Assisted communication system for individuals with spastic cerebral palsy: technological innovation and comprehensive solutions

Prototipo de comunicación automatizado para personas con parálisis cerebral espástica: innovación y oportunidades

Reyes-Delgado, Aurea Teresa*[a], Martínez-Dávila, Javier Eduardo[b], Padilla-Cruz, María Belén[c] and Martínez-Urzúa, Ximena[d]

[a] ROR Tecnológico Nacional de México, Tecnológico de Estudios Superiores de Jocotitlán, División de Ingeniería en Sistemas Computacionales, LMO-3205-2024, 0009-0002-8024-3514, 921487
[b] ROR Tecnológico Nacional de México, Tecnológico de Estudios Superiores de Jocotitlán, División de Ingeniería en Sistemas Computacionales, LTE-3864-2024, 0009-0008-8105-3484, 2077143
[c] ROR Tecnológico Nacional de México, Tecnológico de Estudios Superiores de Jocotitlán, División de Ingeniería en Sistemas Computacionales, LMO-3931-2024, 0009-0008-9486-119X,2077146
[d] ROR Tecnológico Nacional de México, Tecnológico de Estudios Superiores de Jocotitlán, División de Ingeniería en Sistemas Computacionales, LTE-3976-2024 0009-0001-4549-8741,2077150

CONAHCYT classification: **DOI:** https://doi.org/10.35429/H.2024.12.84.97

Area: Engineering
Field: Engineering.
Disciplina: Electronic Engineering.
Subdisciplina: Computing.

Key Handbooks

This work contributes to the development of accessible technological solutions aimed at improving communication for people with spastic cerebral palsy through an automated prototype connected to a mobile application. The research identified the key needs of patients and specialists through online surveys and employed the Extreme Programming (XP) methodology to ensure an adaptable and user-centered design. To generate universal knowledge, it is essential to understand user needs and develop accessible, simple, and connected technologies that can adapt to diverse contexts and populations. Additionally, this work highlights the importance of integrating participatory approaches and agile methodologies to create solutions that can be replicated and scaled globally. The proposed prototype aims to significantly improve communication capabilities in people with spastic cerebral palsy. With 94.4% of respondents considering that connection to a mobile application optimizes interaction, and the majority being unaware of other technological solutions, a significant opportunity emerges for further innovations in this field.

Citation: Reyes-Delgado, Aurea Teresa, Martínez-Dávila, Javier Eduardo, Padilla-Cruz, María Belén and Martínez-Urzúa, Ximena. 2024. Assisted communication system for individuals with spastic cerebral palsy: technological innovation and comprehensive solutions. 84-97. ECORFAN.

* ✉ [aurea.reyes@tesjo.edu.mx]

Handbook shelf URL: https://www.ecorfan.org/handbooks.php

Abstract

Spastic cerebral palsy significantly affects the communication abilities and quality of life of those who suffer from it. Despite the urgent need for technological solutions, there is a lack of accessible and effective prototypes in this field. This article presents the development of an automated communication system designed for individuals with spastic cerebral palsy, facilitating their interaction and expression. The prototype was designed using the Extreme Programming (XP) methodology, with requirements gathered through online surveys directed at patients and specialists, followed by quantitative analysis. Key functionalities identified include ease of use, communication efficiency, and economic accessibility. Results revealed that 94.4% believe a prototype connected to a mobile application would improve patient communication. Moreover, most participants were unaware of existing technological solutions, highlighting a significant opportunity for development in this area.

Objectives	Methodology	Contributions
 Develop an automated communication system for individuals with spastic cerebral palsy.	 Extreme Programming (XP), an agile methodology used for prototype development.	 Accessible and effective prototype that improves communication for individuals with spastic cerebral palsy.
 Identify key functionalities that enhance user interaction and expression.	 Online surveys, a tool for gathering requirements and opinions from patients and specialists.	 Identification of users' needs and expectations regarding communication technologies.
 Evaluate users' perceptions of existing technological solutions.	 Quantitative analysis, a method for evaluating the collected data and obtaining meaningful results.	 Raising awareness about the lack of adequate technological solutions in this field.

Spastic cerebral palsy, Automated communication system, Mobile application, Assistive technology, User-centered design

Resumen

La parálisis cerebral espástica afecta significativamente la capacidad de comunicación y la calidad de vida de quienes la padecen. A pesar de la urgente necesidad de soluciones tecnológicas, hay una escasez de prototipos accesibles y efectivos en este campo. Se presenta el desarrollo de un sistema de comunicación automatizado diseñado para personas con parálisis cerebral espástica, facilitando su interacción y expresión. Para el diseño del prototipo, se empleó la metodología de Programación Extrema (XP), recopilando los requisitos mediante encuestas en línea dirigidas a pacientes y especialistas, con un análisis cuantitativo. Como funcionalidades clave identificadas se encuentran la facilidad de uso, la eficiencia en la comunicación y la accesibilidad económica. Los resultados revelaron que un 94.4% considera que un prototipo conectado a una aplicación móvil mejoraría la comunicación de los pacientes. Además, la mayoría de los participantes desconoce la existencia de soluciones tecnológicas evidenciando una oportunidad de desarrollo en esta área.

