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PAPER

An Educational Inclusion Model for Adults with Diverse Neuromuscular Conditions through the Use of an Artificial Intelligence Algorithm

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ABSTRACT

An estimated 790 million individuals globally are afflicted with at least one form of disability. Among this population, 79 million are afflicted with diverse neuromuscular disorders. The educational inclusion of these people is complicated by the loss of the ability to communicate and breathe, difficulty walking, dressing, and/or eating without the assistance of another person. Several studies have demonstrated that assistive tools can function as a means of providing support. However, the feasibility of obtaining these instruments is hindered by limited supply, exorbitant prices, intricate operation, and substantial maintenance requirements. As a result, they are promptly abandoned following their acquisition. In contrast, artificial intelligence algorithms are of paramount importance as they enable the execution of computational processes that acquire knowledge from data, thereby enabling progressive performance enhancements deprived of explicit human intervention. The current study is aimed to tackle the obstacle of ensuring that this population has access to education by developing a mobile application that utilizes an eye-tracking algorithm to gather fixation data from individuals afflicted with this condition. This enabled the development of an innovative and personalized learning environment, which yielded outcomes including enhanced usability, accessibility, autonomy, time management, and physical barrier elimination.

KEYWORDS

inclusive education, diverse neuromuscular conditions, education for diversity, universal access to education, eye tracking algorithm, artificial intelligence

1 INTRODUCTION

Ensuring educational accessibility for individuals with diverse conditions (referred to as disabilities) is a complicated undertaking, rendered even more so by the presence of a degenerative neurological disorder. In the latter case, people

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have the neurons of the central nervous system affected, which die or are damaged causing various serious conditions, and finally producing the loss of the ability to communicate and breathe, leading sufferers towards death [1]. The condition is characterized by muscle rigidity, which are motor disorders that hinder the ability to engage in activities such as feeding, dressing, or walking independently. For this reason, they are also referred to as diverse neuromuscular conditions [2].

Although diverse neuromuscular conditions are frequently encountered in old age, their onset may occur much earlier. As the global population ages, its incidence has increased substantially in recent years, and this tendency is anticipated to continue [3]. As of now, the issue at hand has evolved into a burden due to the fact that its cause remains unknown and there is no known remedy. Treatments are symptomatic in nature; they do not aim to achieve a permanent cure for the disorder.

From the perspective of access to educational opportunities for people with diverse neuromuscular conditions, little information is available. Some scholars in the spectrum of the subject indicate that the educational content offered to this population should cover topics associated only with the maintenance of their daily routines and self-care. For other researchers, the topics of the curriculum should be the same as those offered to all people, at the levels of the educational systems of the countries. However, another group indicates that it is not necessary to offer educational services to this population, since they do not represent any significant contribution or competence to the productive system, a radical position that is totally opposed to the universal right to education.

To promote educational accessibility, a range of assistive devices have been developed to aid individuals with diverse neuromuscular conditions in performing daily tasks with a certain level of independence [4]. However, these tools are costly, difficult to obtain, non-customizable, require an excessive amount of maintenance, and are comprised of a vast array of auxiliary components that can make their operation, mobility, and use challenging at times. Consequently, they are abandoned shortly after their acquisition because they are rendered unviable [5], [6], [7], [8].

Certain researchers argue that, in order to improve the efficacy of assistive equipment (hardware), its physical limitations should be addressed through software applications (algorithm-based computer applications) [9], [10]. Algorithms of artificial intelligence, which are defined as a set of logical, sequential, finite, and precise procedures designed to solve a particular problem, accomplish a particular task, or make decisions autonomously, are sometimes implemented.

Algorithms are fundamental to the field of artificial intelligence because they enable data-driven learning, pattern recognition, decision-making, and the execution of complex tasks, thereby emulating the human capacity for problem-solving and reasoning. An algorithm that is employed to monitor and document an individual's eye movements is referred to as "eye tracking". This enables the measurement and analysis of how people gaze and navigate a screen or physical environment [11]. The gathered data is significant in facilitating comprehension of users' visual behavior, attention, and preferences. This knowledge is crucial for informing decision-making processes, such as when analyzing the buttons of a computer application that is presented on a tablet, smartphone, or computer screen during the utilization of a virtual educational course.

This paper introduces a model specifically developed for adult individuals with a diverse neuromuscular condition, incorporating eye tracking, an artificial intelligence algorithm. The objective is to provide a computer-based assistive tool serving as a didactic tool so that individuals afflicted with this ailment may attempt to reach an education through the utilization of virtual educational courses, regardless of their proficiency level, and without necessitating intricate supplementary aids.

2 MATERIALS AND METHODS

2.1 Theoretical background

Limited articles were identified in the systematic review of the literature that encompassed the entire scope of the subject. The objective was to demonstrate how earlier works have been modified. The conceptualization, interpretation, and consolidation of the discovered works center on the subsequent approaches:

Studies associated with diverse muscular conditions. The analysis of the chosen papers reveals that the United States and European countries have the highest concentration of production. Furthermore, it became apparent that significant variations exist among the definitions of the concept of "diverse condition." These variations primarily stem from the manner in which it is conceptualized, potentially carrying significant ramifications for the approach taken and the strategies implemented to advance educational access and equal opportunities for individuals with diverse conditions. The following are some of the most significant distinctions among the definitions of the concept (Table 1) [12]:

Table 1. Existing differences in the concept of diverse muscular condition

Differences	Definition	Authors
Medical vs. social	It focuses on the functional limitations of the person.	[13]
	It focuses on the social and environmental barriers that prevent the full participation of these people in society.	
Deficiency vs. participation	They are based on the presence of a physical, sensory, intellectual or mental impairment or limitation.	[14], [15]
	They are based on the person's ability to participate fully in daily life.	
Individual vs. group	They focus on the individual limitations of the person with diverse conditions.	[16]
	They focus on the social and environmental barriers that affect these people as a whole.	
Regulatory vs. relative	They are based on regulatory standards of what is considered "normal" or "functional".	[17]
	They are based on a relative perspective that recognizes the diversity and variability of human capabilities.	

