The Contribution of Game-based learning: Children with Autism Spectrum Disorder and Dyscalculia

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Abstract: This paper explores the potential of games to mathematics learning and promotion of global psychomotricity, relational/social skills in children with Autism Spectrum Disorder (ASD) and/or Dyscalculia students of Basic Education in Portugal. Inspired by Space Adventure: Defend the Planet! (SADP), an educational research-based game to children's primary mathematics' learning [PTDC/COM-CSS/32022/2017], a game-based intervention was created to psychomotricity sessions at school facilities. The study was conducted by the researcher, Superior Technician of SEN and Rehabilitation. A mixed method approach is used to research: what impact does the intervention have on participants' motivation, engagement, learning of mathematics and development of participants? Five schools in Portugal participated in the study, between December 2021 and March 2022, with 12 sessions, one session/week, 45 minutes. The sample: 19 participants: 12 boys, 9 with ASD and 3 with Dyscalculia; 7 girls, 2 with ASD and 5 with Dyscalculia. The average age is M=8.6 with SD=1.8. Prior to the intervention, the following instruments were applied: pre-tests of math skills, communication and social interaction, receptive and expressive language; Childhood Autism Rating Scale; a Battery Movement Assessment Battery for Children; questionnaire Technologies/Video Games and Questionnaire of Support Measures for Learning and Inclusion. During the intervention, an observation grid and alternative communication materials were used per session. A PC, the SADP, gymnasium/relaxation room with a chair, table and gym supplies. From the results, computers, tablets, and mobile phones are the most frequently used by children. GRID/ABC Autism, Bini ABC/Human Body, and Minecraft/Troll are video games often played by participants. One girl aged 12 explained to the researcher how to create worlds on Minecraft, which is an indicator that "good" video games could be beneficial for ASD. "I feel free to explore my imagination!"- she said. Most children expressed rich verbalizations about SADP: "I love it", "This game is interesting". As preliminary results children were motivated, participative, engaged with learning math, and able to co-create motor activities inspired by SADP challenges. The data analysis of the present study is in progress and will be presented.

Keywords: Special Education, Autism Spectrum Disorder, Dyscalculia, Children, Game-based learning

1. Introduction

1.1 The Concept of Disability and Policies for Inclusion

Foucault's (1974-75) discourse in Abnormal, on disability, focuses on the historical-political time from the Middle Ages to the beginning of the 20th century. It highlights the meanings of segregation or exclusion of people with disabilities. It refers that in this historical period, the discourse of the political, medical and judicial power of abnormality was characterized as "grotesque" or "ubuesque". The speech was based on the assumption of disqualification of the subject.

The United Nations (UN) estimates that about 10% of the world's population lives with some type of disability. According to the Directorate General of Health (2015), the health of the Portuguese in terms of years of life lost as a result of problems of health, disability or death are as follows: non-communicable diseases 85%, injuries 9%, other 6%. According to the World Health Organization (2021), the commitment to "leave no one behind" and "to ensure healthy lives and promote well-being for all at all ages'', represents the global intention of the 2030 Agenda of ONU Sustainable Development. Reducing inequality and ensuring inclusive quality education is one of the goals of the World Health Organization. According to the practical guide from the National Institute of Rehabilitation (2019), around 11% of people residing in Portugal have some type of physical, intellectual or sensory limitation. The Constitution of the Portuguese Republic (CRP) establishes in Article 26(1) that "the rights to personal identity, personality development, civil capacity, citizenship, good name and reputation, image, word, to the privacy of private and family life and to legal protection against any form of discrimination". It enshrines in Article 13, the Principle of Equality, determining that all citizens are equal before the law, and no person can be discriminated against according to their condition. In 2009, Portugal ratified the Convention on the Rights of Persons with Disabilities and its optional protocol, which aims to "promote, protect and guarantee the human rights and fundamental freedoms of persons with disabilities, promoting respect for their inherent dignity and recognizing its self-determination". The National Institute of Rehabilitation, I.P. (INR, IP) is the public body whose mission is to ensure the planning, execution and coordination of national. In 2018, with the publication of Decree-Law no. 54/2018, the concept that it is necessary to "categorize" in order to intervene was abandoned, as it was recognized that the curriculum and student learning are at the center of school activity.