Objectivos	Metodología	Contribuciones
 Desarrollar un sistema de comunicación automatizado para personas con parálisis cerebral espástica.	 Programación Extrema (XP), metodología ágil utilizada para el desarrollo del prototipo.	 Prototipo accesible y eficaz que mejora la comunicación de personas con parálisis cerebral espástica.
 Identificar funcionalidades clave que mejoren la interacción y expresión de los usuarios.	 Encuestas en línea, herramienta para la recopilación de requisitos y opiniones de pacientes y especialistas.	 Identificación de necesidades y expectativas de los usuarios sobre tecnologías de comunicación.
 Evaluar la percepción de los usuarios sobre soluciones tecnológicas existentes.	 Análisis cuantitativo, método para evaluar los datos recopilados y obtener resultados significativos	 Generación de conciencia sobre la falta de soluciones tecnológicas adecuadas en este campo.

Parálisis cerebral espástica, Sistema de comunicación automatizado, Aplicación móvil, Tecnología asistiva, Diseño centrado en el usuario

Introduction

Spastic cerebral palsy is a neurological condition that affects a significant number of people worldwide, severely limiting their ability to communicate and fully participate in daily life. This disability not only impacts those who suffer from it but also poses significant challenges for their caregivers and healthcare professionals. Despite the growing need for technological solutions to facilitate communication, there is a notable scarcity of accessible and effective prototypes that specifically address these needs.

This researchpresents the development of an automated communication system designed for individuals with spastic cerebral palsy, enabling them to express their needs and desires more effectively. Unlike other existing solutions, which are often too complex or expensive, this system is designed with key features such as accessibility, ease of use, and mobile device integration, providing a more intuitive interface for users. T

he main added value of this system lies in its focus on economic and technological accessibility, making it viable for a broader population of users.

The main problem addressed by this research is the lack of effective technological solutions that meet the specific communication needs of people with spastic cerebral palsy.

The central hypothesis is that an automated communication system will significantly improve the ability of these individuals to interact autonomously with their environment, thereby improving their quality of life. This study is structured as follows: the first section provides a review of the literature on spastic cerebral palsy and assistive technologies.

The second section describes the methodology used, including the prototype design and data collection through an online survey. The third section presents the results and discusses the effectiveness of the prototype. Finally, the last section offers conclusions and recommendations for future research and development.

Literature Review

1. Spastic Cerebral Palsy

According to Kleinsteuber, Avaria, and Varela (2014), cerebral palsy (CP) is defined as a problem that affects muscle tone, movement, and motor skills, resulting in difficulty for the body to move in a coordinated and deliberate manner. This condition affects other bodily functions, such as motor skills, muscles, breathing, bladder and bowel control, feeding, and speech. Furthermore, Palomo, et. al (2022) mentions that spastic cerebral palsy produces motor and sensory disorders that impair function in the affected limb, negatively impacting daily living activities. Advances such as motor imagery, action observation therapy (AOT), and mirror therapy (MT) have proven to be useful.

According to Universidad Autónoma de Nuevo León. (s.f), spasticity is the increase in muscle tone, causing stiffness that hinders or prevents movement, depending on the individual scenarios resulting from brain damage that impedes the proper transmission of messages to each muscle.

This spasticity arises from damage to the motor cortex of the brain before, during, or after birth. In this context, Rosendo and Vericai (2023) describe the existence of a highly sensitive and specific tool consisting of the assessment of general movements according to Prechtl, which can be complemented with technological applications for the early detection of cerebral palsy—a significant challenge for healthcare systems worldwide. According to Kleinsteuber, Avaria, and Varela (2014), spastic cerebral palsy predominantly exhibits pyramidal signs and is classified based on its topographical distribution (see Figure 1).

Box 1

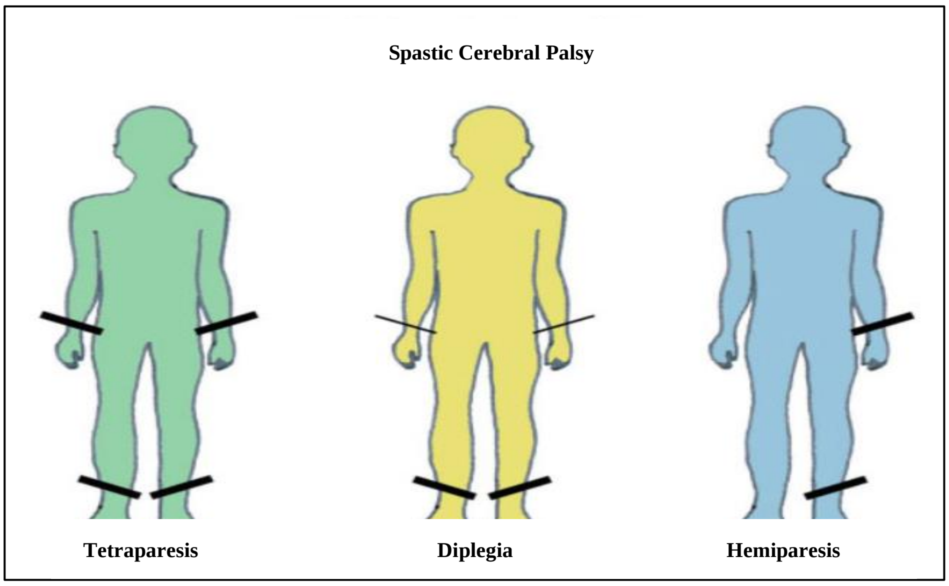

Figure 1
Topographic distribution

Finally, according to Naranjo et. al (2023), cerebral palsy is a neurodevelopmental disorder with a high incidence in the pediatric population, representing a fundamental cause of motor disability that impairs functional independence and the individual's integration into their community. Controlling the main risk factors is crucial for improving perinatal and postnatal care. According to Boa (1995), spasticity is highlighted as a major problem, defined as speed-dependent increased resistance to passive muscle stretch or, alternatively, as inappropriate involuntary muscle activity associated with upper motor neuron palsy, both of which trigger functional problems in activities of daily living.