Source: Own construction.

Research studies associated with access to educational opportunities. The notion emerged during the 1970s in response to the endeavors of the civil rights and diverse conditions movements, which sought to advocate for equitable educational opportunities [18]. Jerome Seymour Bruner, an American psychologist, professor, and educator, was among the earliest authors [19]. In his influential book Toward a Theory of Instruction (1966), Bruner argued that instruction ought to be tailored to the unique requirements of every student. An additional significant author was Lev Semionovich Vygotsky, a Jewish-origin Russian psychologist and epistemologist who, during the 1930s, formulated the theory of student-centered sociocultural learning [20]. During the 1980s, academics including Sally Tomlinson and Mel Ainscow initiated research and published works regarding the notion within the domain of special education. Their work underscored the criticality of student engagement in decision-making processes and the imperative to modify educational frameworks and methodologies in order to guarantee inclusion [21]. In addition to the authors mentioned above, Susan Stainback, Michael Fullan, and Thomas Hehir have also made important contributions. The notion exhibits a historical and logical connection to the following other fundamental concepts (Table 2):

Table 2. Connection of concepts associated with access to educational opportunities

Concepts	Description	Authors
Human Rights	It is founded on the principle that every individual, regardless of origin, gender, sexual orientation, diverse condition, or any other factor, has the entitlement to receive a high-quality education.	[22]
Diversity	It is linked to the valuation and acceptance of diversity in all its forms, whether ethnic, cultural, linguistic, religious, among others, and the adaptation of educational programs to include all students.	[23]
Equity	It is associated with the pursuit of equitable opportunities for every learner, regardless of their individual attributes or personal circumstances.	[22]
Accessibility	It is characterized by the elimination of barriers to educational opportunity, be they of a physical, financial, or cultural nature.	[22], [24]
Participation	Facilitates the active and meaningful engagement of every student in the educational process in order to guarantee that their concerns are addressed and their needs are met.	[24]
Education for all	This pertains to the idea that universal access to education is a fundamental human right, regardless of geographical location, gender, age, or any other distinguishing characteristic.	[22], [24]
Personalized learning	It is connected to the premise that each student has unique needs and learning styles, and that education should adjust to meet those needs.	[25]

Source: Own construction.

While there are a number of opposing viewpoints and terms that are put forth as alternatives to the concept of access to educational opportunities, it is crucial to acknowledge that they do not inherently contradict one another. Some of these perspectives are listed in Table 3:

Table 3. Perspectives that oppose or present as an alternative to the concept of access to education for people with diverse conditions

Concepts	Description	Authors
Integration	It refers to the inclusion of students with various disabilities in the regular educational system, while maintaining the structure and curriculum of traditional education.	[22]
	Rather than the educational system adapting to the student's requirements, the focus is on the student's adjustment to the current system.	
Segregation	It refers to the separation of students with special needs in schools or special programs from the regular educational system.	[26]
	It is based on the belief that the people of this community require a specialized educational environment to meet their needs, and it focuses on adapting the educational system to the needs of the student, but only through the development of specialized educational systems.	
Exclusion	Represents the denial of education to certain groups of students due to their gender, race, religion, socioeconomic background, and other factors.	[21]
	Emphasis is placed on the necessity of minimizing obstacles that impede access to education for specific student populations.	
Diversity	Demonstrates and celebrates cultural, linguistic, ethnic, and gender differences in education.	[21]
	It emphasizes on promoting an educational environment that values and respects diversity and ensures the inclusion of all students, regardless of their unique attributes.	
Equity	It focuses on removing barriers that prevent certain groups of students from accessing educational resources and benefits.	[21]

Source: Own construction.

2.2 Complexity of access to educational opportunities

Educational inclusion, which refers to the provision of educational opportunities, carries significant theoretical implications. In general terms, it denotes the notion that every individual ought to have unrestricted access to high-quality education and actively engage in all facets of the educational process, regardless of their unique attributes or specific situations.

A redefinition of the role of education in society stands out as a highly significant theoretical implication. Conversely, rather than regarding education as a mechanism that discerns and categorizes students based on their aptitude or capability, the premise underlying access to educational opportunities is that it ought to serve as a mechanism to advance social justice and equal opportunities [21].

An additional significant theoretical implication is that there is a need for a change of paradigm in the development and execution of educational policies and programs. Access to educational opportunities requires careful consideration of the unique requirements of each student, as well as the diversity of the communities and cultures in which schools function [25], as opposed to an emphasis on uniformity and homogeneity. They should permit the full participation and success of all students, including those with diverse conditions, special needs, and learning styles, in this context. Furthermore, the provision of educational opportunities necessitates increased cooperation and collaboration among communities, institutions, and families in order to establish safe, welcoming, and inclusive learning environments for all [21], [22].

