category	Attribute
Intent	Animate	Ask to do
		Enroll the learner
		Ask for a response
		Building trust after destabilization
	Evaluate	Note a question
		Note the answer with repetition
	Inform	Reminder with indication
		Inform with indication
Means	Linguistic resources	Ask a question
		Pass the play pieces to the child
	Others resources	Position the indicator paper
		Show a paper to the child
		Enrolling papers
		Produce an action
Affective parameters	Emotional support	Verbal motivation
		Motivation by applause
		Motivation by offering a reward
	Attention management	Attract the child's attention
Strategies	Task initiation	Encourage to take the test
		Order the child to start
	Response facilitation	Encourage to respond
	Behavioral modeling	Imitate an action
		Imitate a sequence of movements
	Task repetition	Repeat tasks

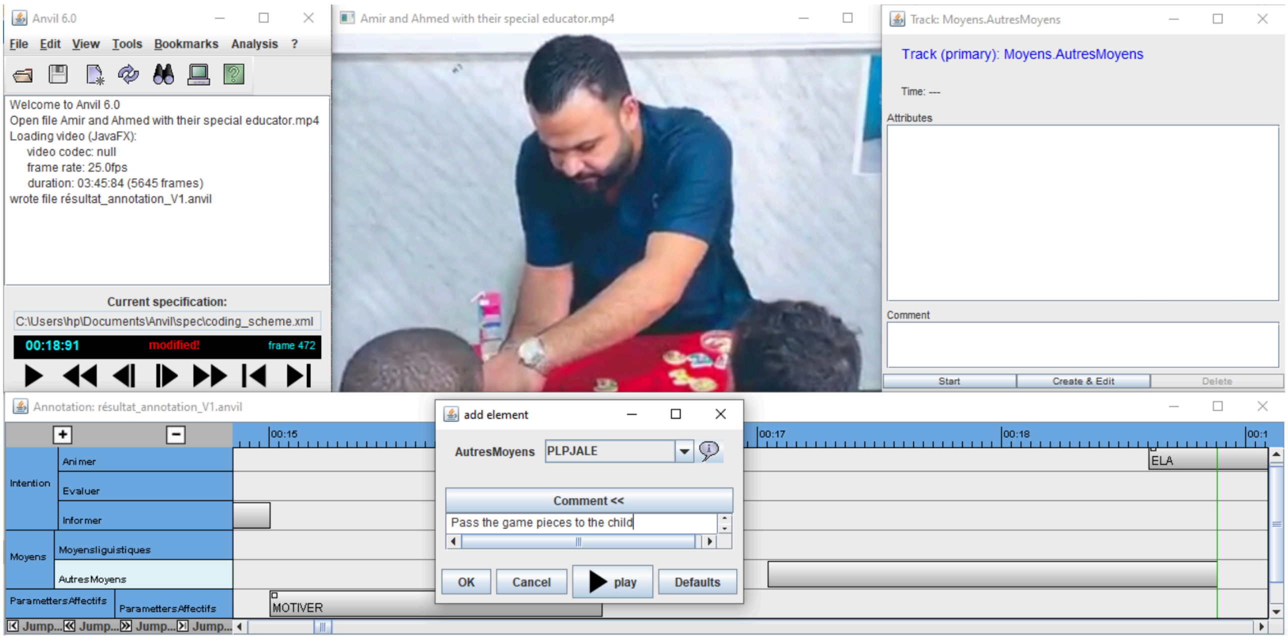

Fig. 1: Example of video annotation with ANVIL

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Table 4: Association between learning scenarios and coding scheme

Learning Scenario	Dominant attributes in the coding scheme
Recognizing the letters of the alphabet	Ask for a response, Repeat task, Inform with indication
Learning to count	Encourage to take the test, Order the child to start
Memorizing simple elements	Reminder with indication, Enrolling papers
Drawing various shapes	Imitate a sequence of movements, Produce an action
Identifying common objects	Show a paper to the child, Pass the play pieces to the child
Imitating related actions	Imitate an action, Imitate a sequence of movements

Table 5: Scenarios details

Scenario	Levels	Score	Skills
1	1	No	Match a letter to an object
	2		جَ جُ جِ جْ جٌ جٍ جً جا جو جي
2	1	Yes	Identify numbers
	2		Place objects in a container
3	1	Yes	Recognize 4 objects
	2		Recognize 6 objects
	3		Recognize 8 objects
4	1	No	Color regions of an object
5	1	No	Identify family photos
6	1	No	Imitate an action

The first scenario has two levels. The first level teaches children the correct pronunciation of letters and helps them identify objects that begin with each letter. The second level focuses on how letters are pronounced when combined with vowels.