2. Communication Systems for Cerebral Palsy

According to Arroyo (2022), speech is a complex bodily task that involves numerous cognitive and motor functions, where many individuals with cerebral palsy require the use of systems that complement speech (augmentative communication) or supplement it (alternative communication) to maximize their communication potential. Additionally, Briones et al. (2019) defines an augmentative or alternative communication system (AAC) as a set of signs and techniques that address different communication needs of a person, with the aim of enhancing the capabilities of individuals who face severe obstacles to achieving functional verbal communication.

Centers that serve individuals with cerebral palsy, according to Torres (2001), should have a high availability of tools for support, alongside professionals who work with individuals with cerebral palsy to improve communication and learning. Meanwhile, Arroyo (2022) emphasizes the need for the use of dynamic communicators with speech output, with vocabularies organized optimally for the user and an appropriate access system for individuals with disabilities; to develop and apply support technology for the universalization of such solutions to all people with disabilities.

Certain methods, according to Calleja et., al (2015) contribute to creating more efficient communicative patterns in specific situations, where the need may arise to introduce additional communication methods. A clear example is found in adults with cerebral palsy, who may produce relatively intelligible speech in their closest environment, but when interacting with other interlocutors, their communicative competence is affected. According to Murphy et., al (2009), an overview of augmentative and alternative communication (AAC) systems is provided, within the identified technologies, they were divided into low and high technology systems. More specifically, most of the high technology systems had speech output, while all the low technology systems required interpretation (reading) of the message by the listener.

In recent years, various classification instruments have been developed regarding gross motor function, manual ability, and communication skills of children and adolescents with cerebral palsy, such as the Gross Motor Function Classification System (GMFCS), the Manual Ability Classification System (MACS), and the Communication Function Classification System (CFCS). These systems provide a standardized classification to determine the prognosis and treatment of children, with the intention of improving communication among doctors, researchers, parents, and other caregivers (Efisiopediatric, 2016).

Box 2

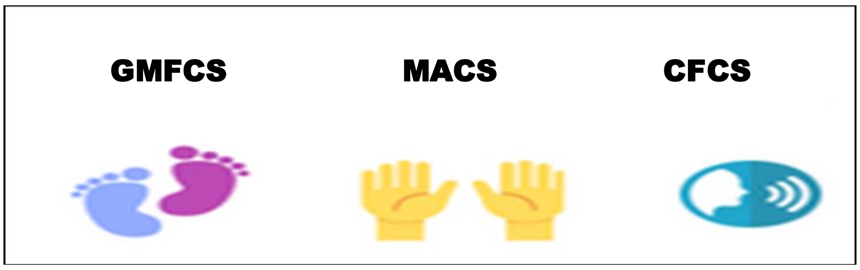

Figure 2

Classification of Systems

Source: Efisiopediatric (2016).

3. Communication Prototypes for Individuals with Cerebral Palsy

There are assistive devices, such as the one presented by (Kurten et., al 2023), which features a screen word visualizer, an audible text-to-speech synthesizer, keys for exiting the application and for quick responses (YES-NO), punctuation, and storage of what is written on the screen. This device consists of a graphical interface that allows users to select letters to form words and/or phrases, which can then be spoken aloud, enabling communication between the user and their environment. Similarly, Iza (2018) introduces a wireless prototype designed to assist individuals with motor disabilities (cerebral palsy) by sending events via Wi-Fi to a management server, consisting of a LOLIN V3 electronic board and flexible sensors responsible for transmitting events to the management server to issue sound alerts that the operator can use to make various decisions.

On the other hand, Serna (2020) developed a bioelectronic system to capture and analyze brain signals from a person and emit, through a computer, an audio signal indicating the response to a specific task, with potential use in individuals with cerebral palsy to respond to certain questions. As mentioned by Bahamonde Santander (2023), augmentative and alternative communication systems (AAC) are created to assist individuals who have communication difficulties in performing various actions, including children with CP (cerebral palsy). However, many technological solutions tend to be very expensive or not very user-friendly, highlighting the need for accessible solutions.

Teletherapy, as mentioned by Azcárate (2021), in the psychological treatment processes of children and young people with cerebral palsy incorporates technology to establish relationships between professionals and children, generating a significant impact on the dynamics involved in teletherapy, such as family and individual interactions that transform lifestyle and the interaction and construction of the environment. As mentioned in Palacios et., al (2023), communication systems are used as a therapeutic tool for the population diagnosed with cerebral palsy (CP), who have restricted vocabulary, poor syntactic structuring, unintelligible speech, and limited exploration of their environment. Augmentative and alternative communication systems are one of the therapeutic strategies used by speech therapy professionals, contributing to the development of linguistic and communicative skills in this population.

3.1 Innovations in Automated Prototypes for the Rehabilitation of Patients with Spastic Cerebral Palsy

Prototypes that assist rehabilitation, such as the one developed by Ayudas Dinámicas (s.f.) for patients with spastic cerebral palsy, utilize robotic orthoses that favor the modulation of spasticity, reduction of pain, recovery of joint mobility range, and quality of life for patients with this condition and upper motor neuron syndrome. This approach progressively reduces pain while increasing the gain in joint mobility ranges.