Access to educational opportunities, on the other hand, is described as complex and multifaceted, particularly for individuals with diverse conditions, due to the constraints they face. The following are several challenges and trends, with the latter being presented as solutions to the problems (Table 4):

Table 4. Limitations and trends associated with access to educational opportunities for people with diverse neuromuscular conditions

Limitations and Trends		Description	Authors
Practical disadvantages	Stigmatization	The concept of diverse condition is frequently associated with inferiority or disability, which can lead to stigmatization and discrimination of people with different conditions.	[17], [27], [28], [29]
	Subjective definition	Diverse conditions can be classified subjectively based on others' perceptions and opinions, which can lead to incorrect interpretations and incorrect labeling of people.	
	Medicalized view	The focus on diverse conditions can lead to a medicalized view of this population, which means paying too much attention to their situation rather than their unique abilities and needs.	
Advantages of including all people, regardless of their characteristics or needs, in education and within the same environment	Promoting equality	Attempts to ensure that all students have equal learning opportunities, regardless of their backgrounds or abilities. This may help to reduce social inequality and promote a fairer society.	[26], [30], [31], [32]
	Social skills development	Students who learn in an inclusive environment can interact with a diverse range of people with varying experiences and abilities, which can help them develop valuable social and emotional skills.	
	Improving academic results	It can help students improve their academic results by providing the support they need to reach their full potential. Furthermore, students with a variety of disabilities can receive the additional support they require to succeed in the classroom.	

(Continued)

Table 4. Limitations and trends associated with access to educational opportunities for people with diverse neuromuscular conditions *(Continued)*

Limitations and Trends		Description	Authors
Research	Accessibility	Allows people to identify and address the barriers that prevent them from fully participating in society. When these barriers are recognized, steps can be taken to remove them and make the environments more accessible.	[18], [22], [24]
	Equal opportunities	Helps to recognize that this population has different needs and abilities than other people, and that policies and practices must be adjusted to ensure that everyone has equal opportunities.	
	Public policies	It is critical for the development of public policies that address people's needs and rights, such as inclusive education, employment, medical care, and accessibility.	
Research limitations	Resource requirements	To effectively implement access processes to educational opportunities, additional resources such as more personnel and specialized technology may be required. This can be costly and difficult to fund for some schools or educational systems.	[26], [21], [31], [32]
	Classroom management difficulties	It can present challenges for teachers and other educational professionals because they must adapt their instruction to meet the needs of a diverse range of students with varying abilities and needs.	
	Potential social resistance	It may face social or cultural opposition, as some groups see it as a threat to educational quality or an interference with traditional teaching.	

Source: Own construction.

2.3 Assistive computing tools

Although there are no specialized tools designed for individuals with muscular disorders, these tools are applicable to a broader range of situations and conditions. There are technical aides available on the market that facilitate the operation of electronic devices, including computers, digital tablets, and mobile phones. Screen readers, screen magnifiers, voice recognition systems, Braille lines, text-only browsers, keyboard emulators, touch screens, keyboard filters, alternative input devices, and validation and repair tools are examples of these primarily handcrafted hardware technical aides [33], [34]. The critical factors of usability and accessibility are predominantly considered in the development phase of web pages or online services, as viewed through the lens of computer programs [33], [35].

In many different fields, including education, artificial intelligence has emerged as an asset. Its algorithms are procedural mechanisms that enable it to acquire knowledge from data and enhance its performance continuously, without requiring explicit human intervention. Within the context of education, particularly in aiding individuals who have diverse neuromuscular disabilities, these algorithms play an essential role. Their purpose is to scrutinize patterns and data that pertain to the unique characteristics of each person. By employing machine learning methodologies, it becomes possible to discern the unique requirements and inclinations of every individual, thereby enabling an individualization of educational opportunities [36]. Educators may also engage in real-time monitoring of students' progress and performance, modifying instructional plans, strategies, and activities in response to obtained feedback. This results in a cycle of continuous enhancement that adjusts to evolving neurological conditions and fluctuating student needs [37]. Examples of computer tools powered by artificial intelligence that adapt to individuals with various neuromuscular conditions are provided below (see Table 5).

Table 5. Assistive computing tools using artificial intelligence

Category	Tool	Description
Communication and control	EyeGaze	Allows users to control devices and communicate with others while tracking user's movements.
	Sip-and-Puff Systems	Use a spoon or sucking motion to control computers and electric wheelchairs, which is appropriate for people with cerebral palsy.
	Brain-Computer Interfaces (BCIs)	Allows communication through cerebral activity, which is useful for people with severe paralysis.
	Voice Recognition Software	It converts spoken language into text, assisting people who have difficulty communicating verbally.
	Adaptive Keyboards and Mice	Adaptive keyboard and mice that adapt to reduced mobility requirements.
Rehabilitation and therapy	Virtual Reality Rehabilitation	Uses virtual reality and artificial intelligence to improve physical and motor rehabilitation.
	Robotic Exoskeletons	Assist individuals afflicted with diverse neuromuscular conditions regaining mobility through the use of robotic devices.
	Machine Learning for Gait Analysis	Uses automatic learning algorithms to assess and improve the performance of people with motor difficulties.
Web and application accessibility	Screen Readers	Software that converts text to speech, making it more accessible to people with different visual and reading disabilities.
	Speech-to-Text Apps	Convert speech to text, which is useful for people who have difficulty writing.
	AI-Powered Captioning Tools	Provides automatic subtitling in real time, improving accessibility for people with hearing problems.
	Adaptive Mobile Apps	Mobile applications that assist people in adapting to their needs.

Source: Authors' adaptation.

Alternative tools that implement these algorithms are referred to as "eye-tracking tools." They are utilized in the development of software applications that facilitate the gathering of gaze data. The data may comprise gaze points, which are Cartesian coordinates in two dimensions ("x" and "y") that typically denote a location on a screen or in a real-world natural environment [4]. Fixation is essential for target identification [38]. Certain eye-tracking metrics, including pupil dilation, saccadic movement, and blink frequency, which are associated with cognitive processes occurring during attention and choice, may be utilized [39]. These computational tools using artificial intelligence algorithms are an alternative for people with diverse neuro-muscular conditions to use electronic devices [40]; although it is emphasized that patience is required during the training stage to start using them on a common computer.

