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Assistive Technology for Enhancing Fine Motor Coordination: From Prototype to Implementation and Initial Acceptance Testing

Thiago Adriano Coleti [**State University of Northern Paraná** | ***thiago.coleti@uenp.edu.br***]
Victória Martins [**State University of Northern Paraná** | ***martinsvictoriaa@gmail.com***]
Lucas Chaves Generoso [**State University of Northern Paraná** | ***lucaschavesgeneroso@gmail.com***]
Gabriela Cristina de Oliveira [**State University of Northern Paraná** | ***gabriela.cristina@uenp.edu.br***]
Maisa Lúcia Cacita Milani [**State University of Northern Paraná** | ***maisa@uenp.edu.br***]
Daniela de Freitas G. Trindade [**State University of Northern Paraná** | ***danielaf@uenp.edu.br***]
Maria Renata de Mira Gobbo [**State University of Northern Paraná** | ***mr.gobbo@uenp.edu.br***]
Thais Helena C. Patelli [**State University of Northern Paraná** | ***thaispatelli@uenp.edu.br***]
José Reinaldo Merlin [**State University of Northern Paraná** | ***merlin@uenp.edu.br***]

State University of Northern Paraná, Rod. BR 369, Km 54, Vila Maria, Bandeirantes, PR, 86.366-570, Brazil.

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Abstract: Fine Motor Coordination (FMC) refers to the use of hand and wrist muscles and is related to functional activities of daily living, such as eating or studying. Individuals with Down Syndrome, Autism Spectrum Disorder and Attention Deficit Hyperactivity Disorder often exhibit have fine motor skills deficits, which can result in impaired joint mobility and muscle tone. Considering these characteristics and the importance of FMC in promoting independence, this project aimed to design an Assistive Technology in form of assistive games to support FMC evolution in institutions that work with people with disabilities. The project was performed in two stages. In the first, to design and refine the proposal, interviews with professionals, followed by prototyping and evaluation were conducted with the aim of creating and evaluating the prototypes, which were considered satisfactory. In the second phase, a functional tool comprising four assistive games was developed and applied at the Equotherapy Center. Professionals from the Equine Therapy Center used the tool with four practitioners and reported that it was well accepted and considered promising for long-term treatment.

Keywords: Assistive Technologies, Assistive Games, Fine Motor Coordination, User-Centered Design

1 Introduction

The objective of Assistive Technology (AT) is to promote independence, autonomy, and a better quality of life for people with disabilities (PwD), through a wide range of resources and services. These can vary from simple devices, such as eyeglasses and canes, to advanced technological solutions, such as applications and computerized systems [Sousa *et al.*, 2024].

AT is widely used in special education, as it aims to adapt both tools and methodologies to the specific needs of each person. Additionally, it provides individuals with the possibility to adapt or assimilate more easily than conventional processes, which are designed from a collective perspective. The development of AT requires specific actions to understanding the users' requirements and develop the functionalities, ensuring that the methods, techniques, and/or tools are developed correctly.

Fine Motor Coordination (FMC) refers the use of small muscles in the hands and wrists to handle objects with precision. This ability enables basic daily activities such as eating, handling objects, or using a cell phone to be performed. FMC deficiencies are particularly observed in individuals with conditions such as Down Syndrome (DS), Autism Spectrum Disorder (ASD), and Attention Deficit Hyperactivity Disorder (ADHD), leading to difficulties in tasks such as getting dressed, studying, and manipulating objects in general [Memisevic and Macak, 2014; Coppede *et al.*, 2012; Ferreira-Vasques and Lamônica, 2015]. Education and health professionals working with individuals with these conditions apply various activities, both in the classroom and during physical therapy sessions, to address theses challenges [Suggate *et al.*, 2017; Rule and Stewart, 2002; Stewart *et al.*, 2007; Guardia and Coelho, 1993].

Researches underscores that Information Technology (IT) and AT approaches can support improve FMC [Axford *et al.*, 2018]. However, computational strategies, methods and tools specifically designed for FMC are scare, which leads to the adaptations of tools intended for other functionalities. Furthermore, Lin *et al.* [2017] and Lorenzo *et al.* [2015] highlight that it is common to use resources designed for individuals with typical development, which often leads to unsatisfactory results in the development of FMC.

This paper presents the actions performed in partnership with Association of Parents and Friends of the Exceptional (APAE) in the city of state of Paraná, for the specification and prototyping of an Assistive Technology in the form of assistive games to support the development of Fine Motor Coordination (FMC). The specification and prototyping were carried out using User-Centered Design (UCD) techniques, which place the user at the center of the design process. In the first phase of the research, the users were the professionals from APAE, and in the second phase, the users were professionals from the Equine Therapy Center at Northern Paraná State University (NE-UENP).

As a result, in first phase, we provided prototypes of a tool with functionalities that, according to APAE professionals, would be significant to support activities with FMC were presented. In second phase, we developed functional assistive games, which were applied with NE-UENP practitioners and evaluated by professionals from that organization.

This paper is an extension of **User-Centered Design for the Proposal of an Assistive Technology for Fine Motor Coordination** by Coleti *et al.* [2024], presented at the V Workshop on Implications of Computing in Society (WICS) at the 44th Congress of the Brazilian Computer Society. The original work presents the process of defining the context of use, eliciting requirements, prototyping and evaluating an Assistive Technology proposal for CMF. Thus, the context of the first article was understanding the possible advantages and challenges in using Assistive Technologies for the development of FMC and in the construction and validation of prototypes for a set of games.

In this paper, the content consists of a description of the implementation of a functional tool and the use and evaluation of four games, developed based on the games proposed in the original article, with practitioners from the Equine Therapy Center of the State University of Northern Paraná, with disabilities/disorders that impact FMC. In the article's extension, the main information on the development of the games, their use at NE-UENP, the results and discussions are presented. Thus, this article presents approximately 50% of new content.

In addition to this Introduction Section, this paper is organized as follows: The Section 2 presents the research background, the Section 3 presents the Methodology that is organized in Design, Prototyping and Validation, from original paper, and Development of functional software application, from extension, the Section 4 presents the Results and discussions, the Section 5 presents Limitations and Threats to Validity, the Section 6 the Conclusions and the Section 7 the Future Works. Also, we present a Section with Declarations.

2 Background

This section introduces the foundational concepts that guided this research: Fine Motor Skills, Assistive Technologies, User-Centered Design, Game Design, and related studies.

2.1 Fine Motor Coordination

Fine Motor Coordination form the basis of many everyday activities in the early stages of life, such as eating, drawing and dressing [Memisevic and Macak, 2014]. It concerns the use of small muscles in the hands and wrists to manipulate objects precisely and are also essential for a successful transition to school, e.g. [Luo *et al.*, 2007].

Changes in FMC are found both in children with typical development [Strooband *et al.*, 2020] and in children with atypical development, such as Down Syndrome [Oliveira *et al.*, 2016], Cerebral Palsy (CP) [Montoro-Cardenas *et al.*, 2022], Autism Spectrum Disorder (ASD) [Kangarani-Farahani *et al.*, 2024], Attention Deficit Hyperactivity Disorder (ADHD) [Montes-Montes *et al.*, 2021], among others. For these, conventional therapy aims to improve, enhance and even recover the motor function of the upper extremity [Levac *et al.*, 2017].

Limitations in FMC make it difficult to carry out daily activities and self-care, which negatively affects patients' quality of life and increases the burden on caregivers [Ouyang *et al.*, 2020]. In addition, it limits children's participation in family, school and recreational activities [Chen and Howard, 2016]. Therefore, improving the motor function of the upper limb can facilitate the execution of these tasks and, consequently, improve quality of life, by allowing greater involvement in social and educational contexts.

To make the improvement of FMC possible, health and education professionals apply a series of activities. Usually, small objects are made available that are manipulated by the patient in games, such as: passing a thread through beads, putting coins in a piggy bank, painting and pinching insects in a garden [Suggate *et al.*, 2017; Rule and Stewart, 2002; Stewart *et al.*, 2007; Guardia and Coelho, 1993].

