A Systematic Mapping of Serious Games for the Rehabilitation of Fine Motor Coordination

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Abstract. *Motor development is an important part of an individual's evolution and the Serious game creation is a useful tool when used in motor development. This article carried out a systematic mapping to identify an overview of games aimed at rehabilitating fine motor skills. The objective was to identify scientific literature that addresses activities that stimulate the player's motor coordination and verify which ones are specific for fine motor skills and their characteristics. It was concluded that the use of mobile devices is still little explored, but it is a potential tool for the development of solutions for the rehabilitation of fine motor skills because it includes technologies such as accelerometer, gyroscope, and touchscreen, which allow the assessment of balance, tremors, direction, and tilt of the device. In addition, the touchscreen allows movements such as tapping, dragging, and pinching. Another finding is the lack of motor assessment methodologies, artificial intelligence applications, and game frameworks for coordination rehabilitation development.*

Keywords— *serious games, fine motor coordination, rehabilitation*

1. Introduction

For society at large, the computer science research area provided support for the digital revolution, which gave rise to the information age that we know today, and which can be used in various fields, as the medical area, as the mapping of the human genome and educational areas as serious games, for example (Williamson, 2021). In this regard, along with the emergence of new devices that can detect the movements made by people, it has become possible for studies aimed at developing computational solutions for the improvement and verification of coordination of the individual.

Motor development skills are acquired and refined as the individual grows. Activities such as climbing stairs, riding a bicycle, and jumping are related to gross motor skills, as they require effort from the large muscles of the body. However, tasks such as writing, cutting paper, and tying shoes involve small muscles and are considered fine motor coordination. Both are essential for the full development of human beings as, in addition to increasing the capacity of muscle movements, they help in mental stimuli and efforts so that motor actions are precise and balanced (Pellegrini, 2000).

Mechanisms are being developed to stimulate motor development, such as games. Cruz (2014) states that digital games are tools in which the individual is "challenged to complete a task and conquer challenges in which they can develop their visual, physical, cognitive, auditory and psychological capacity".

The literature has references to games that help in the development of motor coordination, such as precision and movement speed games (Brandão et al., 2010), movement detection and pressure applied to a sensor (Zhao et al., 2021), motor coordination rehabilitation (Souza & Classe, 2021), among others.

In order to have an overview of games for the rehabilitation of fine motor coordination, this work carried out a systematic mapping. The objective is to identify studies that address activities that stimulate the motor coordination of players and those which address fine motor skills. The mapping was carried out from 2010 to 2021 and the method of Kitchenham & Charters (2007) was used. Five search repositories were considered: ACM, Scopus, IEEE, SciELO, and Google Scholar.

2. Serious Games and Motor development

Serious games are apps that use the technologies employed in video games, with similar approaches such as 3D environments, simulation of objects, characters, environments, challenges, etc., but with purposes that exceed entertainment, such as education and learning (Meftah et al., 2017). The application of serious games can be a way to improve cognitive skills to bring students and professionals closer to real-world activities and experiences (Garcia da Luz, 2021; Pereira et al., 2021).

According to Pessoa (2003), motor development can be divided into 2 categories: gross and fine motor skills. Gross motor ability is related to movements that use large muscles, such as jumping, running, and squatting, and is related to the practice of sports activities such as football, basketball, and tennis, among others. On the other hand, the fine motor ability is related to using small muscles, usually the feet and hands. This ability is related to precise movements, such as writing, drawing, and manipulating small objects.

Thus, the review work proposed in this article intends to answer the following question: "What is the panorama of serious games for the development of fine motor coordination?", to identify which audiences have already been created, which subjects are covered, which technologies are used and for which devices, among other questions that are detailed in the next section.

4. Research methodology

The method used to carry out this systematic mapping was that of Kitchenham & Charters (2007). Works concerning the objective of this research were identified in the period from 2010 to 2021. The period was defined to contemplate the current available and emerging technologies related to motion detection. Figure 1 illustrates the process adopted.