1.2 Children with Autism Spectrum Disorder (ASD) and Dyscalculia

Autism Spectrum Disorder (ASD) represents a disorder in human development with an impact on social interaction, verbal and non-verbal communication and symbolic play (Monteiro, Pimenta, Pereira, & Roesler, 2017). The Diagnostic and Statistical Manual of Mental Disorders (DSM-5) (APA, 2014)describes three levels of PEA with different support needs (Level 1 – Support; Level 2 – Substantial support; Level 3 – Very substantial support) in terms of social communication and restricted and repetitive behaviors. In the DSM-5, dyscalculia, is described as a coding within the specific learning disorder: "impaired in mathematics" (p.315.1). It exposes four areas in which difficulties arise: number sense; memorization of numerical facts; accuracy or fluency in calculation and accuracy in mathematical reasoning.

According to Villar (2017), the work developed by Ohlweiler (2016) indicates that learning is a process of acquisition and conservation and that, in the face of stimuli and experiences, brain changes occur in the Central Nervous System (CNS). The school has a key role in bringing the child closer to Mathematics, enabling their motivation to explore the process of mathematical knowledge, and stimulating the action-reflection-action and cognitive process (Borges, 2015). Following this thought, psychomotricity emerges in the present study. Psychomotricity was constituted in the educational context as a new psycho-pedagogical perspective. It has a multidisciplinary foundation and has a fundamental and essential place in perceptual-motor education, in the global education of the child (Fonseca, 1976).The General Directorate of Education and Science Statistics (DGEEC) estimates that in Portugal between the academic years 2016/2017 and 2017/2018, the number of students attending Structured Teaching Units for the education of students with ASD registered an increase of 9%, mostly in basic education.

1.3 Games and Learning

According to (Probst, 2017) special education communities have not valued the impact of digital media use on special education students, namely those with (ASD) and EBD. Videogames have played an increasingly important role in our society, whether as a leisure activity or applied to education and rehabilitation. With previously defined learning objectives, video games can be integrated into the educational process in different ways, either by game creation or by using commercial games (Gee, 2007; Choi, Shin, Ryu, Jung, Kim and Park, 2020). For Salen & Zimmerman (2010) there is an important distinction between videogames aimed at learning/research and learning obtained through commercial games. Young people use play as a medium where they can develop adaptive behaviors (Pellegrini, Dupuis, Smith, 2007). Learning strategies based on digital games have shown more significant effects than traditional approaches, namely expository ones, thus allowing higher and more effective learning gains (Sousa & Costa, 2018). For (Sousa & Costa, 2018) videogames are considered an engaging medium, they can create meaningful learning experiences, with immediate and concrete feedback, performance before competence, with optimal levels of challenge and frustration, while failure is used as a motivational tool (Gee, 2007; Granic, Lobel, & Engels, 2014).

The research proposed here seeks to explore the potential of games as facilitators of mathematics learning and promoters of global, communicational, relational, and social psychomotor development in children with ASD and/or dyscalculia, in Basic Education. The digital game "Space adventure: Defend the planet!", created within the scope of the research project GBL4deaf, is used in the present investigation as a starting point for carrying out a psychomotor intervention with children with ASD and/or dyscalculia focused on the development of math competences. The main question of this investigation is: what is the impact of games on the teaching-learning process of mathematics, as well as on the global psychomotor, relational, communicational and social interaction development in children with ASD and/or dyscalculia in basic education in Portugal? The specific questions are: a) What are the cognitive and learning gains in the process mediated by the game "Space adventure: Defend the planet!"? b) What differences will there be in terms of motivation and engagement? c) What are the existing differences in the relationship between the game experience factors and the learning and performance of mathematics by psychomotor representation in children with ASD and/or dyscalculia? d) What differences will exist in terms of global psychomotor development? e) What differences will exist in terms of language, communication and social interaction? f) What is the correlation between the game experience, cognitive, learning and communication gains in the mediated process?