In addition, Reyes (2023) created a viscoelastic foam prototype that incorporates curved indentations to position and support the elbow and arm, as well as a protruding shape located in the palm of the hand. This prototype is specifically designed for individuals with central nervous system damage (such as strokes or traumatic brain injury), peripheral nerve insufficiency, orthopedic limitations, and vasomotor disorders. Similarly, prototypes such as a dynamic wrist splint developed by Reyes (2023) have functions for patients with mobility issues, cognitive impairments, potential fractures, and particularly for patients with ruptured flexor tendons in the fingers. This design emerged from the high percentage of tendon surgeries caused by cuts in manual labor and the lack of specific postoperative rehabilitation support systems.

Finally, the prototype created by Álvarez (2022) involves proposing, designing, building, and testing a medical tool that allows for better wrist and hand positioning in patients with any alteration or deformity. The design consists of an individualized orthosis that facilitates better muscular or joint rehabilitation for the patient. Meanwhile, Pérez (2020) developed a robotic orthosis capable of detecting alterations in muscle-dependent activity with the goal of improving movement capacity during active elbow movements in pediatric individuals with spastic cerebral palsy (CP).

3.2 Rehabilitation and Social Integration Unit of Jocotitlán

In 1977, the Mexican Institute for Childhood and Family (IMPI) and the Mexican Institute for Assistance to Children (IMAN) merged, leading to the creation of the National System for the Comprehensive Development of the Family (SNDIF). With the enactment of the law establishing the SNDIF in 1986, its powers were expanded, granting it the role of coordinating assistance efforts at the federal, state, and municipal levels, as well as coordinating the work among institutions and organizations, both public and private, that provide social assistance services.

The institution facilitating this collaboration is part of the National System for the Comprehensive Development of the Family (DIF), a decentralized public organization responsible for coordinating the National Public and Private Social Assistance System. Its mission is to comprehensively protect the rights of children and adolescents, based on the constitutional principle of the best interests of the child, in addition to promoting the comprehensive development of the individual, the family, and the community.

This effort primarily focuses on individuals who, due to their physical, mental, or social condition, find themselves in vulnerable situations, aiming to fully integrate them into a productive life. In particular, work will be carried out with the Rehabilitation and Social Integration Unit, located at Elvira Hernández Gómez Manzana 008, San Juan, 50700, Ciudad de Jocotitlán, Mexico.

Methodology

A quantitative analysis was conducted to obtain perceptions regarding the design and effectiveness of an automated communication system for individuals with spastic cerebral palsy (SCPCA). Through a data collection instrument, key information was gathered from participants with prior informed consent, who provided insights into their knowledge of spastic cerebral palsy, the main challenges in caring for individuals with this condition, as well as the perceived effectiveness of assisted communication systems.

The instrument also allowed for the assessment of familiarity with automated communication and rehabilitation prototypes, the advantages that a communication system could offer, and the feasibility of a splint connected to a mobile application as a tool to improve communication and the quality of life for patients. This contributed to the analysis to determine the technical viability of the prototype and the potential acceptance and impact on the daily lives of users and specialists.

The sample size calculation for this study was conducted considering a finite population, using key parameters such as the population size in Jocotitlán, a critical Z value of 2.58 for a 99% confidence level, and a precision of 0.05, corresponding to 95% confidence. Based on these conditions and data from INEGI 2020 regarding individuals who have direct contact with patients with cerebral palsy (Aguilar, 2005), a representative sample of 250 participants was determined for the instrument to assess the viability and utility of the research project, considering the perspectives and needs of healthcare professionals working with this disability.

On the other hand, the methodology employed for the design of the proposed prototype was Extreme Programming (XP), as it provides agility and flexibility in project management, characterized by its ability to adapt to user requirements, along with its precision and continuous adaptation. XP facilitates the achievement of a quality product within the software life cycle and allows for fluid and constant communication among team members and the end user, enabling collaborative decision-making (see Figure 1.3).