The second scenario also has two levels. The first level introduces children to number recognition. Through interactive games and engaging visuals, children learn to identify and name basic numbers. This lays the groundwork for understanding elementary mathematics. The second level builds on this knowledge by introducing the concept of containers. Children learn to associate quantities with objects by placing them in the correct containers. This helps them develop their ability to manipulate concrete numerical concepts.

The third scenario has three levels of increasing complexity. On the first level, children are encouraged to identify four everyday objects from simple illustrations. This promotes visual association and memory. The second level increases the challenge by asking children to identify six objects, further engaging their memory and attention. The third level reinforces these skills by asking children to identify eight objects, enabling them to consolidate their knowledge while stimulating their curiosity and observational skills.

The fourth scenario is a single-level game that focuses on identifying and coloring different parts of an object. The objective is to develop fine motor skills and hand-eye coordination while teaching children to follow instructions for coloring specific areas. This activity also helps children learn vocabulary related to objects and spatial organization.

In the fifth scenario, children identify family members in photos or illustrations. This activity strengthens the emotional bond between children and their families while developing social vocabulary. Children learn to recognize family roles, such as mother, father, brother, and sister. They also learn to associate names with faces.

In the sixth scenario, the child is invited to imitate simple actions that are either demonstrated by an educator or shown on the screen. These actions may include everyday gestures, such as clapping, waving, or jumping. The goal of this level is to develop motor coordination and encourage learning through imitation and physical expression.

Architecture

The system consists of two main components: the front end and the back end. Fig. 2 shows the overall architecture.

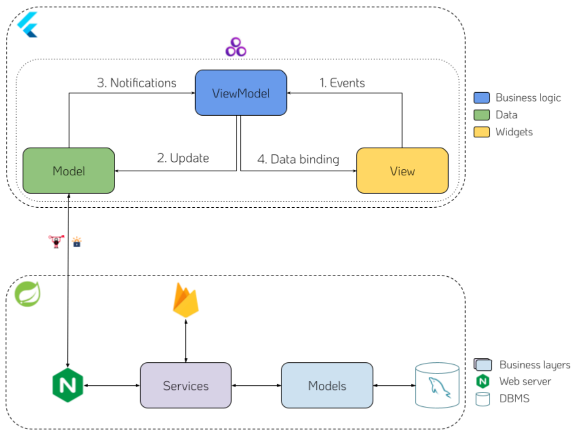

Fig. 2: Architecture of the proposed system

The front-end is developed using Flutter and the GetX state management library, employing the MVVM design pattern. When a user interacts with a widget in the application, the associated view-model is invoked. The view-model then calls the corresponding Model, which communicates with the targeted Web service. Once the result is returned, the model notifies the view-model, which updates the View.

The back end is implemented using Spring Boot and follows the MVC pattern. When a request is sent from the front end to a web service on the back end, the NGINX web server receives it and forwards it to the

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appropriate service. This service can communicate with Firebase if necessary. The back end performs the necessary operations using model classes that interact with multiple database tables.

Thus, the overall architecture clearly separates the presentation layer (Flutter), the business logic (view models and back-end services), and the data management layer (models and the database). This modular approach simplifies maintenance and testing, enabling the system to evolve smoothly over time and ensuring a dynamic user experience.

Results

From February 2024 to February 2025, experiments were conducted on a sample of 45 autistic children aged 6 to 15. The sample included 32 males and 13 females. Participants were divided into four groups based on the severity of their symptoms: Mild (12), Moderate (8), High (5), and Profound (20).

Children in the mild category could follow basic instructions and participate in activities. However, they often had difficulty paying attention for long periods of time. They were easily distracted by external stimuli and sometimes needed reminders to stay on task.

Children in the moderate category had communication difficulties, such as limited verbal expression and echolalia (repeating others' words). They inconsistently followed multi-step instructions and displayed repetitive behaviors, such as hand flapping or rocking.

(a)

(b)

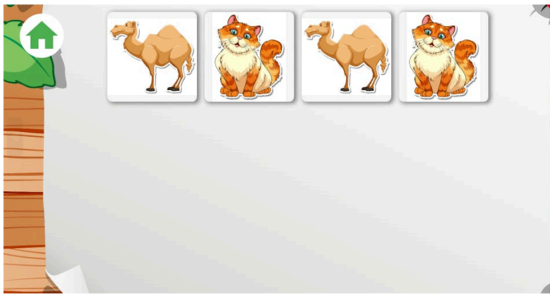
Fig. 3: Illustration of Scenario 1 (a) Some letters of the Arabic alphabet (b) Example of an animal whose name begins with 'ب'

Children in the high category had minimal verbal communication skills and exhibited intense sensory sensitivities, such as covering their ears or avoiding eye contact. They also struggled with transitions between activities.