2. Method

A mixed method approach has been used. The quantitative investigation will focus on the documented functions of cognition, measured by non-verbal scales. Qualitative measures will document engagement and motivation with the "game" and psychomotor intervention activities. The evaluation of the gaming experience will allow

documenting variables related to the factors that constitute it: engagement/involvement, flow, immersion, presence and challenge. Direct observation, interviews, questionnaires, observation grids, psychomotor assessment, and application of validated scales to assess the game experience are part of the applied methodology. Mediators of learning and of verbal and non-verbal communication were adopted. Direct observation and the application of scales to assess the game experience are part of the methodology applied to obtain data, based on the main research question. The data obtained will be compared, in the Baseline and Endline evaluation, of the same experimental group, using statistical tests to compare populations from paired samples or repeated measurements (Maroco, 2007, p.269). The game experience performed and developed by the students will be analyzed through quantitative and qualitative data, together with the data of the Endline learning results, by the correlation coefficients. One of the aims is to quantify the intensity and direction of the association between several variables (Maroco, 2007, p.42). The quantitative data obtained in the experimental group in the final intervention will be compared through statistical tests to compare results through independent samples, achieving a quasi-experimental approach (Peng & Ziskin, 2008). Qualitative data obtained in the experimental groups (game, digital/psychomotor intervention) will also be evaluated, by direct observation of students with ASD and/or dyscalculia. They will be analyzed using content analysis methodologies, to systematize and quantify the content obtained (Drisko & Maschi, 2016).

2.1 Student sample

The sampling is for convenience, resulting from the professional relationship of the Special Education and Rehabilitation Technique with the Resource Center for Inclusion, which operates in the Group of Schools from which the sample was taken. The sample: 19 participants: 12 boys, 9 with ASD and 3 with Dyscalculia; 7 girls, 2 with ASD and 5 with Dyscalculia. The age range of the sample is between 5-10 and 15-16 years old. The mean age is M=8.6 with SD=1.8. The group(s) of students representing the case study, with ASD and/or dyscalculia, attends the Basic Education (1st, 2nd and 3rd Cycle) of the Cluster of Sample Schools. Students are distributed across 5 schools. The Frequency of Basic Education is divided between the 1st, 2nd, 3rd, 4th, 6th and 7th years.

Table 1:-Sample representation by: age, school and year of basic education

Ages	**Percentage %**	**School**	**Percentage %**	**Frequency of Basic Education**	**Percentage %**
5-6	15,8%	E001	5,3%	1st Year	21,1%
7-8	42,1%	E002	15,8%	2nd Year	10,5%
9-10	26,3%	E003	10,5%	3rd Year	26,3%
15-16	15,8%	E004	52,6%	4th Year	26,3%
		E005	15,8%	6th Year	5,3 %
				7th Year	10,5%

Data for the (2016/2017) school cluster academic year indicate that at the level of teaching and non-teaching staff, there were 165 teachers, of which 45 were in the 1st Cycle of Basic Education and 85 in the 2nd and 3rd Cycle of Basic Education, with only 12 special education teachers.

2.2 Materials and Instruments

2.2.1 The Videogame "Space adventure: Defend the planet!"

According to (Marcelino, L., Costa, C., Neves, J. C., Melo, A., & Soares, F. M., 2020), the videogame "Space adventure: Defend the planet!": is an educational game in the field of mathematics for use in formal and informal learning contexts, developed within the scope of the GBL4deaf – Game-based Learning for Deaf Students project [PTDC/COM-CSS/32022/2017]. The player must use math skills to solve four challenges in order to build a space base. Each challenge consists of three levels of difficulty, designed to provide the player with the use of mathematical knowledge. The player is rewarded with the resources needed to build and upgrade their space base. Challenge 1 consists of an addition and subtraction puzzle, where the player must add or remove particles from an atom to obtain resources that allow him to move forward. In Challenge 2, there are multiplication and division tasks, where the player must decide the number of cars needed to transport the produced pulleys. It must also determine the total amount to be made in each round, using multiplication reasoning.

For the present study, only two challenges will be evaluated (1 and 2), a decision taken into account the selected population and its characteristics. The evaluation of the students will be carried out by direct observation at two different moments (initial and final) with a record of the student's performance in the two challenges.

Additionally, the material used in the fieldwork was: gamer computer; chairs; support desk; 1 room board; diverse pedagogical material used by the researcher in psychomotricity sessions and to complement the digital game (balls, wooden pieces; pieces, pictures, puzzles, among others).