Figure 1. Methodology overview.

The search for primary studies was performed in five digital libraries, namely: ACM, Scopus, IEEExplore, SciELO and Google Scholar (considering the articles up to the fifth page of the results). The search terms were debated among the authors of this research, which resulted in the following search string: TITLE-ABS-KEY ("fine motor") AND TITLE-ABS-KEY (gam*).

4.1. Selection of Studies

The researchers who carried out the mapping were the evaluators of the primary works collected and the inclusion and exclusion criteria were then defined. The inclusion criteria are presented in Table 1.

Table 1. Inclusion and Exclusion Criteria

Criteria	
Inclusion	**Exclusion**
- Articles relevant to the covered subject;	- Duplicate articles;
- Articles written from 2010 onwards.	- Articles with title and abstract outside the scope;
	- Articles that do not cover digital games.

Selected articles must answer the following research questions: Q1) What activities/subject, what kind of games, execution platform, target audience are included in games that address fine motor skills? Q2) What are the tools/technologies employed and how do they relate to fine motor development? Q3) Are there fine motor coordination methods implemented in these games? Which are they? How do these methods assess the fine motor skills of the player? Q4) There are games that apply some type of artificial intelligence algorithms to help stimulate the fine motor skills of the player? The Table 2 presents the Number of works per repository

Table 2. Number of works per repository

Repositories	ACM	Scopus	IEEExplore	SciELO	Google	Total
The amount	14	181	15	3	43	256

From the search results, a selection process was performed using the inclusion and exclusion criteria to narrow down the articles. Altogether, at the end of the selection process, approximately 91.79% of the included studies were eliminated by the exclusion criteria. Figure 2 shows the result of the process of executing the exclusion criteria.

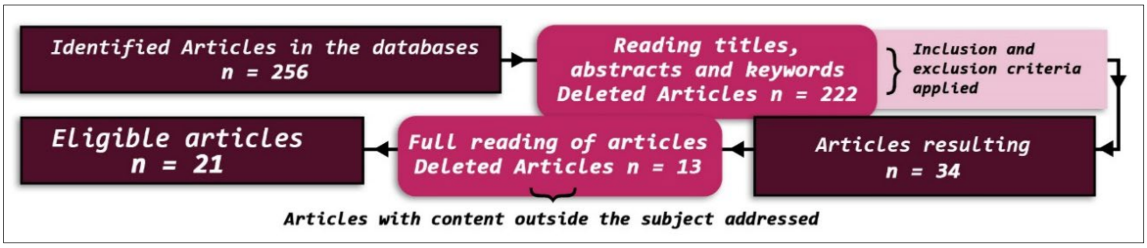

Figure 2. Result funneling process.

5. Results

The results presented in this section correspond to information taken from the 20 primary studies that were selected according to the inclusion criteria. Table 3 presents the eligible articles in this study and are represented by their reference (ID).