2.4 Links of learning with information technology

Bearing in mind recent studies that explore strategies to improve the quality of life of people with diverse neuromuscular conditions, it is important to mention that IT solutions must be dynamic and adaptable, as pointed out by [41] in their proposal for an Augmentative and Alternative Communication – AAC. This approach takes into account the evolving requirements of individuals with such conditions. Utilizing fuzzy logic and artificial intelligence to develop AAC systems that adapt to the progression of the disease is the foundation of the strategy, which emphasizes the need for adaptable technological solutions to facilitate the learning process for users [41].

Furthermore, the application of eye-imaging-based human-computer interaction for AAC in patients with amyotrophic lateral sclerosis (ALS) is discussed in the systematic literature review [42]. This review exposes a variety of technological approaches, such as Eye-Gaze, Eye-Blink, Eye-Tracking, and hybrid strategies, that have been developed to improve AAC in individuals with ALS. These technological approaches possess the capability to detect and track eye movement, as well as categorize the condition of the eye. Although, it is imperative to clarify that there are restrictions in the research due to the limited number of participants with ALS and the methodology used in some studies [42].

On the other hand, [43] present a study using artificial intelligence-based eye-tracking technology to assess symptoms of attention deficit hyperactivity disorder (ADHD). This study demonstrates the application of computer technology in evaluating and facilitating the learning process, despite adopting a distinct methodology. In doing so, it underscores the significance of incorporating sophisticated technologies to enhance inclusive education for students with particular needs. Eye-tracking and artificial intelligence software developed specifically for this purpose were implemented on a tablet in this study [43].

According to the above, it can be indicated that the links between learning and information technology, especially in the context of artificial intelligence, have the potential to positively transform inclusive education, providing innovative tools and models that can benefit individuals with diverse neuromuscular conditions and thus promoting equal opportunities in the educational environment.

3 METHODOLOGY

This study focused on the design and implementation of an artificial intelligence-based eye-tracking model aimed at improving educational accessibility for adults with some type of neuromuscular condition. Previous research has explored the potential of artificial intelligence algorithms in this context [4], pointing to the possibility of overcoming barriers and promoting inclusion through advanced technological solutions. The following is a detailed description of the four phases of the methodology used, from data collection to prototype evaluation, as shown in Figure 1.

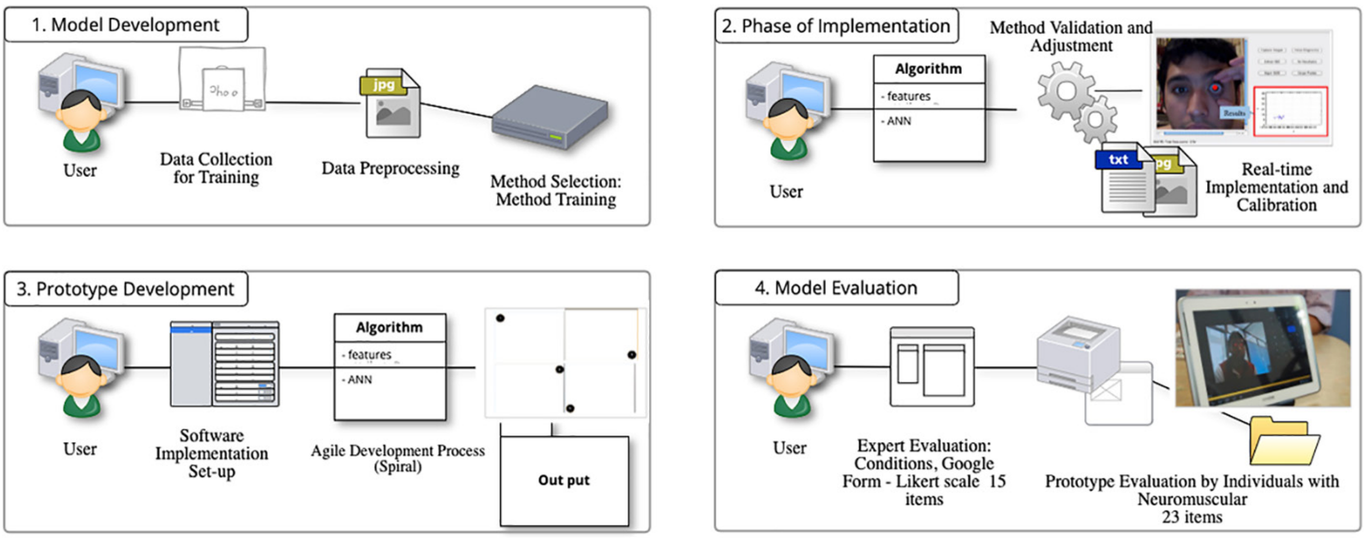

Fig. 1. Phases of the methodology used

Source: The authors.

3.1 Model development

During the initial phase of model development, data collection for training was conducted by observing different points on the screen to obtain image data corresponding to the training phase. Following this, data preprocessing was executed, which included normalizing the data, designating the eye coordinates, and adjusting the images to ensure uniform quality. After this, a method selection process was conducted in which a specialized eye-tracking architecture was chosen and the corresponding neural network was developed. Following the selection of the method, method training was conducted to refine the model's ability to identify patterns associated with the eye position during reading.

3.2 Phase of implementation

During the subsequent phase, the implementation was executed, followed by the validation and adjustment of the method. If the performance of the method was deemed unsatisfactory, the architecture of the method was modified. The implementation was then carried out in real time by continuously capturing images with a camera and predicting the present position of the eyes using the method. Calibration was concluded by assessing individuals with a variety of neuromuscular disorders through the task of maintaining a fixed fixation on a sequence of reference points displayed on the screen.