Furthermore, some patients report that conventional therapy protocols are repetitive, long and monotonous, which can reduce motivation and adherence to therapy [Ribeiro *et al.*, 2015; El-Shamy, 2018]. Thus, in recent years, games have been used as a therapeutic option that presents results as a good auxiliary tool along with traditional rehabilitation methods [Ashwini *et al.*, 2021].

2.2 Assistive Technology

The use of assistive technology in special education has grown significantly since the 1990s, expanding into a broader range of applications [Edyburn, 2000]. While initially associated with individuals having sensory and physical disabilities, such as motor impairments, mobility limitations, and visual or auditory impairments, AT has evolved to address neuropsychiatric and cognitive deficits as well, fostering a more inclusive approach [Baltzar *et al.*, 2023].

AT is designed to break down barriers and foster active participation among students with disabilities, particularly by developing fine motor skills essential for everyday tasks like writing, using small objects, and precise manipulation [Golchin *et al.*, 2024]. For instance, tablet apps and software can help students improve their fine motor coordination through touch and drag games that involve connecting dots in a picture or threading virtual beads.

These touch-controlled activities offer customizable parameters such as speed, size, and sensitivity to accommodate the unique abilities of each user. Furthermore, a game designed to enhance fine motor skills could involve tasks like pinching to manipulate virtual objects on the screen, simulating real-world actions.

AT can provide benefits to students with and without disabilities, offering resources that facilitate enhanced interaction and learning outcomes [Bernardo *et al.*, 2016]. For instance, a child who exhibits a preference for visual and tactile learning modalities can utilize tablet-based games to develop fine motor skills through tasks involving dragging and dropping, thereby cultivating greater motor control. Whether traditional, board or digital, games offer a space where students can experience social roles and cultural rules, while actively constructing new knowledge [Nascimento, 2024]. This reinforces the idea that interaction with digital games not only contributes to literacy, but also strengthens the development of cognitive and social skills.

According to Prensky [2012], digital games go beyond merely engaging students, as they have the potential to develop essential 21st century skills such as critical thinking and problem solving. When used with pedagogical intent, they also foster a playful environment for exploration, interaction and the re-signification of knowledge.

As noted in Baltzar *et al*. [2023], assistive technology resources include assistive games, which can be adapted in two ways: (1) by modifying existing games to accommodate user needs through features like adjustable speed, touch sensitivity, and visual or auditory feedback. This allows players to practice fine motor skills by completing tasks such as manipulating small objects or tracing paths on a touchscreen. (2) By creating games specifically designed for particular needs, such as audio or visually stimulating games, which provide guided instruction and challenges. These games are developed from the ground up to meet the unique requirements of users, teachers, and students.

To illustrate assistive games for fine motor skill development, consider a game that requires users to employ a pincer grasp to "capture" virtual objects on the screen. This reinforces the movements essential for tasks such as writing and manipulating small objects. Moreover, the use of alternative input devices, including adaptive pencils and touch-sensitive joysticks, significantly enhances accessibility.

The integration of AT and gamified activities demonstrates the potential to render the rehabilitation process more interactive and motivating. Such games enable users to practice motor skills within a controlled environment, facilitating the ongoing monitoring and adaptation of therapeutic interventions to meet the specific needs of each individual.

2.3 User-Centered Design and Game Design

The end-user satisfaction of software applications is a constant concern for researchers, who promote methods and techniques for the conception of technologies, and for developers, who must apply them effectively and efficiently. Meeting the demands, characteristics, and other specificities of users should be the objective of a design project and it is necessary to search for methods, techniques and tools to support these actions.

User-Centered Design (UCD) is a systematic approach that prioritizes the user throughout the design and development process [Cybis *et al*., 2015]. Key UCD principles, as outlined by Souza and Savi [2015], include user focus, active user involvement, iterative development, simplified representation, prototyping, contextual evaluation, and a holistic design perspective. Given the widespread use of UCD in educational product development, this approach was adopted to create the games in this project.

UCD is often visualized as a cycle, as depicted in Figure 1 (adapted from Cybis *et al*. [2015]). Beyond problem identification, the UCD process typically involves the following steps:

- Specification of the context of use: This phase aims to gain a deep understanding of end users, their environment, and their specific needs. Designers can focus on qualitative data collection, such as interviews, questionnaires, and ethnographic studies, to uncover factors that will influence the design.
- Requirements Definition: a phase in which the information obtained in the previous phase is documented and analyzed seeking to capture the expectations and goals of users in relation to the proposed product or service;
- Prototype Generation: a fundamental step in UCD that, through high or low fidelity designs, assists in the experimentation, testing, and refinement of design concepts in an iterative and collaborative manner. By facilitating the visualization of ideas, testing usability, reducing costs and time, facilitating effective communication, validating concepts, and maintaining a focus on the user;
- Testing/Evaluation: through a set of evaluation methods and techniques such as inspection, usability testing and A/B testing, they assist in maintaining and ensuring that the project is in accordance with the user's needs.

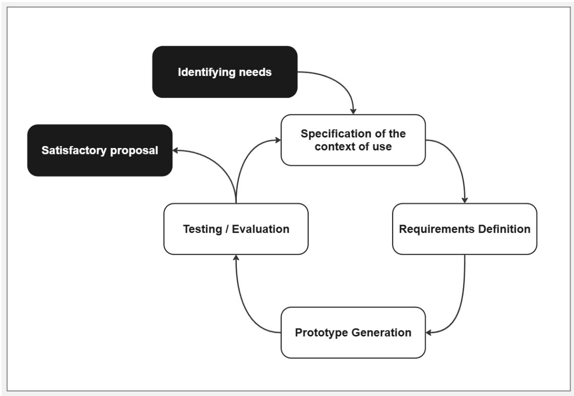

Figure 1. UCD Model - Adapted from Cybis *et al*. [2015]

When considering the construction of Games as the focus of the solution, concepts such as Game Design should be used within UCD to ensure that game mechanics are appropriately applied, for example, for assistive games. Vitor *et al*. [2024] highlight several Game Design concepts, which in general lead to the definition of Game Design as the use of creativity and design to create design elements, rules, mechanics, and game resources such as stories, characters, goals, rules, and challenges.

While there is no one-size-fits-all approach to educational game design, Valenza *et al*. [2018] provides a comprehensive set of guidelines to inform the development process. Although not exclusively focused on children, these guidelines offer valuable insights for designing games for young audiences. In the context of this work, we highlight the following:

- Simplify the use of interaction devices: mechanisms should be designed considering the characteristics of the

users, for example, children do not have the motor development of an adult;
- Provide efficient mechanisms of Human-Computer Interaction with the elements;
- Prefer recognition over recall: information should be presented in a way that the user can recognize its use, instead of needing to memorize it;
- Use a predominantly visual interface: with a focus on non-literate users or those seeking a specific objective that is not related to literacy, the use of non-visual elements can facilitate interaction;
- Give visibility to interaction elements: highlight the elements with which users, especially children, should interact. Children tend not to analyze interfaces, but to conduct immediate interactions with elements as soon as they identify them;
- Design interesting and challenging activities: seek to develop stimulating activities, with resources that arouse interest and maintain attention and motivation.

Ultimately, it can be assumed that the combined use of UCD strategies with Game Design methods and techniques can provide efficient, motivating, and applicable games for a wide range of purposes, especially when games are applied to support assistive activities.

2.4 Related Works

In the literature, it is possible to find works that seek to employ technology to contribute to the development of FMC. The works that will be cited had as their main objective to apply tools or techniques that were not specifically designed for FMC. There is a scarcity of works aimed at developing tools and/or assistive technologies specifically for FMC.