Table 3. Eligible articles

ID	Article Name	Author/Year
S1	Jecripe: stimulating cognitive abilities of children with down syndrome in pre-scholar age using a game approach	Brandão, A., et al. (2010)
S2	Effect of fine-motor-skill activities on surgical simulator performance	Chung, A. T., et al. (2017)
S3	Gesture-based video games to support fine-motor coordination skills of children with autism	Ruiz-Rodriguez, A., et al. (2019)
S4	A Rhythm-Based Serious Game for Fine Motor Rehabilitation Using Leap Motion	Shah, V., et al. (2019)
S5	Development of an arcade controller for children with intellectual disabilities to improve fine motor skills through video games	Merchán-García, D. A. et al. (2020)
S6	C-Hg: A Collaborative Haptic-Gripper Fine Motor Skill Training System for Children with Autism Spectrum Disorder	Zhao, H., et al. (2021)
S7	An Interactive System for Fine Motor Rehabilitation	Posada-Gómez, R., et al. (2016)
S8	Stroke Patient Rehabilitation: A Pilot Study of an Android-Based Game	Carabeo, C. G. G. et al. (2014)
S9	A case study of gesture-based games in enhancing the fine motor skills and recognition of children with autism	Cai, Su et al. (2018)
S10	PinchFun: A Cooperative Fine Motor Training Game for Preschool Children with Developmental Delay	Wang, I. F., et al. (2016)
S11	A Series of leap motion-based matching games for enhancing the fine motor skills of children with autism	Zhu, G., et al. (2015)
S12	Serious games for Parkinson's disease fine motor skills rehabilitation using natural interfaces	Foletto, A. A., et al. (2018)
S13	Design of a Haptic Virtual System for Improving Fine Motor Skills in Children with Autism	Zhao, H. et al. (2017)
S14	A gamified approach for hand rehabilitation device	Carneiro, F., et al. (2018)
S15	Serious game to improve fine motor skills using Leap Motion	Hidalgo, J. C. C., et al. (2018)
S16	Immersive Virtual System Based on Games for Children’s Fine Motor Rehabilitation	Pruna, E., et al. (2018)
S17	Motion-Based Serious Games for Hand Assistive Rehabilitation	Afyouni, I. et al. (2017)
S18	Interactive Training Chopsticks to Improve Fine Motor Skills	Chia, F. Y., & Saakes, D. (2014)
S19	Leap motion-controlled video game-based therapy for upper limb rehabilitation in patients with Parkinson’s disease: a feasibility study	Fernández-González, P., et al. (2019)
S20	Virtual Rehabilitation System for Fine Motor Skills Using a Functional Hand Orthosis	León, M. A., et al. (2018)

The answers for each research question are presented below.

5.1. Q1 - What activities/subject, execution platform, target audience are included in games that address fine motor coordination?

There is common sense when looking in the literature for serious games and fine motor skills. All selected studies focus on the development and rehabilitation of motor functions. Some include additional requirements, such as article S2, which encourages cognitive development, S4 which presents an approach considering five steps: Empathize, define, devise, prototype, and test, and articles S7 and S11 encourage social skills through cooperation.

Regarding the types of games, there is no standardization, nor an ideal game style, in the S1 work, for example, a series of mini-games was developed, where the player imitates dancing and clicks with the mouse in specific places to activate the music, in the S7 work, a virtual and augmented reality game was developed, in which the user needs to replicate the design presented through gestures using a device that detects the movement performed.

Considering the selected studies, studies S3; S5; S6; S7; S10; S12; S16; S17; S18; S19 did not specify which platform they were developed for. The S4; S11; S13; S14; S15 and S20 studies were developed for computers with Windows operating system and only one study S8 was developed for the Android system, and study S2 was created for its embedded system. There is a concern from the works in developing serious games for children with Autism as reported by S3; S6; S9; S11; S13 studies and for people with some form of physical limitation S4; S7; S8; S14; S20, including people who have suffered a stroke (cerebrovascular accident) who generally need motor rehabilitation. In addition to these, other audiences were also identified in the studies: those with Parkinson's disease S12; S19, people with intellectual disabilities S1; S5; S17) and children between the ages of 3 and 14 S10; S15; S17; S18. In just one study S2, the game included undergrad students, specifically medical students, to improve fine motor skills in a cataract surgery simulation. Figure 4 presents the target audience's chart.

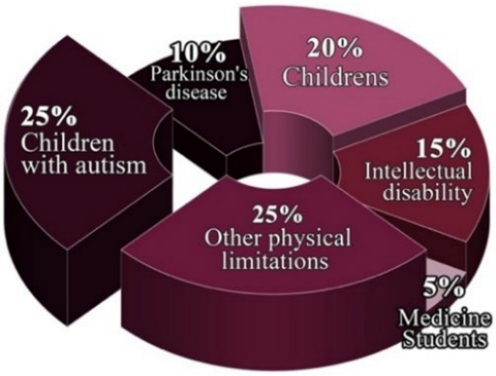

Figure 4. Target Audience.