3.3 Prototype development

In the third phase, the development of the prototype, an archetype was built using the C++ programming language and the OPENCV library, incorporating the developed algorithm. An agile development approach was used, specifically the Spiral or Mobile Development Process, which takes into account usability evaluation and consideration of individuals with various neuromuscular conditions throughout the design life cycle.

3.4 Model evaluation

Finally, the evaluation of the model comprised two parts: the evaluation by experts, where a survey was designed in Google Forms for a group of experts to evaluate the model using a Likert approach and criteria established in the ISO/IEC 25010:2011 standard [46]; and the evaluation of the prototype by individuals with neuromuscular conditions, for which a 23-item Likert scale was created as an evaluation instrument.

4 RESULTS AND DISCUSSIONS

4.1 Eye tracking algorithm design

The eye-tracking algorithm comprises the following fixed sequence of seven steps, which are described in general terms in Algorithm 1:

Algorithm 1: Eye-Tracking

Input: reading of the movement of the eyelids.
Output: selection of a letter of the alphabet or number within the display.

Start
Step 1: Gathering data for training.
1. Collect data from the images by looking at different points on the screen.
2. Record the coordinates of the eye positions in each image.
Step 2: Data preprocessing
3. Adjust the images ensuring uniform quality.
4. Normalize the data.
5. Label the coordinates of the eyes.
6. Split the data into training and test.
Step 3: Method selection
7. Select specialized eye-tracking architecture.
8. Develop the eye-tracking neural network.
Step 4: Training the method
9. Recognition of patterns in the data that relate to the position of the eyes when a person is looking.
10. Minimizing the difference between the coordinates suggested by the method vs. the actual eye coordinates.
Step 5: Method validation and adjustment
11. Evaluate the performance using the test data set.
12. If the performance is not satisfactory
Then
Adjust method architecture
Step 6: Real-time implementation
13. Continuously capture images by means of a camera.
14. Process the captured images using the method.
15. Predict the current position of the eyes.
Step 7: Calibration
16. Conduct tests with people with diverse neuromuscular conditions, having them fixate their gaze on a series of reference points arranged on the screen.
End

In the beginning, the algorithm gathers, registers, and labels the image data using points that are dispersed across the screen. Adjusting the image quality, sorting the data, and verifying that the labels are registered correctly are the subsequent steps. Then, the specific artificial intelligence method to be implemented is chosen. Subsequently, the training process starts by modifying the approach to forecast the eye focus coordinates on the input images while utilizing the dataset. Following this, the efficacy of the approach is assessed by utilizing the dataset and identifying any necessary adjustments. Following the verification of real-time image capture, eye tracking predictions are generated. Users with various neuromuscular conditions participate in usability testing and evaluation to ascertain that the system is effective and accessible regarding interactions with the content of the virtual educational course.

4.2 Prototype

The prototype was constructed employing the C++ programming language, more particularly the OPENCV package, with the results of the preceding steps (algorithm) considered. At this phase of the undertaking, the agile development process referred to as Spiral or Mobile Development Process is in operation. Spiral was selected, among other reasons, because it incorporates usability evaluation criteria, and takes into account individuals with diverse neuromuscular conditions throughout the entire design life cycle. We determined which test images induced participants to fixate their gaze on predetermined focal points prior to implementing the prototype. The person fixes their gaze on these points as they become visible, as this action was performed in order to initiate a diagnosis within the mobile application. Following the extraction of the data, the mobile application generates results containing the extracted information (Figure 2a).

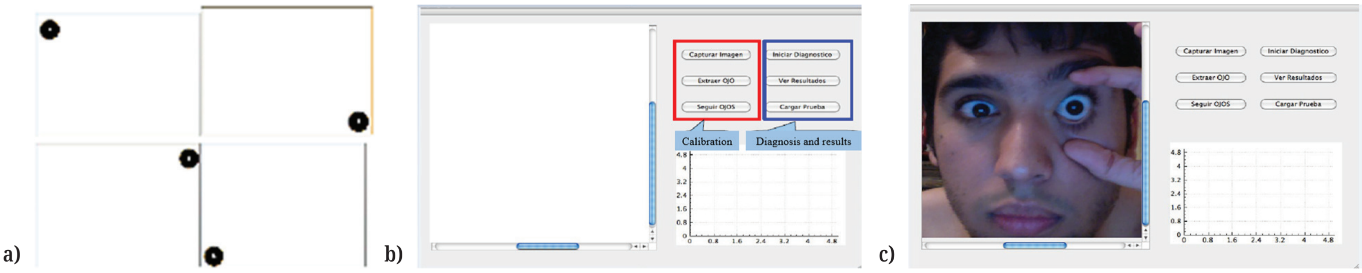

Fig. 2. a) Images used in the diagnosis test; b) Main interface of the mobile application (software) developed during the research; c) Calibration stage in the developed software

Source: The authors.

A detailed description of the mobile application's features can be found in the subsequent section. The algorithm executes in the mobile application or computer program, displaying the individual's video images in a designated region while the eye's monitoring and detection processes are carried out. As shown in Figure 2b, the remaining six controls are divided into two sections: one for calibration and the other for diagnostic and accompanying results.

The program initiates the collection of portraits when the "Capturar imagen" (Capture image) icon is activated. This enables an expert user, such as a teacher, caregiver, family member, or physician, to verify that the captured image depicts an eye or multiple eyes, in preparation for subsequent analysis (see Figure 2c). This process is known as the calibration stage.

The eyes of an individual with diverse neuromuscular conditions are automatically detected once the calibration images of the application have been captured; this occurs when the "Extraer ojos" (Extract eyes) icon is activated. The mobile application has the capability of identifying the presence of an eye in the captured photographs. This is very helpful for additional analysis (Figure 3).