Nacher *et al.* [2018] assessed the ability of 55 children, both male and female, aged 5 to 10 years with SD, to develop gestures on a touch screen. Activities were developed in which children interacted with a tablet using gestures such as touch, drag, and rotate. Instructors collected data to assist in the study of metrics such as success rate, completion time, and number of touches. As results, problems with long touch accuracy and multiple touches were identified. However, the results were considered positive, as the success rate was above 90% for all tasks, except for the long touch, which was 70%.

Axford *et al.* [2018] aimed to investigate the effectiveness of iPad applications in developing fine motor skills. They selected 53 children aged 5-6 from two preschools (25 in the control group and 28 in the experimental group). Participants underwent assessments of visual perception, visual-motor integration, motor control, writing skills, and functional motor performance before and after the intervention. The control group engaged in traditional FMC activities such as cutting, stacking blocks, and shape sorting, while the experimental group used iPad applications for 30 minutes daily during class time.

The results of the study by Axford *et al.* [2018] presented small changes in both groups, but the experimental group demonstrated greater gains in writing, unilateral skills, scissor use, dressing, and hand grasping compared to the control group. The control group showed greater proficiency in drawing shapes and tying shoelaces after the intervention. Finally, the authors highlight that iPads may positively influence fine motor development, but caution against generalizing these results based on preliminary findings.

Axford *et al.* [2018] also identified a set of tools that implement actions that can be used for fine motor skills development, such as touch activities, object sorting, and pathways. However, none of these tools were specifically designed for fine motor skills or for the population that typically faces this type of disability.

The forms of interaction in digital games, such as touch, slide, drag and drop are widely used in entertainment games, commonly available on online gaming platforms, such as the game Busy Shapes & Colors [Edoki Academy, 2024], which aims to teach shapes and colors, using interactions of dragging and fitting objects, as well as helping in the development of cognitive and motor skills through playfulness.

3 Methodology

This section outlines the materials and methods in the research. Manzini [2006] highlights that the developing methods, techniques and tools, such as Assistive Technologies, for education requires a set of steps that include: (1) understanding the domain; (2) generating ideas; (3) choosing a viable alternative; (4) representing the idea; (5) building the object; (6) evaluating the use; and (7) monitoring the use. These steps align with the UCD process, as described by Torres *et al.* [2018] and Sobral [2019] and presented in Figure 1.

The similarities motivated the decision to adopt the UCD process, incorporating techniques and deliverables to address the requirements of both phases, as explained:

1. The first phase focused on design, prototyping and validating of a proposal, without developing a fully functional product. In this phase, deliverables were created based on the proposed by Pereira [2019], which aim to support the specification and development of digital products with a strong focus on user experience;
2. In the second phase, a functional software application based on assistive games was developed. The games were tested and evaluated by a group of users as physiotherapy professionals, physical education professional and psychologist from the Equine Therapy Center of the State University of Northern Paraná (NE-UENP).

Actions regarding to the ethical issues of this research are presented in the next subsection.

3.1 Ethical Issues

The research adhered to the ethical principles of Brazilian regulations, safeguarding the participants' rights. The project was submitted to and approved by the Research Ethics Committee of the Northern Paraná State University - UENP (CAAE 77523024.0.0000.8123).

Before application of the tests, physiotherapists signed the Informed Consent Form, after being informed of their rights, the risks, and benefits of the research. Anonymity of the responses was ensured, with written observations being typed rather than handwritten.

When approaching the minors' guardians, simple language was used, avoiding technical terms that were difficult to understand. They were informed of the objective of the project and the risks and benefits of the minors' participation in the research. These risks could include: fatigue when carrying out the activities, possible nervousness due to not knowing how to play the games, and breach of confidentiality regarding the participants' identity. They were also informed of the measures to mitigate these risks, which were: carrying out activities of short duration, supervision by professionals during the execution, and anonymity of the observations. To ensure privacy protection, no images of minors or other types of personal records would be taken. After agreeing, the guardians signed the Free and Informed Consent Form.

The children's consent was obtained after a detailed explanation of the activities, considering the participants' cognitive and communicative abilities, ensuring that everyone understood the process and could make informed decisions. They were informed that they could stop the activity at any time, without any consequences. Also, they were informed that if they had any difficulties during the activity, they would be helped by the therapists. Specific measures were taken to address the vulnerability of the research participants. The activities were administered and analyzed by therapists with whom the children were already familiar, rather than by the project's technical team. The aim was to ensure the children felt safe expressing their feelings. The professionals are trained to monitor the participants' well-being while carrying out the activities.

To ensure the well-being of participants, the time and needs of participants were respected during the testing, with the team always available to support and adjust the approach as necessary, aiming to minimize any risk of discomfort or harm. At all times, participants were invited to express their desire to continue or stop the testing, and the team, composed of three professionals, was present to monitor stress, frustration, fatigue, and offer support whenever necessary.

Although some participants expressed disappointment during certain moments of the games, the team was ready to offer emotional support and try again, ensuring that the experience was positive and comfortable for everyone.

3.2 Design, prototyping and validation of the proposal

This subsection presents a stage of the project published in the paper ***User-Centered Design for a Proposal of an Assistive Technology for Fine Motor Coordination*** by Coleti *et al*. [2024] at the 5th Workshop on Implications of Computing in Society (WICS) at the 44th Congress of the Brazilian Computer Society. In this stage, we aimed to understand the needs, demands, and characteristics of the FMC and how the technology could support it. A set of prototypes addressing the identified requirements were also created and evaluated.

3.2.1 Identifying Needs and Specifying the Context of Use

This stage aimed to understand the characteristics of the actions carried out by APAE professionals support the development of FMC in students with this condition in the APAE unit. Five interviews were conducted[1] and a brainstorming session with the professionals involved in the project. These activities were intended to gather insights about the activities focused on FMC implemented at the institution.

The participants in this stage included three physiotherapists, one occupational therapist and three teachers. They were asked about general aspects of their work, activities they developed and their expectations regarding the use of AT in activities related to FMC. It is important to highlight that, in this project, the students from APAE did not participate, and the researchers did not have access to any personal data; only the methods used by professionals were analyzed.

Regarding the **general aspects** of their work, the following information was gathered: (1) the physiotherapists reported that older students (+10 years) tend to have well-developed FMC while younger students face greater difficulties; (2) the occupational therapist stated that he works with students both with and without developed FMC and that there may not be much difference between them in some activities; and (3) the teachers emphasized that students with compromised FMC have greater difficulty picking up objects because "*their hands are very soft and flat*".

Regarding the **activities developed**, the responses were similar. The physiotherapists and the occupational therapist work with small objects, toys, beads and blocks to fit together, based on verbal and visual commands. In the classroom, these skills are developed through cutting, gluing and drawing activities. Additionally, adapted teaching materials are used, such as pencils with a larger circumference or in a triangular shape. The teachers emphasized aspects of the children's writing, such as: (1) in the first interview, they pointed out that children can write in capital letters after learning to read and write, but face difficulties with cursive handwritten; (2) in the second interview, the professional mentioned that the use of adapted teaching materials supports FMC development.

Professionals were asked about their expectations and potential of using AT to assist in FMC activities. The physiotherapists were the ones who highlighted possible characteristics for an AT. These professionals emphasized that an application could significantly contribute to physiotherapy activities if it includes characteristics such as:

- Writing resources should be handled with care, both in quantity and functionality;
- The AT should have its functions segmented by skills to support personalized application;
- The application could make use of *tablet* resources for bilateral training;
- It could present resources to test the student's speed and challenge them, to feel motivated;
- It should be intuitive, catching the student's attention

[1] The number of interviews was influenced by the professionals' availability to participate and time available for discussion.

but not to the point of not wanting to leave the cell phone;
- It should be aligned with pedagogical objectives to teach color, numbers and letters; and
- It should challenge students' skills more, since they are already accustomed to simple gestures on social networks.

Regarding the use of the tablet, it is worth noting that professionals emphasize that the slightly larger size of this device, together with its ability to support gestures such as tap, double tap, long tap, tap and drag, pinch to increase, decrease or rotate, makes it ideal for the activities.