Box 3

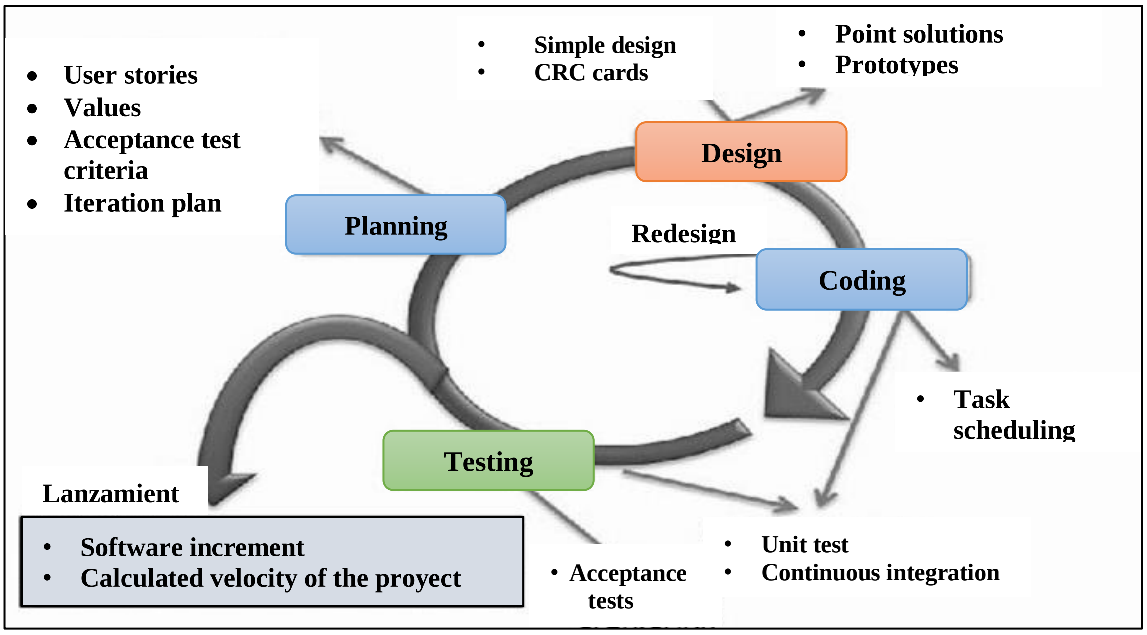

Figure 3

Phases of the Extreme Programming (XP) methodology.

Source: Bustamante et al., (2014).

The use of XP enables constant feedback and adjustments to the prototype through periodic testing, where the team can assess the project's progress and make the necessary changes to align development with the established objectives.

Results

When gathering perceptions about the design and effectiveness of an automated communication system for individuals with spastic cerebral palsy (SCPCA), it was noted that there was a 57.5% participation from women compared to 42.5% from men. Regarding knowledge of spastic cerebral palsy, 68.3% of respondents are aware of what it entails, with greater knowledge found in the age group of 26 to 40 years, where 19% of women and 16% of men showed more interest in the prototype. Participants indicated challenges in caring for a person with spastic cerebral palsy, such as the time required (47%), communication difficulties (28.5%), and motor problems (24.5%). Women aged 26 to 40 prioritize time, while men in the same age group prioritize communication. Communication systems are considered a great help for individuals with this condition by 97.6% of respondents, reflecting a strong need for accessible and functional prototype development for this disability.

Regarding access to and knowledge of technologies, 72.6% of respondents are not aware of any existing prototypes focused on automating communication for patients with this disability, indicating an opportunity for developing and promoting new solutions. The most important points that the prototype must fulfill are: affordability (30.6%), ease of use (30.2%), and effectiveness in communication (24.6%). Consequently, 94.4% of respondents believe that a prototype connected to a mobile application could enhance communication, while 51.2% consider the creation of a communication prototype with a splint feasible, indicating significant support for the technological solution.

This feedback led to the design of a prototype for an automated communication system for individuals with spastic cerebral palsy, which was carried out using the Extreme Programming methodology through the following phases:

User Requirements Gathering: The online survey provided specific needs of the end users, both patients and specialists, identifying important functionalities of the prototype, such as ease of use, communication efficiency, and affordable cost, which are displayed in the following figure according to the acceptance percentage.

Box 4

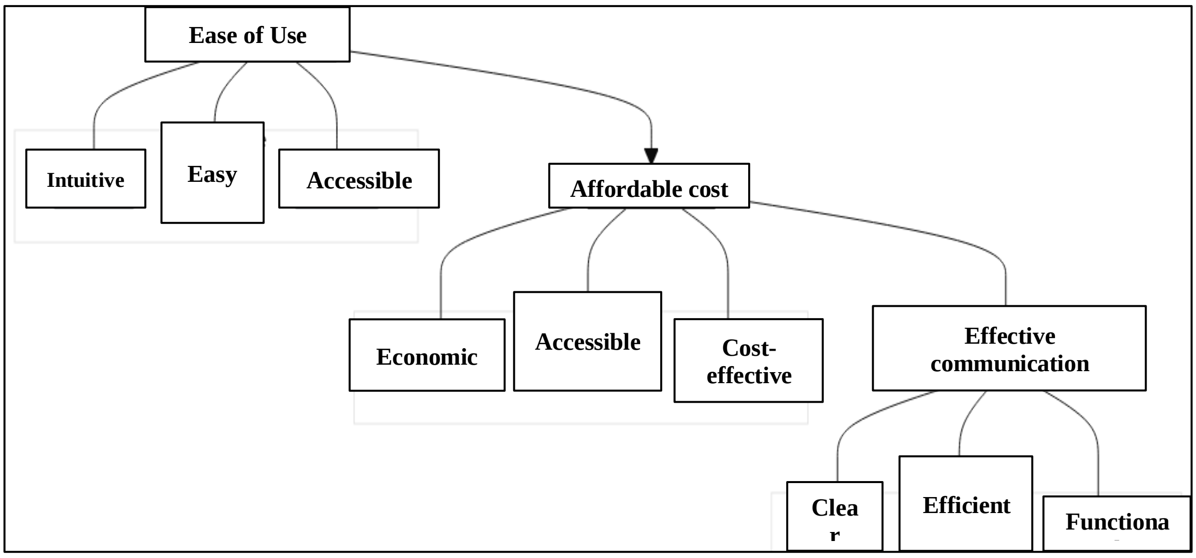

Figure 4

Características con mayor aceptación

Source: self-made.

System Architecture Design: Based on the obtained requirements, a modular architecture was designed to allow for future expansions and/or modifications, ensuring the adaptability of the prototype to the diverse needs expressed by the users. The prototype consists of a splint base, unshielded twisted pair cables (UTP), and a force sensor MF01-N-221-A01, selected to contribute to the optimization, functionality, and efficiency of the system.