5.2. Q2 - What are the tools/technologies used and how do they relate to fine motor development?

The device most used in the studies selected for this mapping is the Leap motion, which consists of a small device with a sensor capable of capturing the movements of the users' fingers (Techtudo, 2014). It is a popular device to work with fine motor coordination, proven by the percentage of use, which corresponds to 50% of the selected studies: S3; S4; S9; S10; S11; S12; S15; S16; S17; S19. Other technologies detected in this review are: Mouse, related to select, click and drag movements (S1); a specific device that simulates cataract surgery, similar to a haptic device (S2); haptic device and/or sensors that measure the applied pressure (S6; S13; S14); arcade controller containing six buttons and a stick (S5); a pen that emits light and webcam for motion detection (S7); tablet (S8); gyroscope, accelerometer or magnetometer sensors (S14; S18), and finally the article (S20) presents the use of an MYO Armband, which reads the electrical activity of the muscles and the movement of your arm combined with a functional hand orthosis to detect finger movements.

In addition to these primary devices, other devices were used in some studies to add to the capture of information, such as the case of primary studies S10; S13; S18 that used the Arduino device or other similar microcontrollers and S16 articles; S20 that used Rift augmented reality glasses.

5.3. Q3 - Are there fine motor coordination methods implemented in these games? What are they? How do these methods assess the player's fine motor skills?

The selected studies S1; S2; S7; S10; S11; S12; S13; S14; S15 and S18 do not have a defined assessment methodology, they consider the successes or errors of movements. For example, moving an object to a correct location, the player receives feedback (S2), a questionnaire about the efficiency of the game (S11; S12; S14), a questionnaire about the game and player preference by gender and age group (S15). Study S13 was not carried out to demonstrate improvement in motor skills, but to observe how users felt interacting with the system and documenting their performance. The S18 considered creating a prototype to train movements and the future application of a questionnaire.

Studies S3 and S4 used a method that assesses fine motor development through repetition and movement successes or errors, with the user receiving a bonus with positive reinforcements and stars (S4). Study S5 assesses the level of fine motor skill, comprising 3 steps: i) Session Management containing the participant's profiles and session intervals, ii) eye and hand coordination exercises and visual simulation presentation with video game, finally, iii) analysis of the results with the application of fine motor coordination tests through the reporting of information obtained from the session.

In S6, the methodology comprises a pre-test evaluation, three training sessions, and a post-test. The pre and post-test consists of a mixture of virtual and real tasks. So, to measure fine motor performance in real-world tasks a subtest was used called the Beery-Buktenica Developmental Test of Visual-Motor Integration (VMI Motor Coordination Test). Virtual tasks are individually assessed based on hand movement and pressure control quality. In the end, the user answers a prepared questionnaire using the 5-point Likert scale (Nemoto & Beglar, 2014) composed of 9 questions.

Work S9 developed a method to search for information in the literature for game design, target audience definition, measurements including fine motor skills and a recognition scale with children with Autism Spectrum Disorder (ASD) (APA, 2000) through observation and analysis of evolution during the period that the user was exposed to the game.

S16, S17 and S19 used a methodology with Leap Motion to capture data. From these studies, work S16 assesses the usability of virtual systems to determine user acceptance related to ease of use, security, sensation, inconvenience, etc. The S17 job uses metrics provided by the device to calculate the angle of hand movement. In S19, a non-probabilistic sampling of non-consecutive cases was performed considering two groups: one experimental group received treatment based on serious games designed by the research team using the LMC (Leap Motion Controller) system for upper limbs and the other group a control that received a specific intervention for upper limbs. Grip muscle strength, coordination, movement speed, fine and gross dexterity, as well as satisfaction and compliance were assessed in both pretreatment and posttreatment groups.