The occupational therapist highlighted that it would be interesting to have examples in the software, to be used in a demonstration given by the professional or by the application, which would teach how to do it for the student with DS to repeat. Furthermore, the tool should be playful with verbal or gestural explanation, with little (or no) text because it is assumed that they would not read. Finally, teachers emphasized that it should attract attention and stimulate interest, as students tend to be quite stubborn and resistant to things that do not interest them.

The interviews allowed us to assume that an AT can support teaching activities in special education. Through the interviews and brainstorming, it was possible to understand the main characteristics, elements and needs of the APAE professionals and the activities for the development of FMC in children with DS. Additionally, we identified the characteristics of an AT application expected by the professionals who work with FMC and, based on these data, the requirements of the tool were proposed, which are described in the next subsection.

3.2.2 Requirements Definition

This stage began with the proposition of the user profile. It was done using *Personas*, which are fictitious representations of end users created based on data obtained during actions with the target audiences of the tool [Branco *et al.*, 2020]. One *persona* was created for the student profile and another for the professional profile.

The *persona* representing the students was "Isabela", a student under the age of ten, who presents the following characteristics: **Literacy** - some students develop this skill late, in addition to experiencing difficulty in identifying letters out of sequence; **Friendliness** - since students with DS are kind and affectionate with these professionals, as they have known them for some time; and **Difficulty handling school materials** - Isabela struggles with handling school materials and is farsighted. Isabela's *persona* is shown in Figure 2[2].

The APAE professionals were represented by the *persona* "Roberta", presented in Figure 3. This *persona* is characterized by having ease with technology, once she has contact with social networks, and in acquiring and applying new knowledge in her daily life, important characteristics to enable the application of this project in contexts that primarily involve traditional training.

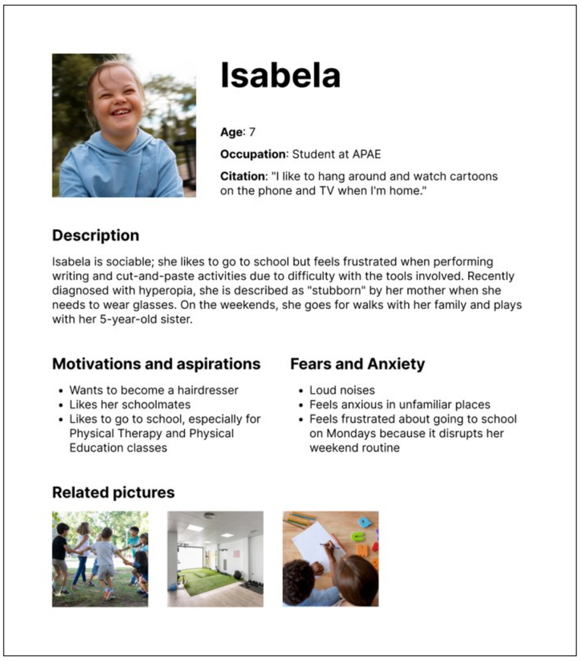

Figure 2. *Persona* Isabela.

At this stage, the activities to be developed within an AT were also outlined. These are presented in Table 1. The activities were defined considering the need for simple games, playable by children, that explored the FMC development actions using resources usually native to *tablet* such as touches and lateral movement.

Each skill developed in the games is needed to perform movements in daily activities. The pincer grasp is essential for many daily activities, such as buttoning and unbuttoning clothes, opening and closing zippers, picking up food with your fingers, handling jars, and holding a pencil to write or draw. The ability to drag and position objects correctly helps organize and handle toys and school supplies, as well as correctly positioning plates, cutlery, and glasses on the table. Bilateral coordination is essential for gross motor activities, such as riding a bicycle or tricycle, holding an object with one hand while manipulating it, getting dressed, and cutting food with a knife and fork. The ability to single and double touch can help in activities such as pressing buttons on remote controls, calculators, and touch devices, opening and closing objects that require quick and precise touches, such as pencil cases, and using switches and doorbells.

An initial set of non-functional requirements related to usability and user experience was also defined, which included: avoiding excessive text; ensuring readability; segmenting activities according to the trained skill; testing the student's speed in completing the activity; enabling the demonstration of challenges and aligning the system with pedagogical objectives, such as teaching colors, letters and numbers.

3.2.3 Prototypes

In this stage, prototypes for an AT to support FMC activities were developed. The activities described in Table 1 were considered, along with the user profiles and requirements identified in Subsection 3.2.2. The prototypes were

[2]The images used in the personas were taken from the image banks https://www.pexels.com/pt-br/, https://unsplash.com and https://br.freepik.com (last accessed on 27 May 2025)

Table 1. List of identified skills and proposed activities

Skills	Activities	Description
Pincer movement	Object hunting	Finding a specific object among several, being able to enlarge the image.
	Zoom in on shapes	Make a shape larger or smaller with pinch movements
Touch and move	Connect an object to its name	Connect a column with objects to a column with their names.
	Maze	Guide an object through a maze using a touch gesture.
	Connect Shapes	Connect two shapes randomly presented in the interface.
	Decorate an image	Use the camera to take a photo and decorate it with items predefined by the tool.
Bilateral Coordination	Rotation	Move the *tablet* level to move an object to a target.
	Drive car with steering wheel	Move the *tablet* level to move the vehicle along a road.
Single and Double Tap	Painting Activity	Coloring Drawings with Single and Double Tap.
	Catch fruits	Catch fruits by double tapping as they fall on the screen.

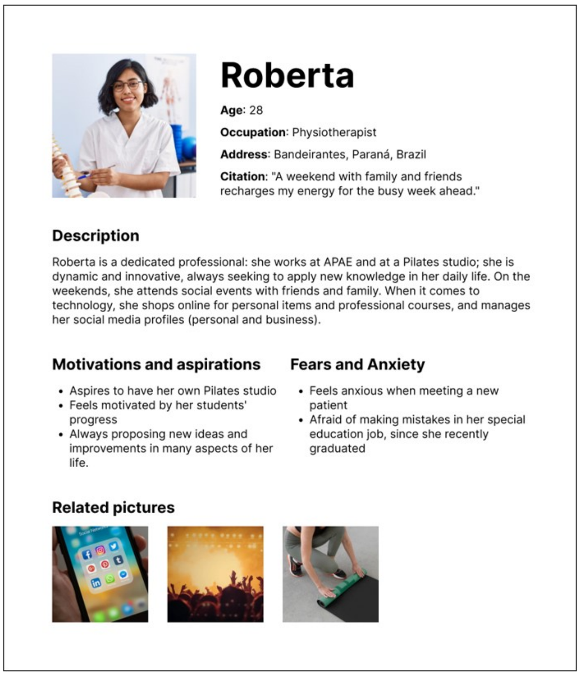

Figure 3. *Persona* Roberta.

built with the Figma tool[3] and are presented in the *layout* for *tablet*, due to the expectations of the professionals, mentioned in the previous subsection.

It is worth noting that the prototypes were developed to define the interface's general structure and how the games' main elements would be distributed in the game interfaces. At this stage, the difficulty levels of the games or the applicability of the game elements by type of user or other specific characteristics were not considered, leaving this decision to be evaluated together with professionals who will use a functional version of the games. For example, in the second stage, presented in Section 3.3 where functional games were implemented for validation, the difficulty levels and technical details of the games were defined together with professionals from NE-UENP.

By default, it was defined that the activity interfaces should present a central space, occupying approximately 70% of the screen size, which would be intended for the presentation of the activity elements; and two buttons (Restart and Back) located at the upper ends. All interface elements were designed with the usability and experience requirements discussed in Section 3.2.2.

For the **Pinch Movement** skill, the prototypes for the **Object Hunt** game are presented in Figure 4. In this activity, free images available on websites such as Pixabay were used[4], providing enough content for the student to enlarge or reduce the image size with pinch movement to identify different objects.

Figure 4. Object Hunt Game Interface Prototype - Created by Generative AI.