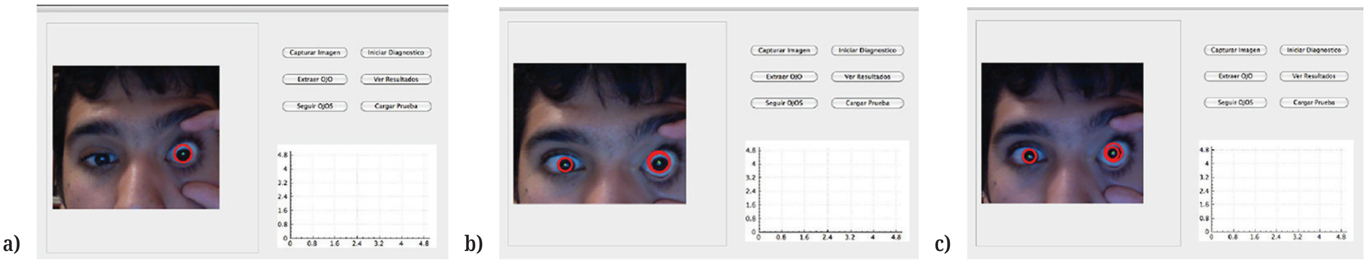

Fig. 3. a) Calibration stage in the developed mobile application; b) Detection of two eyes during the calibration stage; c) Extraction of three eyes, so calibration is very necessary

Source: The authors.

After the evaluations mentioned above have been finished, a more rigorous calibration process can be undertaken, which entails the observation of both eyes. To accomplish this, simply click "Seguir ojos" (Track eyes), which will display a person's eye tracking. The accuracy of the tracking at this stage of the experiment is contingent on the environment in which the photographs are taken; therefore, the images might or might not be practical (Figure 4a).

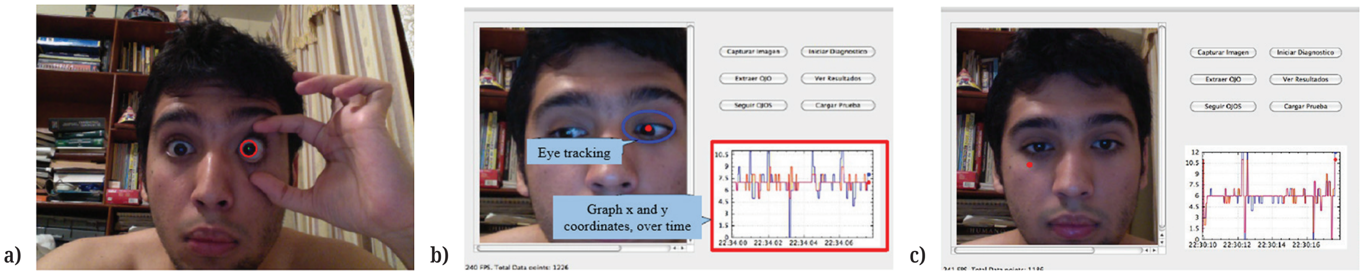

Fig. 4. a) Correct extraction of the left eye; b) Real-time eye tracking and real-time results graph; c) In this case, the test failed due to poor calibration

Source: The authors.

Following the calibration of the mobile application, the "Iniciar diagnóstico" (Start diagnosis) icon is activated. At this point, the collection of spatial data regarding the eye movement during the tracking of the locations delineated as test images across time intervals begins. The aforementioned data are presented in real time in the lower portion of the screen as "x" versus "time" and "y" versus "time2". In order to determine the spatiotemporal correlations of the eye movement, both Figure 4b and c depict the overlap in the same region.

The diagnosis is finalized upon clicking the "Ver resultados" (See results) icon, at which point the mobile application generates a graph containing the gathered data. The latter is useful for getting started with the tool via a virtual educational course (Figure 5).

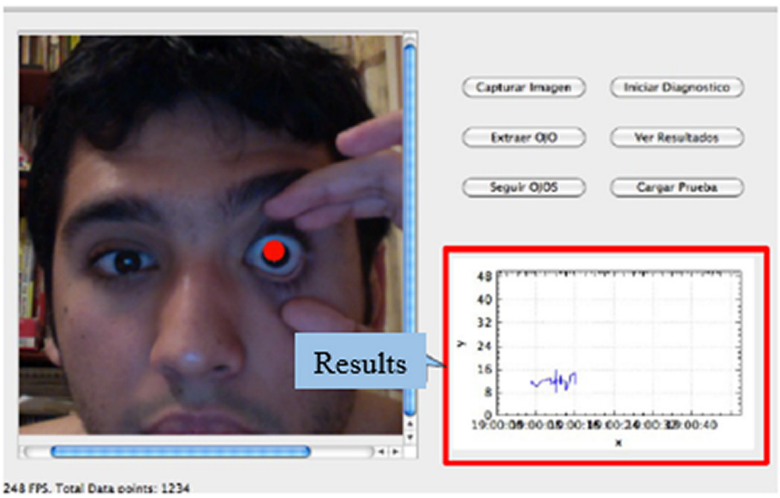

Fig. 5. Results obtained from the test performed

Source: The authors.

The prototype navigating an application for various mobile devices is depicted in Figure 6. Embedded into the application is an eye-tracking algorithm. The device's screen presents the keyboard, which consists of both letters and numbers. An automated selection process is executed for every single letter. Upon the application detecting the person with the diverse neuromuscular condition blinking, which is a visual gesture, the user enters the currently selected letter or number.

Fig. 6. Performance of the designed algorithm, through execution in an application for differrent mobile devices

Source: Authors' adaptation based on [44].