Finally, the S20 study covered a formulation of movements to be used as a form of interaction in games and was based on Finkelstein's test (1930). During the game, movements are requested to perform some tasks, and the user receives real-time feedback on whether it is executing the right move. Table 4 presents the criteria for the assessment of fine motor development presented in the studies.

Table 4. Evaluation Criteria

Studies	Fine motor assessment criteria
S1; S2; S7; S10; S11; S12; S13; S14; S15; S18	Assertiveness in movements.
S3; S4	Repetition and hits/errors of movements.
S5	Assessment in 3 stages: i) Session Management, ii) hands eye coordination exercises, iii) analysis of the results with the application of fine motor coordination tests through the reporting of information obtained from the session.
S6	Pre-test evaluation, training session and post-test, using the Beer-Buktenica Developmental Test of Visual-Motor Integration)
S8	Evaluate movement accuracy and timing.
S9	Observation and analysis of the evolution during the time that the user was exposed to the game.
S16; S17; S19	Performance attributes provided by Leap Motion, such as moving angle, for example.
S20	It encompassed a formulation of movements to be used as a form of interaction in games and was based on Finkelstein's test (1930).

5.4. Q4 - Are there games that apply artificial intelligence algorithms to help stimulate the player's fine motor skills?

Among the selected studies, only study S7 used any artificial intelligence technique. The work in question used an approach applying machine learning techniques to classify the right or left hand using an oriented gradient histogram (OGH) feature descriptor and machine-based classification of the Support Vector Machine (SVM).

6. Discussion and Conclusion

The present work presented a systematic mapping to identify the panorama of serious games for the development of fine motor coordination, to identify to which audiences they were created and what are the subjects, technologies, and devices.

It was possible to identify some works developed for children with autism and people with physical limitations. In addition to games developed for children in development, followed by people with intellectual disabilities, such as down syndrome, and on a smaller scale, works for Parkinson's patients.

The device most used as a tool for user interaction with games was the Leap Motion, which consists of a small device with a sensor capable of capturing the movements of the users' fingers (Techtudo, 2014). Devices such as haptic sensors, among others, were also used, however, in fewer studies.

Half of the works (10 studies) did not specify which platform the game was developed for, but considering the devices and images, they were developed for workstations, mainly with Microsoft Windows operating system. Only work S8 made use of mobile devices

A methodological absence was also identified for motor evaluation, except for one work (S6) that used Beery-Buktenica Developmental Test of Visual-Motor Integration (VMI Motor Coordination Test), the others used the player's accuracy during the game as a performance metric.

As a result of the mapping, it was observed that only one study (S7) used an approach with machine learning techniques to classify the movements of the right or left hand.

With this study, it was possible to perceive a gap in the development of serious games aimed at the rehabilitation of fine motor skills using mobile devices, which makes it an area to be explored in future work, as well as assessment methodologies and frameworks for specific game developments for this purpose, in addition to being a popular device all over the world, in addition to being a popular device all over the world, proven by research created by the GSMA (2021) that identified that at the end of 2020, 5.2 billion people will be using mobile services, representing 67% of the global population. In other words, in the global context, there are many mobile devices.

Technologies used in mobile devices, such as accelerometers, gyroscopes, magnetometers, and touchscreens classify them as inertial reference units (URI) (Antonio et al., 2020), which help in the rehabilitation of fine motor skills. In this way, the device can assess the device's balance, tremors, directions, and tilt, in addition to the touchscreen that allows movements such as tap, tap, drag, pinch and pinch in reverse.

The use of artificial intelligence techniques is also little explored in serious games and can be an interesting strategy for classifying user groups since users who need fine motor rehabilitation may have different degrees of difficulty, even if similar in age or other characteristics. As such, ranking algorithms for studies and dynamic difficulty adjustments can make games more inclusive.

Acknowledgments

This work is funded by the European Regional Development Fund (ERDF) through the Regional Operational Program North 2020, within the scope of Project GreenHealth - Digital strategies in biological assets to improve well-being and promote green health, Norte-01-0145-FEDER-000042.

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