For the **Enlarge shapes** game, presented in Figure 5, geometric shapes or various designs such as stars or animals were used. The pinch movement allows the size to be increased or decreased to a predetermined size, presented in dotted lines.

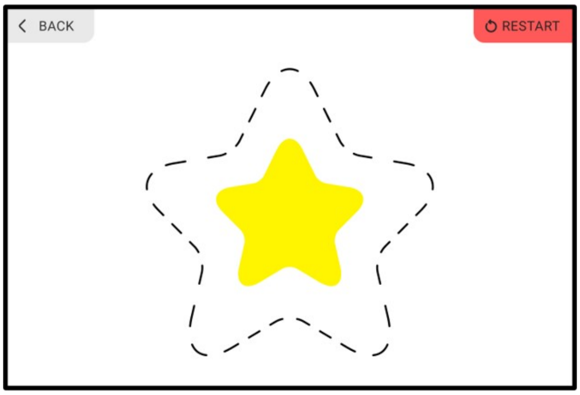

Figure 5. Prototype of the Enlarge Shapes game Interface

[3]https://www.figma.com/ - Last accessed on 25 May 2025.

[4]https://pixabay.com/pt/ - Last accessed on 25 May 2025.

For the **Touch and Move** skill, prototypes were created for game which the user must select an object and move it. In general, these are *connecting elements* activities presenting in the interface, with variations between texts, shapes and images. For the **Connecting an object to its name** game, the prototype presented in Figure 6 was proposed, which the student must connect an image to its respective name, assuming that the child already has a certain level of literacy.

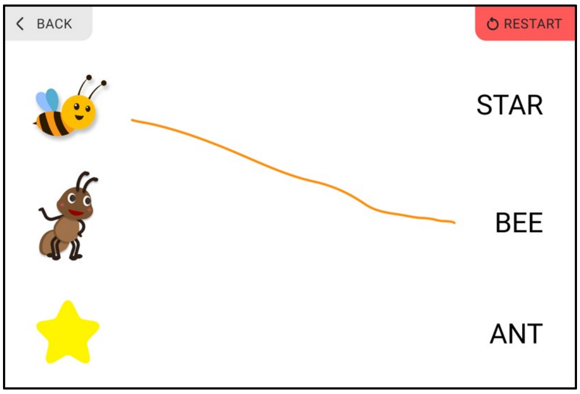

Figure 6. Interface prototype of the Connect an object to the name game.

For the **Labyrinth** game, the prototype is presented in Figure 7. In this game, the student must move the bee along the highlighted path to the honeycomb. In this game, other character options and more complex paths can be used as the children develop this skill.

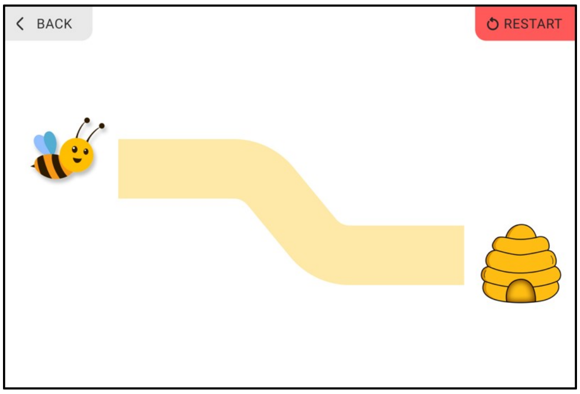

Figure 7. Maze game Interface Prototype

Still on the **Touch and Move** skill, the prototype for the **Connect shapes** game, presented in Figure 8, follows the same logic of connecting information as the two previous game.

The prototype of the **Decorate an image** game, presented in Figure 9, although with features of selecting an object and moving it, uses an image as an object, person, or animal so that the child can select and drag objects available in the tool.

For the **Bilateral coordination** skill, the prototype for a game that uses the gyroscope resource of the tablet stands out and allowing the simulation of a car's steering wheel movement, for example. In this context, the prototype presented in Figure 10 was proposed for the student simulates steering of a vehicle by tilting the tablet laterally.

Finally, prototypes were proposed for the **Single and Double Tap** skill. For this skill, games based on *clicks* that the child can make on the *tablet* screen, either single or double,

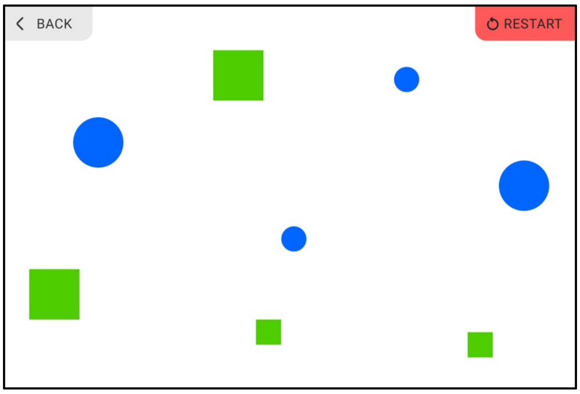

Figure 8. Interface prototype for the Connect Shapes game.

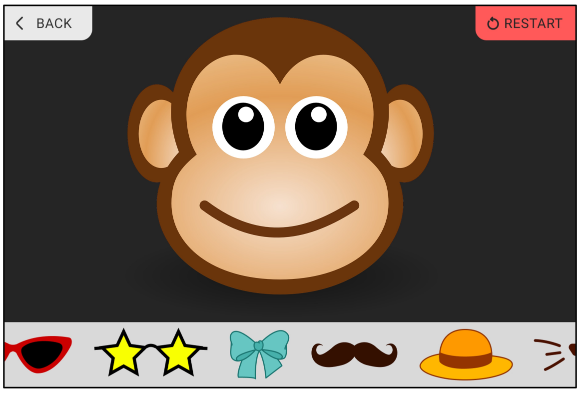

Figure 9. Interface prototype for the Decorate image game.

were proposed. In Figure 11, the child must capture the fruit moving on the screen by means of a double click.

In Figure 12, the prototype of the coloring game is demonstrated, in which the child must select a color and apply it to an area of the drawing, which can vary between several options.

The next subsection discusses the validation of prototypes.

3.2.4 Validation of prototypes

The evaluation phase was conducted with the presentation of interactive prototypes and the performance of usability tests, which are considered efficient technique, since the participants interact with a version of the product [Teixeira, 2014]. The prototypes were presented to the physiotherapists who participated in the project. Their exclusive participation was due to the fact that the tool was proposed to support specific physiotherapy activities. The interactive simulation feature of the Figma tool was used for validation, which allowing users to perform interactions similar to those that will be available in the final product.

After evaluating the prototypes, the participants answered questions related to the degree of compliance the prototype presents with the proposed HCI requirements. Although it is known that the small number of participants limits a consolidated result, it can be stated that, from the participants' perspective, the prototypes and the interaction were well evaluated. The first physiotherapist indicated that the texts were legible, that the names of the activities were understandable for the professionals and the activity descriptions could be assimilated by the students. The second physiotherapist reported that the texts were legible and that the names of the

Figure 10. Prototype of the Driving Car with Steering Wheel game interface.

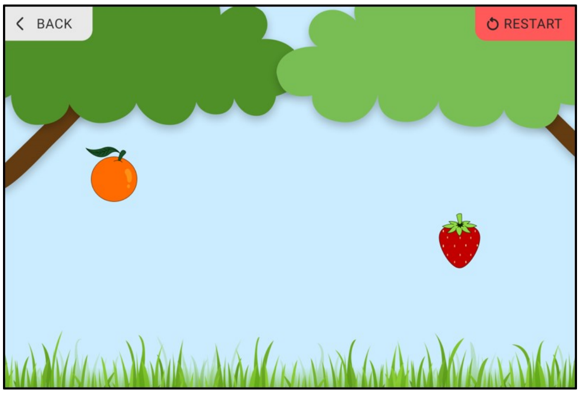

Figure 11. Prototype of the interface for the game Pick fruit

activities were in accordance with what was specified by the professionals.