For effective operation, it is imperative to consider the following recommendations: Support the head and inhibit any rotation of the neck by affixing the chin to a horizontal plane. It is advisable to select a white background in order to mitigate the risk of erroneous object and false eye detection. Eye tracking is rendered impracticable in low-light conditions due to its inability to differentiate circular features within an image [45]. The algorithm implemented in the model exhibits a heightened sensitivity to undetected target displacement caused by inadvertent eye blinking. Consequently, potentially significant information is lost during such fleeting intervals.

4.3 Implementation

Figure 7 shows the graphic representation of an adult with a diverse neuromuscular condition, who is in the sitting and bedridden positions. In this study, it is evident that individuals utilize a virtual educational course that is organized inside a learning management system (LMS) in a self-directed manner. This is facilitated through the utilization of a mobile application that implements an artificial intelligence algorithm, namely eyetracking, which has been developed as part of this research. The visual representations demonstrate the absence of any tangible interaction between the user and the keyboard displayed on the virtual interface. The movement of hands, feet, fingers, and/or arms is not necessary.

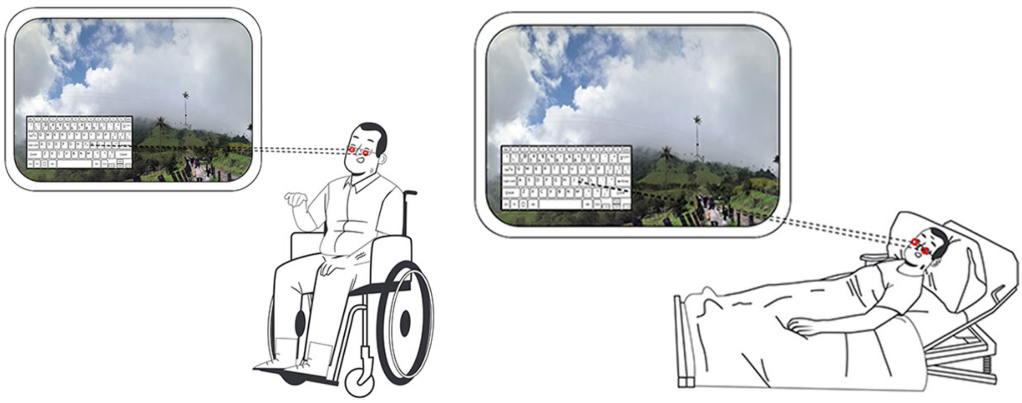

Fig. 7. Diagram of the use of the mobile application with an adult person with diverse neuromuscular conditions

Source: The authors.

The methodology employed for data analysis in the implementation involved two stages. In the first stage, a group of experts assessed the model. In the second stage, individuals with diverse neuromuscular conditions utilized the model and evaluated it.

A survey tool, designed in Google Forms, was developed to facilitate the expert group's evaluation of the model. The group of experts conducted a thorough examination of the material before its implementation. The survey utilized a Likert scale consisting of 15 items, each rated on a five-point scale ranging from 1 (Strongly Disagree) to 5 (Strongly Agree). Furthermore, the foundation of the system or product evaluation in the areas of product quality and quality in use was derived from certain indicators outlined in the ISO/IEC 25010:2011 standard [46]. As illustrated in Table 6, the aim of use [47] serves as an additional indicator. The questionnaires and tables proposed and utilized by [48] were also implemented, as they are established instruments and materials that have been validated in several contexts including the utilization of educational technology incorporating artificial intelligence.

Table 6. Reference indicators for evaluation provided by the group of experts

Indicator	Characteristics	Items
Usability in use	Satisfaction – usefulness	9
Product usability	Appropriateness recognizability Learnability Operability Accessibility	1 2 1 1
Intention of use		1

Source: Authors' compilation.

A 23-item Likert-type scale was developed as an instrument for the prototype assessment, as indicated in Table 7. Performance (pre- and post-tests) is another indicator. The instructors at institutions 1 and 2 created and applied the tests.

Table 7. Reference indicators for prototype evaluation

Indicator	Characteristic	Items
Usability in use	Effectiveness, efficiency, satisfaction (usefulness, trust, pleasure, comfort)	7
Context coverage	Flexibility, context completeness	2
Functional suitability	Functional correctness	1
Product usability	Appropriateness recognizability, learnability, operability, user error protection, user interface aesthetics, accessibility	9
Portability	Adaptability	1
Reliability	Availability	1
Intention of use	Perceived usefulness	2

Source: Authors' compilation.

The results of the application of the material validated by the experts to adults with diverse neuromuscular conditions are presented below. A group of five individuals conducted an evaluation of the model, consisting of four men (80%) and one woman (20%). These individuals were affiliated with two distinct educational institutions. It is important to consider that the sample size of adults with diverse neuromuscular conditions in the context of accessibility is remarkably small. This phenomenon can be attributed to the fact that these cases exhibit extraordinary and/or atypical traits. In general, the perception about the educational inclusion model was positive, although the difficulties experienced by the population in making use of the technology are made clear. A summary of the most noteworthy answers is shown in Table 8. For instance, the fact that 57.2% strongly believe that the educational inclusion model was helpful and benefits learning implementation is highlighted in the usability in use evaluation, which gauges user happiness. Cronbach's alpha indicates that the instrument's internal consistency is 0.873 overall [49].

Table 8. Overall results of the expert group evaluation

Indicator	Characteristic	Outstanding Results
Usability in use	Satisfaction – usefulness	57.2% (SA) and 25.6% (A), utility for learning 43.4% (A) and 31.7% (SA), model elements First level – 38.1% (SA) participants, 48.6% trends, 57.2% context Second level – 51.2% (SA) work team, 61.7% technological, 71.7% pedagogical Third level – 58% (SA) learning environment Fourth level – 51.4% (SA) service monitoring Fifth level – 67.9% (SA) service impact
Product usability	Appropriateness recognizability Learnability Operability Accessibility	49.5% (A) and 28.3% (SA) 46.8% (A) and 58.9% (SA) 63.1% (A) 74.7% (A)
Intention of use		31.6% (A) and 63.2% (SA) in employing TVE for educational use

Note: (SA): Strongly Agree; (A): Agree.
Source: Authors' compilation.