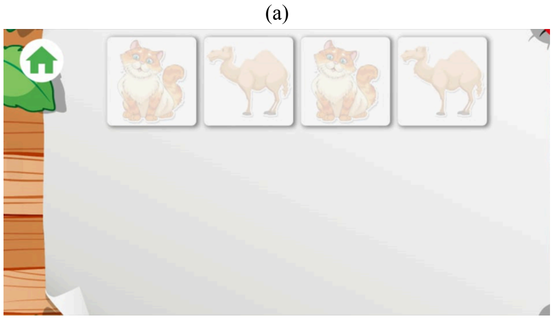
Children in the profound category were excluded from the experiment because they could not meet the minimum participation requirements. They were unable to sit independently, even for short periods of time. They did not respond to verbal cues or visual prompts, and they were often in a state of high distress or disengagement. These factors made interaction and evaluation impossible.

Fig. 3 illustrates the first level of Scenario 1. Fig. 3a shows several letters of the Arabic alphabet. When a letter is chosen, the game shows an object or animal whose name starts with that letter. Fig. 4 shows the second level of Scenario 1. The autistic child can listen to the name of the object by clicking the play button. Then, they must place all of the objects into the container.

Fig. 4: Illustration of Scenario 2



(a)



(b)

Fig. 5: Illustration of Scenario 3 (a) Examples of images originally displayed (b) Examples of partially hidden images

Fig. 5 corresponds to Scenario 3, in which the child must identify pairs of similar objects. First, the images of the objects are shown, and then they are partially hidden. The child must find the matching pairs. Following recommendations from the experts, the images are only partially hidden because hiding them completely would be too difficult for autistic children. Fig. 6 corresponds to Scenario 4, in which the child is asked to color an object.

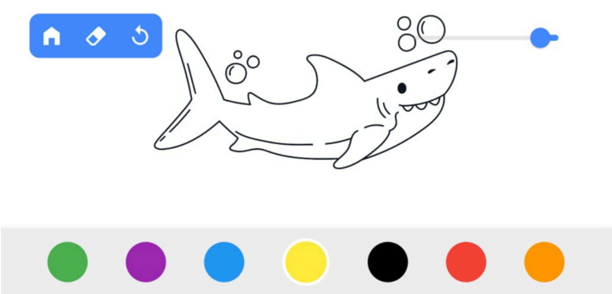


Fig. 6: Illustration of Scenario 4

Three evaluations were conducted. The first assessed autistic children across three categories in relation to the different scenarios. The second focused on the success rate of children in the mild category for each scenario. The third tracked the progression of category levels over a 12-month period.

Regarding the first evaluation, we recorded three indicators:

- Open: The autistic child opened the game in response to the instruction.
- Played: The child played the game as intended.
- Success: The child successfully completed the game.

Since children in the mild category usually have no difficulty beginning games, we primarily focused on the number of successful completions. However, for the moderate and high categories, we recorded all three indicators: Open, Played, and Success.

Open refers to the child's ability to independently initiate an activity or game by accessing it without external assistance, reflecting engagement and initiation skills. Played indicates that the child actively interacted with the game after opening it, demonstrating sustained participation beyond mere initiation. Success corresponds to the successful completion of the game or task according to predefined criteria, reflecting task understanding, goal-directed behavior, and cognitive–motor performance.

In the context of ASD interventions, these three indicators capture different levels of engagement and functional ability: initiation (Open), active participation (Played), and task completion (Success). This distinction is particularly relevant for children in the moderate and high categories, who may show difficulties at earlier stages of interaction even before task completion is achievable.

Table 6: Autistic performance by both category and scenario

Scenario	Level	Mild		Moderate			High		
		Played	Success	Open	Played	Success	Open	Played	Success
1	1	152	142	57	51	28	38	32	20
	2	138	125	49	43	22	33	27	16
2	1	137	118	53	46	21	35	28	15
	2	126	103	47	39	17	31	24	13
3	1	123	97	50	41	18	33	25	10
	2	115	85	45	36	15	30	22	8
	3	101	72	40	32	12	27	19	6
4	1	102	68	48	38	14	32	23	7
5	1	96	52	42	33	11	28	19	5
6	1	90	44	38	29	9	25	17	4

Table 6 provides a summary of the results. For each category, we selected a child with an average performance level. The results show that scores are highest for the mild category, followed by the Moderate category, and then the High category. Additionally, the success rate decreases as the scenarios progress due to the increasing difficulty across levels. We also observed that children initially classified at the moderate category can improve with continuous training and reach the mild category.