Furthermore, the professionals agreed that the proposed application, once available as a usable product, could be applied and assist in FMC activities for individuals.

3.3 Development of functional software application

This section presents the development process of an Assistive Technology with a set of assistive games, which implements the activities proposed in the previous phase in order to support the development of the FMC. This stage also followed the UCD, but we focused on the deployment of a functional application instead of prototypes.

3.3.1 Specification of Usage Context and Requirements

In this stage, we aimed to define in which context of use the software application with assistive games would be used and any additional features that could be implemented.

For these actions, a partnership was established between the research team and the Equine Therapy Center of the State University of Northern Paraná, here described as NE-UENP[5]. NE-UENP has been operating since 2014 and served more than 100 practitioners per week in 2023. The professionals work to use contact with horses to improve physical and cognitive aspects of people with disabilities. Other activities can also be applied to improve the relationship between the student and the animal and/or professionals.

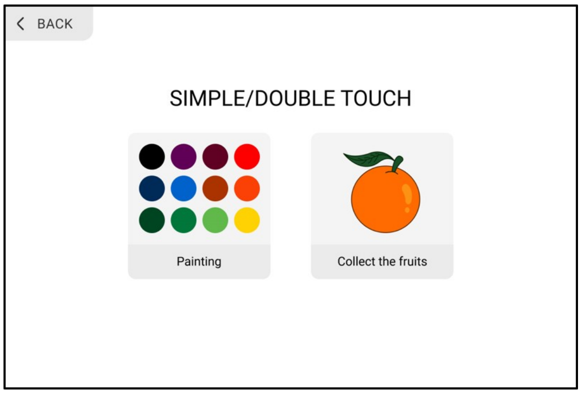

Figure 12. Painting game Interface Prototype

This partnership was motivated by the knowledge and interest of NE-UENP professionals in a software tool to use with their practitioners[6] who had FMC deficits and identified this opportunity based on the work of Coleti *et al*. [2024]. In addition to the paper, NE-UENP professionals were given access to the prototypes and indicated that the tool and games had the potential to effectively support the development of FMC. However, practical testing with practitioners may be required to analyze and evaluate the acceptance and interaction with the tool.

Furthermore, the NE-UENP team highlighted the followed points: (1) the concept of FMC is not limited to people with Down Syndrome (DS) and includes individuals with other syndromes such as Autism Spectrum Disorder (ASD) and Attention Deficit Hyperactivity Disorder (ADHD); (2) they confirmed that using a tablet would be better than using a smartphone, once there was an effort to discourage excessive use of these devices by practitioners. Thus, the research broadened its scope to include a context of use which the tool would not be exclusive to people with Down Syndrome, but any person with a disability in FMC, regardless of other syndromes or disorders.

Regarding the assistive games, it was decided that only one game would be developed for each skill defined in Table 1. It was assumed that, with a game for each skill, it would be possible to assess the applicability and acceptance of the games by professionals and practitioners.

Finally, on the research team's side, there was an interest and need for the developer to apply and evaluate the games in a real-world environment, and these actions would be possible due to the geographical proximity to NE-UENP and accessibility between the teams.

3.3.2 Development of Assistive Games

In this stage, the development of the assistive games defined in the previous stage was performed. For development, the Godot Engine environment was used[7], chosen due to its performance, flexibility and support for resources for mobile devices, such as native support for gestures *multitouch*, which includes the manipulation of gestures such as single touch, multiple touches, drag and drop, pinch to zoom and rotation;

[5] https://uenp.edu.br/noticias/itemlist/tag/EQUOTERAPIA - Last accessed on 27 May 2025

[6] In Equine Therapy, who receive treatment are called practitioners

[7] https://godotengine.org/ - Last accessed on 25 May 2025

and the integration with the gyroscope and accelerometer sensitive input system were decisive for the choice of the environment.

Game strategies (*Game Design*) were also employed, such as interaction through sound, scoreboard, visual predominance, challenging activities and results. Design standards were also considered, such as: appropriate typography to ensure greater readability, with the use of colored, large and simplified format fonts; use of icons and illustrations, to aid in the identification and understanding of objects; and consistency of interface and experience components, to facilitate learning and memorization.

Furthermore, we aimed to meet the requirements and characteristics of the prototypes from the previous phase, but specific changes or improvements, such as in images or interaction mechanics, were applied. The games developed were:

Game for Enlarging Shapes - game developed to practice the Pinch Movement skill. Its graphical interface was based on a centered image, which was randomly selected every time the game was started. The image was initialized in a small size and centered within a dotted outline, which indicated the size to be adjusted. On the sides of the interface, two controls are available that, when the user brings the fingers closer together, reduce the size of the image, while the opposite movement, moving the fingers apart, increases it. An example of this interface is presented in Figure 13.

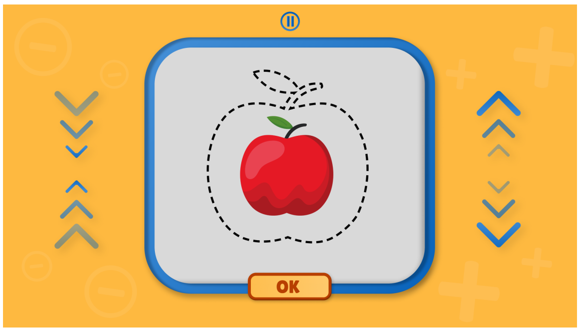

Figure 13. Enlarge Shapes Game Interface

Upon finishing the game, after clicking the OK button in the center of the interface, a verification method that calculates the average difference between the scale values of the width (x) and height (y) of the image in relation to the target scale and returns the corresponding number of stars. The smaller the difference, the higher the score, indicating how close the user was to the goal, as exemplified in Figure 14.

Figure 14. Final star score for the Enlarge Shapes game

Shape Connecting Activity Game - developed for the Touch and Move skill, the game interface has two columns: on the left, there are images that represent a group of objects in a certain order, while on the right is the same group of objects, but in a different order. Using the drag and drop mechanic, the player must connect the plugs to the appropriate sockets, establishing the correct associations between the images, as presented in Figure 15.

Figure 15. Shape Connect Game Interface

On game completion, the outcome is shown. Successful connections are highlighted in green, as depicted in Figure 16, where the user has correctly matched all connections. If the user makes a mistake, it would be presented in red.

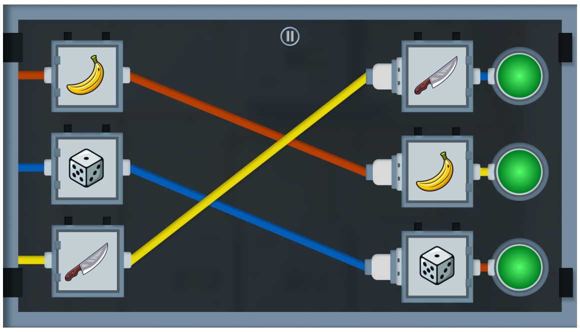

Figure 16. Final screen of the Shape Connection Game

Rotation Activity Game - Bilateral Coordination skill game, set in a forest where various fruits, including strawberries, fall from the trees at the top of the screen. The user must rotate the tablet (rotate left or right) in order to move the basket and collect the strawberries that fall from the trees. This game has a life count feature, which refers to the possibility of user errors, in this case, collecting fruits other than strawberries or failing to collect strawberries. This interaction requires precision in movements, promoting motor control, spatial perception and hand-eye coordination. Figure 17 presents an example of the interface of this game.

At the end of the game, if successful, a scoreboard is displayed showing the number of strawberries collected by the player, as shown in Figure 18.

Game for the Double Click activity - for the Single and Double Tap skill, this activity presents a panel with an indication, in the upper right corner, of a geometric shape and a quantity. The user must select, with a double tap (double click) the indicated quantity of the geometric shape from among the various shapes displayed on the screen. The user then seeks to identify and double-click the correct shape, promoting visual recognition, precision in selection and fine motor control. An example of the interface of this game is pre-

Figure 17. Rotation Game Interface

Figure 18. Rotation game final score

sented in Figure 19.