Using the prototype, the scenario verifies how the model should be applied. Regarding the academic performance indicator, Table 9 demonstrates that there is an overall improvement in results when the model was implemented.

Table 9. Results of student performance tests

Subject	Group	Number	Pre-Test Average	Post-Test Average
Institution 1	Experimental	5	3.0	3.9
	Control	5	2.5	3.5
Institution 2	Experimental	5	2.3	3.7
	Control	5	2.1	3.8

Source: Authors' compilation.

Table 10 presents the outcomes of the chi-squared test, which was employed to conduct a statistical analysis of the grades achieved by the experimental and control groups. The data obtained from the experimental group of institution 1 did not yield sufficient evidence to establish a statistically significant difference. However, the data collected from institution 2 exhibited statistically significant differences, as indicated by the p-values of each group being lower than the predetermined significance level.

Table 10. Results of statistical analysis of student performance tests

Institutions	Experimental Group	Control Group
Institution 1	0.0006084	0.006581
Institution 2	0.0006011	0.06157

Source: Authors' compilation.

Five participants in a general virtual educational course answered the survey. As shown in Table 11, which presents response highlights, students who took part in the prototype generally had a positive opinion of it. For instance, 68.2% of respondents from institution 1 and 79.2% from institution 2 strongly agreed that they would recommend that universities implement the proposed model in the usability-in-use evaluation (the indicator of satisfaction-utility). For institutions 1 and 2, the overall reliability of the instrument was 0.928 and 0.933, respectively.

Table 11. Overall results of the student evaluation

Indicator	Characteristic	Outstanding Results (%)			
		Institution 1		Institution 2	
		A	SA	A	SA
Usability in use	Effectiveness	50	36.4	50	36.5
	Efficiency	45.5	54.5	54.2	45.8
	Satisfaction (usefulness)	31.8	68.2	16.7	79.2
	Satisfaction (trust)	63.6	9.1	58.3	33.3
	Satisfaction (pleasure)	68.2	13.6	65.2	29.2
	Satisfaction (comfort)	68.2	9.1	65.2	29.2
Context coverage	Flexibility	36.4	50	37.5	54.2
	Context completeness	59.1	22.7	8.3	41.7
Functional suitability	Functional correctness	40.9	54.5	66.7	33.3
Product usability	Appropriateness recognizability	59.1	27.3	41.7	37.5
	Learnability	36.4	63.6	37.5	54.2
	Operability	50	50	25	66.7
	User error protection	36.4	4.5	25	8.3
	User interface aesthetics	68.2	9.1	37.5	25
	Accessibility	68.2	18.2	37.5	50
Portability	Adaptability	63.6	18.2	33.3	50
Reliability	Availability	54.5	31.8	41.7	45.8
Intention of use		22.7	72.7	50	50

Note: (SA): Strongly Agree; (A): Agree.
Source: Authors' compilation.

5 CONCLUSIONS

An artificial intelligence-based eye-tracking algorithm was integrated into a mobile application in the following manner: the device's screen displays the keyboard (including both letters and numbers), and an automated selection process is executed over each item. The mobile application notifies the user of the selected letter or number the instant it detects that the person with the neuromuscular condition is blinking their eye. The mobile application exists as an external component to the virtual educational course now being utilized. That is, the population can use the mobile application, and at the same time can use, for example, a learning management system (LMS), or read the news on a web page, or chat with other people, among others.

It is important to acknowledge that while the eye tracking algorithm integrated into a mobile application (software) provides an alternative means for the target audience to attain a certain level of independence, external variables such as environmental conditions have a significant impact on the evolution of its application. As stated previously, considerable patience is necessary throughout the training phase.

The primary contribution of the work presented consists of scientific, technological, didactic, and pedagogical approaches, which pose a transcendental challenge deserving of research. This results in the externalization of a socially significant viewpoint through an examination of the potential of an artificial intelligence algorithm as a therapeutic intervention that facilitates enhanced educational accessibility for adults afflicted with diverse neuromuscular conditions.

The contribution has a great impact since the beneficiary population must be prioritized. For the above, the current causes, characteristics of discrimination, segmentation and in general terms, the invisibilization by the governments, culture and society must be taken into account. In the future, it is expected to generate new lines and products of research using the advances in the neuropsychology and education dyad, oriented to people who suffer not only diverse neuromuscular conditions, but in a wider spectrum, i.e., neurodegenerative diseases in general.

To guarantee universal access to education for individuals of all types of diversity, it is critical to acknowledge that additional successful experiences are required. Additionally, it is important to mention that the research sample is limited in size due to the exclusion of the population, which occurred even within the inclusion programs. An additional rationale is the limited economic resources and challenging mobility faced by families that have a member with this diversity. For these individuals, their body is a real burden.

Regarding the development, innovation, and provision of assistive aids, such as computer tools that employ artificial intelligence algorithms for adults with various neuromuscular conditions, there is still a long way to go and much to be done. This would allow the benefited population to attain a certain level of autonomy. From a didactic (pedagogical) standpoint, these tools may be developed, parameterized, and validated in order to ascertain their prominent function in the educational opportunities offered.

5.1 Competing interests

The authors declare that they have no competing interests.

5.2 Data availability statement

The dataset that supports the findings of this study can be requested from the authors by email.

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