In the second experiment, we selected one child with an average ability level from the mild category and analyzed their success rates across different scenarios, as shown in Fig. 7. Each bar represents a specific scenario, revealing a clear downward trend in performance as complexity increases. The success rates continue to decline progressively across the scenarios, illustrating that the difficulty increases accordingly, with corresponding decreases in average success rates.

For the third experiment, we also selected one child with an average level from each category and tracked their scores over several months. Fig. 8 illustrates this progression. The results show that the most significant improvements were observed in the mild category, followed by the other categories.

Discussion

This twelve-month study examined the use of digital learning scenarios tailored to the Mauritanian context among 45 autistic children between the ages of six and fifteen. Participants were categorized by severity level (mild, moderate, severe, or profound), which revealed significant differences in engagement and interaction. Children in the mild and moderate categories could generally participate. However, children in the severe category had significant communication and sensory limitations that prevented them from participating. Additional staff are required to accompany children in the profound category until they progress from a delicate stage to a more stable one. At this stage, they can perform certain daily tasks, such as responding partially to instructions, washing their hands, and using the bathroom independently. Until they reach this level of autonomy, it is not possible to evaluate their performance with the games offered by our system. However, this transition usually takes longer than the 12 months covered by our study. This is why we started with the less delicate categories to evaluate the effectiveness of our approach, and will subsequently extend our work to the remaining categories.