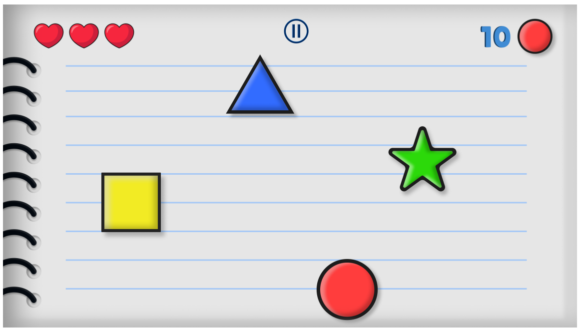

Figure 19. Double Click Game Interface

When an object is clicked, an auditory feedback is provided for a correct selection. In case of an incorrect choice, a different sound will be played. The hearts in the upper left corner represent the number of lives the player has remaining. The player loses a life if they click on the wrong object or if the object disappears from the screen without being clicked. At the end, a scoreboard with the final score is displayed, as presented in the Figure 20.

In the next subsection, we present information about the evaluation at NE-UENP.

3.3.3 Assessment with NE-UENP professionals and people with FMC disabilities

The tablet with the games was made available to the physiotherapist responsible for NE-UENP. She received training on the games and validated that the implemented functionalities were in accordance with what was defined in the requirements stage. This professional was responsible for presenting and training the other professionals, in addition to collecting signatures on the Informed Consent Forms and the Assent Forms. In addition to the physiotherapist, two other

Figure 20. Double Click Activity Scoreboard

physiotherapists, a physical education professional and a psychologist also participated.

Activities were carried out for three weeks during the month of November 2024. Each participant performed each game 2 to 3 times, subject to their tolerance to the games. The selection of practitioners was made by the NE-UENP team, without interference from the developers, based on their treatment objectives and on which the professionals assumed that the games could contribute. Four practitioners between the ages of 4 and 18 participated, including 2 practitioners with Autism Spectrum Disorder and 2 with Down Syndrome, supporting an improvement in this work that FMC is not exclusive to Down Syndrome.

Participants were selected based on specific criteria, considering not only the diagnosis, but also factors such as age range (from 3 to 12 years), difficulties in fine motor coordination, as assessed by professionals, and the availability of participants during the week of the test. The selection was performed randomly, considering these points to ensure a diverse sample, representing different aspects of the individuals' development and needs.

NE-UENP professionals conducted the tests based on standardized criteria that consider precision, dexterity, and control of movements performed with the small muscles of the hands and fingers. One of the common ways of categorizing fine motor coordination includes the following levels: excellent, good, fair, and poor, allowing for a qualitative analysis of motor performance. In the context of hippotherapy, practitioners are subjected to specific fine motor coordination tests, such as the standardized line tracing test, which consists of executing lines within a delimited path, evaluating the ability to maintain the line within the proposed limits, with minimal deviations or tremors. Performance classification is based on observation of the precision of the lines, execution time, and fluidity of the movements.

All possible ethical precautions were considered during the game evaluation activities, as explained in Subsection 3.1, to ensure that participants remained calm and comfortable and guaranteed their rights. Regarding the confidentiality of participants, their identities were protected by the following measures: (1) only NE-UENP professionals had access to the participants; and (2) no personal data was collected, and all other data was recorded using specific coding in an Excel spreadsheet under the exclusive control of NE-UENP.

The spreadsheet with digital data was archived on the research institution's server in an environment with controlled access via institutional email. The physical documents, such as the TCLE, were (and will be) archived by the researchers in a location with controlled access for the minimum time required by law. The results consolidated by the NE-UENP professionals presenting anonymized information were made available following Open Science practices, as highlighted in the **Open Science - Availability of research data and materials** at the end of this text.

The results were presented by the physiotherapist and discussed together with the development team. It is worth noting that, the evaluation aimed to identify the applicability of the games as a tool to assist in the treatment of FMC and to obtain an initial view of the adaptation of the participants. No clinical factors regarding the treatment or the evolution of the health condition, FMC or other health aspects were analyzed, once it requires continued use of the tool and an analysis may considers other factors, which are outside the scope of this article.

Next section presents and discuss the results provided by NE-UENP professionals.

4 Results and discussions

This section presents the results and discussions, especially from the second phase of the project, in which the assistive games proposed in the first phase were developed and used by NE-UENP physiotherapists. The results were presented by the physiotherapists to the research team and were organized into two groups: (1) results of the tool's application with the practitioners, and (2) suggestions for improvements to the games.

Regarding the use of games with the practitioners, after initial guidance provided by the physiotherapists, they presented good adaptation to the games, being able to perform the activities more easily. Also, they provided the following insights for each game:

In the **Enlarging game**, participants initially had difficulty performing the pinch movement, which is necessary for good performance in the task. Many tried to perform the gesture incorrectly, using the index fingers of both hands alternately instead of using the thumb and index finger of a single hand, performing the movement bilaterally and in a coordinated manner. This initial difficulty was mainly related to understanding the dynamics of the game. However, after assimilating the proposal, the volunteers performed the activity satisfactorily, demonstrating good execution of the pinch movement and greater fine motor control in addition to spatial awareness.

In **Connect Shape game**, it was observed that previous familiarity with this type of task, commonly performed on paper in schools, for example, contributed to participants' greater ease in performing it. The practice of matching images and the use of fine motor coordination were well explored, showing that the activity is effective in stimulating manual dexterity, in addition to promoting visual recognition and the association of shapes.

A higher degree of difficulty was observed for the **Rotation Activity game**, especially with regard to bilateral coordination. Participants faced challenges when trying to synchronize the movements of both hands and measure the force applied, which compromised performance at times. This difficulty sometimes caused frustration in the volunteers, leading them to resist repeating the activity. Even so, the game proved effective in working on bilateral motor coordination, a fundamental aspect of global motor development.

Finally, in the **Game for the Double Click** activity, the main difficulty observed was related to the timing and rhythm of the movements since many volunteers performed only one click, which prevented them from scoring points in the game. The requirement of a double click proved to be an initial challenge, but after they understood the dynamics, the participants could exercise the rhythm and motor coordination more efficiently, demonstrating progress in the required skill.

The professionals from NE-UENP highlighted that the good adherence of the practitioners to the tests can be attributed to the format of the games, which are carried out on tablets. The use of screens proved to be increasingly attractive to the participants, mainly because it is a tool that is already part of their daily lives. Many of the practitioners demonstrated enthusiasm and engagement during the activity, which facilitated the learning process and increase motivation to perform the exercises.

The activity clearly demonstrated the progress made in the participants' Fine Motor Coordination. Interaction with the app helped to stimulate specific movements and more refined motor control. With the assistance of the physiotherapists, the participants were able to overcome initial difficulties, which reflects the potential of digital games as complementary tools in the motor development of people with special needs.

Also, the NE-UENP professionals presented a list of suggestions that they considered important to improve user experience with games and that can more effectively support the improvement of FMC. These suggestions included increasing the difficulty level, vary the size and shape of objects, change the speed of actions. The improvements are presented in Table 2.

The information from the assessment provide insights that underline the applicability of assistive games to support FMC development actions and encourage the continuous development of games to support it. The combination of simple games, more complex games and the professionals' emphasis on the need to include difficulty levels encouraged the development highlights the importance of designing games with varying levels of difficulty to cater to different learning curves and motor skills.

The use of tablets, due to the familiarity with screens, confirmed that the mechanism can be used as a platform for delivering the games, bridging the gap between therapeutic activities and enjoyable experiences. The observation of improved motor control through these games confirms the potential of digital tools to complement traditional therapeutic methods, providing an innovative avenue for the development of essential motor skills.