The design of the splint base serves as the main support component, designed to provide stability and comfort to the user. The splint is crafted by specialists from the DIF, ensuring proper alignment of the patient's limb, which is responsible for facilitating communication processes. UTP cables are used for their durability and ability to transmit signals efficiently with low interference. They ensure a stable connection between the different components of the system, which is essential for the precise transmission of signals that allow user interaction with the communication system. The MF01-N-221-A01 force sensor was selected for its high sensitivity and accuracy, which are vital characteristics for accurately detecting the pressure exerted by the user. This sensor translates physical signals into data that the system can process to generate precise responses, thereby enhancing user interaction with the prototype. These components were chosen for their ability to work together harmoniously, providing a robust and effective solution for users while allowing for future system updates without the need for significant structural changes (see Figure 5).

Box 5

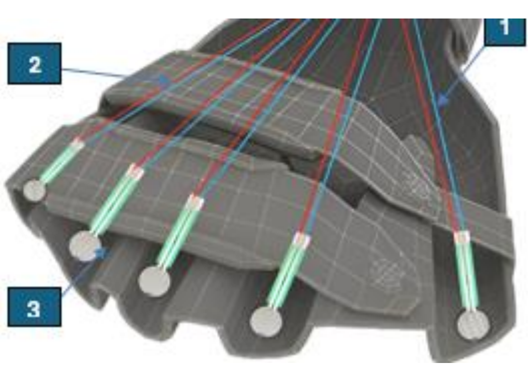

Figure 5

Prototype Communication Design.

The following table presents a description of the key components of the automated communication system prototype for individuals with spastic cerebral palsy. It describes the splint, made from thermoplastic material with an absorbent lining to prevent sweating, which provides a secure fit using Velcro straps to keep the hand firmly attached to the splint. It also shows the male-to-male jumper cables used to connect the various elements of the system in an organized manner. Lastly, the MF01-N-221-A01 force sensor is detailed, which detects the applied pressure, allowing user interaction with the system by modifying its internal resistance based on the force exerted.

Box 5

Tabla 1

Prototype Communication Design

Number	Name	Description	Dimensions
1	**Splint**	Made of thermoplastic with an inner absorbent terry lining to prevent sweating. It incorporates 3 Velcro straps with a safety buckle on the wrist and forearm.	Length: 35 cm
2	**Male to Male Jumper Cables**	Male to male jumper cables are useful for creating cable harnesses or bridging between headers on circuit boards. These cables come in a 40-pin ribbon cable that can be separated to make individual jumpers or kept together for an organized wiring harness.	0.1" sockets on each end that fit snugly side by side on a standard 0.1" pitch header. Each cable is 28AWG (7 strands in 36AWG). Length: 3"
Number	**Name**	**Description**	**Dimensions**
3	**Force Sensor MF01-N-221-A01**	Detects an applied force on the membrane. When a bend is detected in the membrane, the sensor changes its internal resistance. It is made of 2 layers separated by a spacer; the more pressure applied, the more active element points contact the semiconductor, which decreases resistance.	47.20 x 13.00 mm. Weight: 01 g.

Source: self-made

The most representative interfaces of the mobile application are shown below, which is connected and allows the functioning of the prototype architecture by enabling the operation of key components such as the splint equipped with MF01-N-221-A01 force sensors, connected via easily integrated jumper cables. Additionally, user-friendly graphical interfaces are incorporated to facilitate user interaction, a natural language processing module to enhance communication, and integration with mobile devices through a dedicated application, providing an accessible and effective solution to improve the quality of life for individuals with spastic cerebral palsy.

Operation of the Technological Solution: The sensors placed on each finger will be calibrated to detect different levels of force, ranging from 30 grams to 1 kilogram, depending on the type of action to be activated. These force levels are proposed based on studies suggesting that the force exerted by each finger varies according to its use and the context in which it is located.

Each sensor is linked to an ESP32 microcontroller, responsible for sending the signals captured to an application. The range of forces is predefined to activate a specific function when the corresponding threshold is reached. Force Distribution and Assigned Functions:

1. **Thumb:** Activated with 1 kilogram of force. Function: *Eat.*
2. **Index Finger:** Activated with 800 grams. Function: *Emergency*.
3. **Middle Finger**: Activated with 900 grams. Function: *Bathroom.*
4. **Ring Finger:** Activated with 700 grams. Function: *Drink water.*
5. **Little Finger:** Activated with 600 grams. Function: *Sleep*.

This design takes advantage of the ability of each finger to exert different levels of force, as indicated in the study Valencia (2016), which establishes that the middle and ring fingers are the ones that can exert the most force, while the little finger generates the least. This knowledge allows for better calibration of the sensors for each function of the splint. In this way, the system seeks to maximize the use of the residual functionality of the fingers, enabling users to activate specific functions without requiring full hand movement, which improves their autonomy in daily activities.

Figure 6 presents the main interface of the system, which allows user registration under two roles: caregiver or physiotherapist. This functionality defines access options according to the selected role, adapting the available tools to the specific needs of each user. Additionally, in the case of patients, the interface allows for storing and managing progress history, facilitating the tracking of communication data and progress in the communication process, thus optimizing the personalization of treatment by the specialist.

Box 7

Figure 6

Registration Interface

Source: self-made.