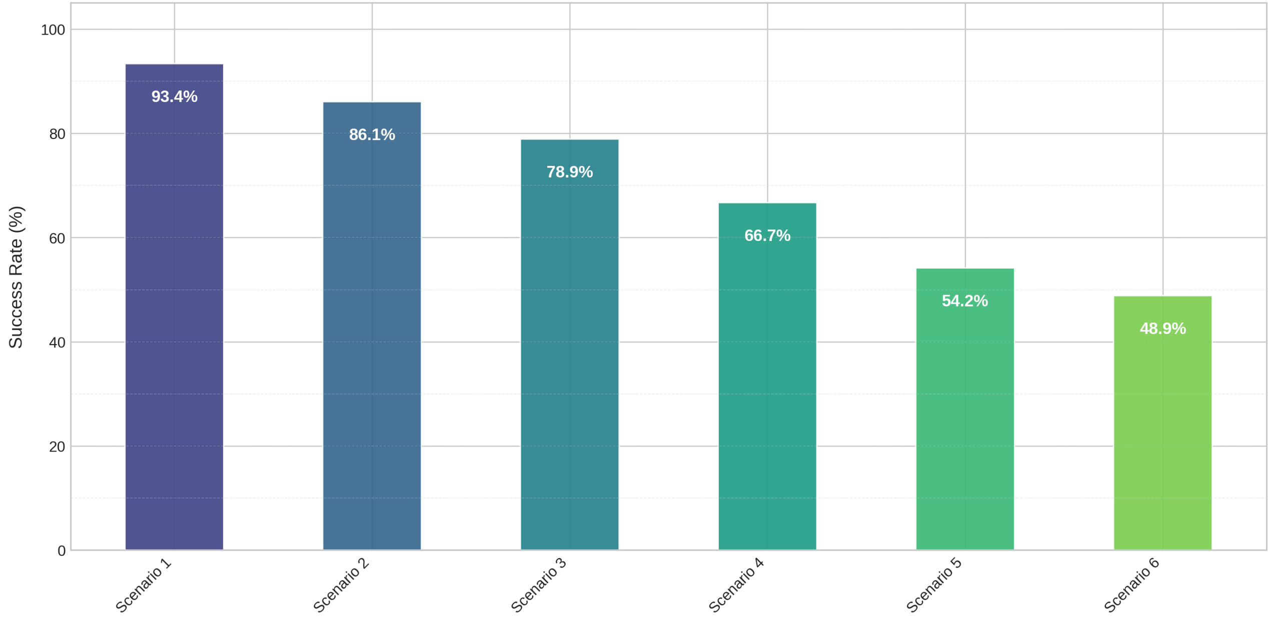


Fig. 7: Success rate analysis for mild category participants

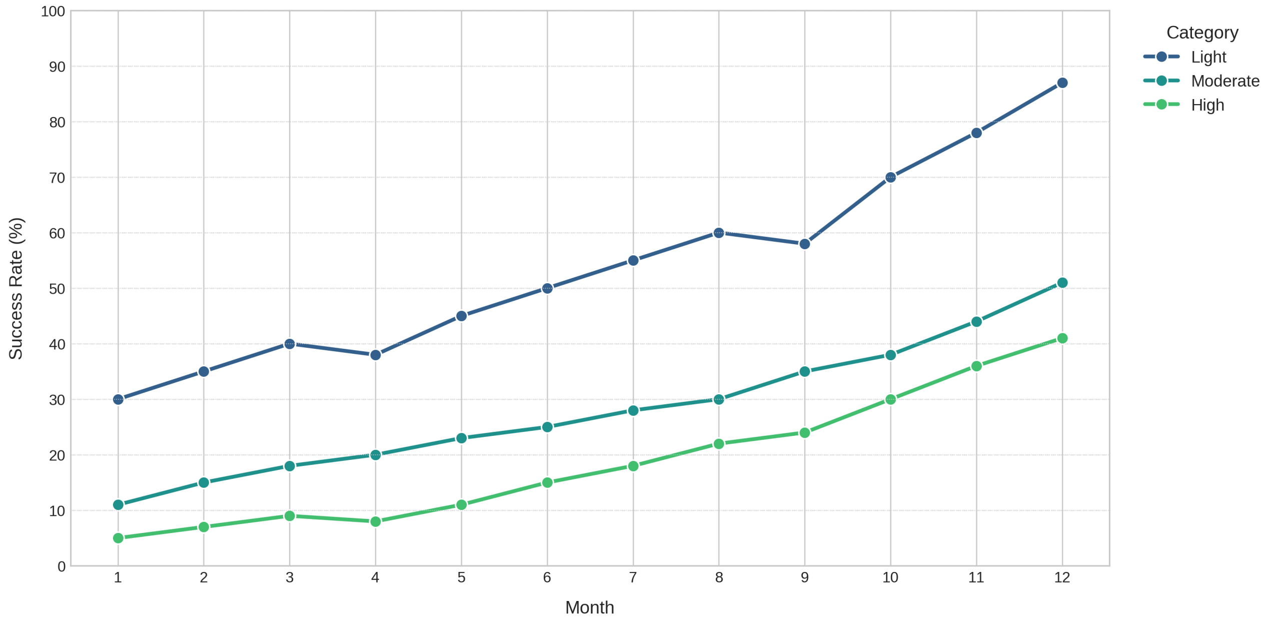


Fig. 8: Monthly success rate progression by category

Performance across interactive scenarios reflected severity levels. Children in the mild category most successfully completed simple tasks, such as letter and object recognition. In contrast, performance decreased with increased task difficulty, especially for more cognitively demanding tasks, such as associating partially obscured objects, among the moderate and severe groups. Analyses of engagement indicators, Open, Played, and Success, confirmed higher success rates in the mild category. Children with moderate ASD showed progress through continuous training. Longitudinal tracking revealed that improvements were most significant among children with mild ASD. This finding underscores the impact of initial abilities on the effectiveness of digital tools.

Overall, the study demonstrates that contextualized digital scenarios can support children with ASD in their learning when task difficulty, pacing, and visual stimuli are carefully adapted. The results highlight the potential for meaningful progress, particularly in mild and moderate cases, and suggest ways to develop inclusive, dynamically personalized tools for settings with limited resources.

Conclusion

This study presented a coding schema-based solution to enhance the education of children with ASD in Mauritania. By developing an interactive mobile application tailored to the local cultural and linguistic context, this research demonstrated how digital technologies can bridge gaps in access to specialized educational resources. The six contextualized pedagogical scenarios, designed through video analysis of real educational sessions, targeted fundamental skills such as communication, cognition, and autonomy.

Experimental results involving 45 autistic children confirmed the effectiveness of the application, with varying success rates depending on symptom severity and scenario complexity. The observed progress, particularly among children in the mild category, highlights the potential of this approach to support inclusion and developmental growth for children with ASD.

In this study, we started with a general coding scheme and developed a more specific one based on the annotation of learning sessions observed in expert videos. In the future, we plan to verify the coding scheme twice using reliability measures, such as Krippendorff's alpha and Cohen's kappa, to evaluate inter-rater agreement.

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Author’s Contributions

Cheikhne Mohamed Mahmoud Seyidi: Collected data, meet with specialists in the autism centers, annotated videos, proposed the coding scheme and system architecture.

Ahmed Mohameden: Implemented the mobile system, carried out the validation experiments and wrote the manuscript.

Mohamed Lamine Diakité: Supervised and guided the work, revised and corrected the paper.

Mohamedade Farouk Nanne: Ensures cooperation with our team and autism centers, and coordinates communication between authors.

Ethics

The article complies with all ethical principles.

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