To further enhance the effectiveness of these games, professionals at NE-UENP proposed targeted improvements, such as adjusting game difficulty, introducing dynamic elements, and increasing the variety of shapes and actions. These refinements aim to create a more adaptive and stim-

Table 2. Suggestions for improvements to assistive games provided by professionals from NE-UENP

Game	Improvement	Description
Enlarge Shapes	Change the side of the tweezers	Randomly switch the position of the tweezer controls so that users can practice tweezer movements (opening and closing) with both hands.
	Vary the size of the tweezers	Gradually reduce the size of the tweezer movement controls to increase the demand for dexterity and motor control.
	Greater variety of shapes	Provide a greater variety of shapes of different sizes and formats to increase the difficulty and cognitive and motor challenge.
Connect Shapes	Increase the difficulty level	Increase the difficulty of the game as the user progresses. This can be done by actions such as: increasing the number of objects to be dragged, adding obstacles to bypass, inserting precision objects for object connection.
	Inclusion of more items	Throughout the game's progression, randomly include new items to be dragged, thus increasing the difficulty of finding, dragging and connecting the object to the destination.
Rotation	Increase the rotation speed	Progressively increase the speed of the game so that the user can make faster and more challenging rotation movements. This improvement can stimulate the user and maintain focus, perception, rhythm and motor control.
Double Click	Include three difficulty levels	Define difficulty levels with progressive challenges. The first level may involve larger and easier-to-click objects, while the third level should present smaller, faster objects in more difficult-to-reach positions.
	Dynamic change of shapes during the game	Provide a change of objects for selection during the game, which allows the change of shape, colors or movements in order to require greater attention and coordination from the user to perform the double click.

ulating experience, thereby maximizing the benefits of the games for practitioners with diverse needs. By incorporating these suggestions, future iterations of the games could better support the holistic development of FMC, ensuring that they remain both engaging and impactful.

5 Limitations and Threats to Validity

The methods, techniques, and tools used in this research may present limitations and threats to validity that could have influenced the final results. Below are some key aspects that, if performed with other methods, techniques, and tools, might have affected the outcomes of the study:

- The primary limitation of this study is the number of Equotherapy practitioners who participated in the practical experiment. Four participants may be considered a small sample size. Also, the number of professionals that applied the software with FMC users is a limitation once other professionals can provide different information. However, despite this limited number, these participants provided valuable insights into the applicability of Assistive Technology.
- The results are specific to the context in which the tool was applied, including the number and profile of users, whether professionals or individuals with disabilities—in this case, the NE-UENP practitioners. Another limitation is the relatively short application period of the games, which lasted only three weeks. A longer usage period could have yielded additional results.
- The Assistive Technology presented in this study was developed specifically for each FMC skill. The development and application of other Assistive Technologies could lead to different outcomes.

Furthermore, since the professionals' profiles, the individuals with FMC, and the manner and duration of game usage directly influence the results, applying the games in different contexts or under varying conditions could lead to distinct opinions and results.

Another limitation of this study is the lack of tactile stimuli provided by digital games to develop fine motor coordination. Virtual environments cannot reproduce some sensory experiences, such as the perception of texture, weight, and shape of objects. This limitation may compromise the improvement of fine motor skills that depend on controlling grip strength and the pressure exerted by the fingers.

6 Conclusion

This paper presented a project aimed at developing assistive games to support Fine Motor Coordination development activities. The project was conducted in two stages. The first stage, focused on defining, prototyping, and validating the idea and was carried out in partnership with an APAE unit. The second stage, focused on the development and evaluation of a functional tool, was conducted in partnership with the Equine Therapy Center of the Northern Paraná State University (NE-UENP).

The project was developed following a User-Centered Design approach, initially focusing on children with Down syndrome. However, as the project progressed, an incremental and iterative knowledge-building process allowed for the evolution of concepts, strategies for Fine Motor Coordination, and software requirements. This enabled the application of the functional tool in an institution other than APAE, with individuals presenting other disorders such as ASD and ADHD.

After applying the games with children and adolescents, physiotherapists presented the results of their interaction with participants and provided suggestions for future improvements. In general, the games were well-received, although some of them required support for use. This is both natural and positive, as some activities demand greater effort to perform and, consequently, yield better results.

The results presented by the professionals, based on their observations during the experiments, highlighted the importance of the systematic application of instruments for assessing fine motor coordination in the therapeutic context as a subsidy for defining individualized goals and work strategies. Thus, we assumed that the project digital games for touchscreens can be used as a tool do support the development of fine motor skills, alongside activities with physical objects, always considering the children needs and professional tasks.

Also, considering technical issues, the development of the functional games demonstrated the feasibility of developing educational games with the Godot engine, as this tool provides the necessary resources, such as animations and sounds, in addition to functionalities for touchscreens.

7 Future Works

The main objective of this research was to verify the applicability of games in an activity involving the development of FMC. This research was an exploratory study, with qualitative data and validation carried out with few participants since its objective was to verify the applicability. However, it is essential to highlight that this work presents great possibilities for continuity and evolution, such as:

- We intend to incorporate improvements suggestions presented by the professionals and apply the games with more participants over a longer period of time.
- Conduct assessments with quantitative and qualitative aspects to evaluate, among other things, performance metrics, usability, user experience, and learning; compare the performance of participants before and after using the tool; and compare the performance of participants who use the tool compared to participants who do not use the tool;
- Explore other sensory aspects that can enrich immersion and interaction, such as: (i) sensory aspects related to touch, through the use of haptic technology to allow users to feel textures, shapes and movements (e.g., devices that allow simulating the sensation of touch); (ii) adaptive interfaces, to respond to touch in a personalized way, to allow people with different motor limitations to interact more intuitively (e.g. ,sensors that detect pressure or movement);
- Propose and implement design patterns and components in interfaces to improve the user experience and playability of applications and make the interaction more dynamic, challenging, attractive, and motivating.

Furthermore, the project is expected to evolve in terms of the quantity and diversity of games and that it can be used by professionals who work with the objective of developing FMC efficiently. As it is an open project, it is expected that it can also evolve collaboratively through the contribution of other research groups, developers, and professionals.

Declarations

Acknowledgments

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Open Science - Availability of research data and materials

The source code of activities is available at `github.com/guaragames/guara`, under the MIT license. All tools and assets used are free from copyright. A brief documentation on how to install and use the games can be found in the same repository, in the README file.

In this phase of the research, only qualitative data were collected, as it was an initial acceptance test. The suggestions for improvements pointed out by the physiotherapists can be consulted in the repository.

Considering that the initial tests demonstrated the feasibility of the proposal, the intention for future work is to expand to more users and perform quantitative analysis. The test protocols and results, duly anonymized, will be made available following open science criteria.

Concerning the use of artificial intelligence

Generative AI was used in this text for two actions: (1) to support the review and improvement of the English text; (2) to generate the image for Figure 4. Furthermore, it is highlighted that AI was not used to generate textual content or content with scientific value.

Competing interests

The authors declare that they have no competing interests.

Authors' Contributions

This work followed the Contributor Roles Taxonomy (CRediT) to specify the contributions of each author:

- Thiago Adriano Coleti: Conceptualization, Methodology, Supervision, Writing – Original Draft Writing – Review & Editing;
- Victória Martins: Conceptualization, Data Curation, Methodology, Software Development, Visualization;
- Lucas Chaves Generoso: Software Development, Validation, Visualization;
- Gabriela Cristina Oliveira: Resources, Investigation, Formal Analysis, Writing – Original Draft.;
- Maisa Lúcia Cacita Milani: Conceptualization, Writing – Review & Editing;
- Daniela Guilhermino Trindade: Conceptualization, Writing – Review & Editing;
- Maria Renata de Mira Gobbo: Writing – Original Draft, Writing – Review & Editing;
- Thais Helena Constantino Patelli: Resources, Investigation;

- José Reinaldo Merlin: Conceptualization, Methodology, Supervision, Writing – Original Draft, Writing – Review & Editing.

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