In the following interface, the caregiver will be able to monitor the record of notifications related to the patient, as well as the detected movements. These movements allow for the interpretation of the patient's responses, where, through the analysis of these movements, simple responses such as "yes" and "no" can be observed, facilitating communication and tracking of the patient's interactions (see Figure 7).

Box 8

Figure 7

Caregiver role interface

Source: self-made.

Figure 8 shows the main interface of the system, where alerts generated by the sensors are received. This interface consists of several buttons, each corresponding to a specific function: Eat, Emergency, Bathroom, Drink Water, and Sleep. When one of the sensors is activated by the user, the button associated with that function visually highlights, standing out from the others to indicate the selected action. This visualization facilitates user interaction with the system, allowing for a quick and efficient response to the generated alerts.

Box 9

Figure 8
Notification Interface

Source: self-made.

Discussions

Through the results obtained from the instrument regarding the effectiveness of an automated communication system for individuals with spastic cerebral palsy (SCPCA), various findings emerge that deserve in-depth discussion. Firstly, the fact that 72.6% of respondents are unaware of existing prototypes focused on automating communication for patients with this disability indicates a clear opportunity for the development of new technological solutions. This suggests a gap in access to tools that could enhance the quality of life for these individuals, highlighting the need for promoting research and innovation in this area.

Additionally, according to the criteria that respondents consider most important for a prototype, economic factors ranked at 30.6%, ease of use at 30.2%, and effectiveness in communication at 24.6%. These are fundamental to guiding the design of future solutions. The high perception that a prototype connected to a mobile application could improve communication at 94.4% underscores the acceptance and positive expectations toward technology in this context. This also suggests that developers should focus on usability and accessibility to ensure these tools are adopted by end users.

In this context, the demographic analysis of participants, which showed a higher participation of women at 57.5% and a significant awareness of spastic cerebral palsy at 68.3%, is also relevant. This may indicate that women, who often assume caregiving roles, are more involved and more aware of the communication needs of individuals with this condition. The identified challenges in caregiving, such as time requirements and communication issues, highlight the urgency of developing systems that address these specific needs.

The methodology employed, which included quantitative analysis and Extreme Programming (XP) for the prototype design, demonstrates an adaptive and user-centered approach, crucial for ensuring that the final product is not only technically viable but also responsive to the real needs of users and healthcare professionals.

Moreover, the designed prototype not only aims to improve communication for individuals with spastic cerebral palsy but also achieves an adaptable and scalable design suitable for various contexts and populations. Thanks to its modular architecture, it allows for diverse adjustments in sensors and functionalities, helping to better address the needs of users with other conditions, limitations, or even diseases. This technological solution focuses on accessibility and simplicity, enabling its implementation in communities with limited access to advanced technology, thereby promoting the universalization of knowledge and technology transfer.

Finally, the use of agile methodologies, such as Extreme Programming (XP), is a replicable model that can be applied to similar projects in various fields, offering an efficient and participatory approach for all stakeholders involved. These characteristics enhance the prototype's capacity to serve as a foundation for developing technological systems in health and communication, further contributing to universal knowledge by demonstrating that an agile, user-centered approach can overcome economic and social barriers in technological design.

Conclusions

According to the study results, there is a clear need to develop automated communication prototypes for individuals with spastic cerebral palsy, as a high percentage of respondents are unaware of existing solutions for this condition. This represents a significant opportunity for research and development in this field. Additionally, the study identified the aspects most valued by users in a prototype, such as affordability, ease of use, and communication effectiveness, which are considered priorities in designing future technological solutions to ensure their acceptance and use.

Moreover, 94.4% of respondents believe that a prototype connected to a mobile application could improve communication, suggesting that integrating technology into the care of individuals with spastic cerebral palsy has great potential to transform their quality of life. The higher participation of women in the study and their knowledge of spastic cerebral palsy indicate that caregivers are a key group in identifying needs and promoting solutions. Therefore, development strategies should consider the perspectives of those caring for these patients.

Finally, the use of the Extreme Programming (XP) methodology in the prototype design has proven effective, enabling continuous adaptation to users' needs and emphasizing the importance of a user-centered approach in developing assistive technologies. The user-centered design and scalability of the prototype allow this solution to benefit individuals with spastic cerebral palsy as well as other populations with similar needs, promoting the advancement of knowledge and technology in society. Future research should focus on evaluating the effectiveness and acceptance of developed prototypes and exploring their impact on users' daily lives and the practices of healthcare professionals.

Declarations

Conflict of Interest

The authors declare that there is no conflict of interest. There are no financial interests or personal relationships that could influence the results and conclusions presented in this study.

Contributions of the Authors

The structure and writing of the chapter were developed by Reyes Delgado, Aurea Teresa, who led the organization of the content. Martínez Dávila, Javier Eduard, provided the essential information for the formulation of the chapter, contributing key data and analysis. On the other hand, Javier, together with Padilla Cruz, María Belén, and Martínez Urzúa, Ximena, were responsible for the design and development of the prototype, ensuring the technical and functional feasibility of the presented system. Each author played a fundamental role in the creation of this work, contributing their specific expertise and knowledge to the development of the complete chapter.

Availability of Data and Materials

The data is available.

Funding

The research was developed using the authors' own resources, and it is expected that the publication will be funded by the Tecnológico de Estudios Superiores de Jocotitlán.

Abbreviations

1. AAC
2. AOT
3. CFCS
4. CP
5. DIF
6. GMFCS
7. MACS
8. MT
9. SCPCA
10. UTP
11. XP

References

Background

Kleinsteuber S. K., Avaria B. M. de los Á., & Varela E., X. (2014). Actualización: Parálisis cerebral. Revista Pediatría Electrónica, 11(2). Universidad de Chile.

Boa, S. (1995). Augmentative and alternative communication systems used by people with cerebral palsy in Scotland: Demographic survey. Academia.

Naranjo V., S. Y., Meriño P., Y., & Soler O., J. A. (2023). Parálisis cerebral infantil. Actualización bibliográfica. En II Jornada Virtual de Medicina Familiar en Ciego de Ávila “MEFAVILA2023”.

Rosendo, N., & Vericai, A. (2023). Evaluación de los movimientos generales en niños prematuros para predicción de parálisis cerebral. Archivos Argentinos de Pediatría, 121(3), 265-271.

Serna, E. (2020). *Investigación formativa en ingeniería 4.* Editorial Instituto Antioqueño de Investigación.

Torres Monreal, S. (Coord.). (2001). Sistemas alternativos de comunicación: Manual de comunicación aumentativa y alternativa: Sistemas y estrategias. Ediciones Aljibe.

Universidad Autónoma de Nuevo León. (s.f.). Parálisis cerebral espástica, el tipo de parálisis cerebral más frecuente. Centro de Investigación y Desarrollo en Ciencias de la Salud.

Basic

Efisiopediatric. (2016, June 15). *Sistemas de clasificación funcional en la parálisis cerebral*. Efisiopediatric.

Murphy, J., Marková, I., Moodie, E., Scott, J., & Boa, S. (2009). Augmentative and alternative communication systems used by people with cerebral palsy in Scotland: Demographic survey. Augmentative and Alternative Communication, 25(1), 26–36.

Bustamante, D., Rodríguez, J. C., & Universidad Nacional Experimental de Los Llanos Occidentales Ezequiel Zamora. (2014). *Metodología* XP [Documento en línea].

Medium

Valencia-Otero, Á. F., Maradei-García, M. F., & Espinel-Correal, F. (2016). Estudio sobre la influencia del diámetro de apertura en la fuerza ejercida por cada dedo. *Revista de Salud Pública, 18*(6).

Reyes T. P. (2023). *Diseño de una férula de muñeca impresa en 3D con soporte para un exoesqueleto de los dedos de la mano* [Trabajo fin de grado, Universidad de Málaga]. Repositorio Institucional de la Universidad de Málaga (RIUMA).

Pérez S. A. I. (2020). *Dispositivo robótico para mejorar la capacidad de movimiento de niños con espasticidad* [Robotic device to improve the movement ability of children with spasticity] (Doctoral thesis, Centro de Investigación y de Estudios Avanzados del Instituto Politécnico Nacional).

Differences

Álvarez D. R. (2022). *Prototipado de un posicionador de muñeca y mano para la fabricación de ortesis avanzadas* [Prototyping of a wrist and hand positioner for the manufacturing of advanced orthoses] (Bachelor's thesis, Universidad de Valladolid).

Ayudas Dinámicas. (n.d.). Posicionador de brazo para silla. *Ayudas Dinámicas*. Retrieved October 8, 2024,

Bahamonde Santander, M. A. (2023). Tablero digital de comunicación para niños con parálisis cerebral [Tesis de pregrado, Universidad de Chile].

Iza Morales, L. E. (2018). Implementación de un prototipo de guante electrónico inalámbrico para ayuda a personas con discapacidad motriz [Tesis de pregrado, Universidad de las Américas].

Kurten P., T., Fernández S., G., Ferrari, F. A., & Gialonardo, J. I. (2023). *Comunicador para personas con parálisis cerebral severa*. 7º Jornadas ITEE - 2023, Facultad de Ingeniería, Universidad Nacional de La Plata

Discussions

Aguilar B. S. (2005). Fórmulas para el cálculo de la muestra en investigaciones de salud. *Salud en Tabasco*, 11(1-2), 333-338. Secretaría de Salud del Estado de Tabasco.

Arroyo D., M. (2022). La comunicación en personas con parálisis cerebral [Master's thesis, Universidad Europea de Valencia].

Azcárate Corrales, L. M. (2021). *Teleterapia psicológica en niños y jóvenes con parálisis cerebral* [Trabajo final integrador, Universidad de Palermo]. Repositorio Académico de la Universidad de Palermo.

Briones, E., Ortega, C., García, G., & Monroy, A. (2019). Un sistema de comunicación alternativo y aumentativo para el tratamiento de personas con parálisis cerebral. Revista de Investigación en Educación, 17(1), 21-33.

Calleja, M., Luque, M. L., Rodríguez, J. M., & Liranzo, A. (2015). Incremento de la competencia lingüística en dos sujetos con parálisis cerebral mediante el dispositivo Makey-Makey: Un estudio de caso. Revista de Investigación en Logopedia, 5(2), 112–134.

Palacios, J., Dorado M., A. C., Vera M., V., & Arguello-V., P. (2023). Communication systems in a population with cerebral palsy. *International Journal of Education and Public Health*, *6*(1). 5

Palomo C. R., Zuil E., J. C., Cabrera G., M., Barreda M., P., & Martínez C. B. (2022). Terapia en espejo y de observación de la acción en niños con parálisis cerebral espástica unilateral: estudio de viabilidad. Revista de Neurología, 75(11), 325–332.