2.2.2 Instruments

For the development of the present study, the following assessment instruments were used: 1) CARS Rating Scale (Childhood Autism Rating Scale); 2) Pre-test of mathematical skills: Diagnostic sheet (1st, 2nd, 3rd and 4th) year school manuals, respectively; 3) Pre-test of mathematical skills (2nd and 3rd cycle): instrument by the GBL4deaf project - Game-based Learning for Deaf Students; 4) Pre-test of Communication and Social Interaction and Receptive and Expressive Language; 5) Battery M-ABC-2 (Movement Assessment Battery for Children – 2nd Ed.), using Band 2 (7 to 10 years old) and Band 3 (11 to 16 years old); 6) An observation and recording grid of sessions; 7) Assessment Questionnaire for Measures to Support Learning and Inclusion; 8) Assessment Questionnaire for Educational and Playful Technologies and Digital Games.

2.3 Procedure

Permission to carry out this research work was requested from the School Cluster, which was approved at a meeting of the Pedagogical Council. The preparation of the intervention took place from October to November 2021. Data from students with ASD and/or dyscalculia were collected from the Pedagogical Technical Report, among the head teachers of the class, special education teachers and non-teaching staff. Pre-tests were applied: mathematical skills, communication and social interaction and receptive and expressive language. The assessment of children's movement was also applied using the M-ABC-2 Battery (Movement Assessment Battery for Children – 2nd Ed, 2007) and the CARS Assessment Scale (Childhood Autism Rating Scale) to assess the level of autism. All questions were read aloud, individually. When necessary, in the case of non-verbal students, alternative communication was used. In November 2021, two experimental sessions were held: the first corresponded to the presentation of the digital game, where students explored the game; second session corresponded to the experience of the digital game with transposition to a psychomotor game (psychomotricity), with the material available in each school. Alternative communication tables were used, constituting an element that facilitates communication and learning. This session was important it worked on the anticipation and mental organization of the following sessions.

Direct and individual observation of the students was carried out by only one evaluator, the Technique of Special Education and Rehabilitation, the researcher of the present study. It was a participant observation. The teaching/learning and observation sessions took place once a week, with a total duration of 45 minutes (30 minutes correspond to effective practice (15`videogame + 15`psychomotricity) and 15 minutes correspond to the presentation/introduction period of the session and necessary transition moment between the part of the digital game session, for the psychomotricity session that took place in the relaxation room or in the gym with work carried out, mostly on the floor. The sessions were carried out in a gym context or in a relaxation room context, based on the conditions of each school. A total of 12 sessions were held between December 2021 and March 2022.

While quantitative research will focus on the cognition functions documented as fundamental in the process of acquiring competences in the field of mathematics, qualitative measures, measured through non-verbal scales, sought to document children's engagement, motivation, engagement with the " game" and psychomotor intervention activities. The evaluation of the game experience (game experience) aims to document variables related to the factors that constitute it, namely: engagement/involvement, flow, immersion, presence and challenge (Brokmayer et al., 2009; IJsselsteijn, de Kort, & Poels, 2013). As this is an ongoing investigation, within the scope of the researcher's doctoral thesis, this study presents preliminary results.

3. Results

In total, 34 different strategies were adopted during the 12 sessions. Here we will present only the strategies corresponding to the sessions presented below. Ten (10) of those were used: in the sessions presented below: **In Figure 2 and 3**: work carried out on the floor; music chosen by the student's; Positive communication (you can do it, go ahead, very well, among others); **Figure 4 and 5:** simple material that I used daily in a school context; puzzle pieces; transition from a digital game to a motor task on a table; **Figure 6 and 7**: giving time to organize thoughts and perform the task; using different material sizes; different colors and different shapes.

This Action Research project involves 19 children and young people who attend Basic Education (1st, 2nd and 3rd cycle) of regular education, with ASD and/or dyscalculia. The sample is heterogeneous, with 19 participants: 12 boys, 9 with ASD and 3 with Dyscalculia; 7 girls 2 with ASD and 5 with Dyscalculia. The mean age is M=8.6 with SD=1.8. The age range of the sample is between 5-10 and 15-16 years old.

In the sample of 19: 84,2% (16) of children have a computer and among them 52,6% (10) play video games on PC. 73,7% (14) have a tablet and 68,4% (13) of children play video games on it. In regards to having a smartphone, 26,3% (5) of children reported to have one, but 47,4% (9) children use it for playing video games, which means they play on other people's mobile phones. Table 2 shows the videogames most played by students on Computer, Tablet and Mobile.

Table 2: Number of videogames by technology

Used technology	**Number of videogames played**	**Most played games/ Percentage %**
Computer	**18**	Grid 60% (6); Animal sounds 50% (5); Draw Shapes 50%(5); ABC Frog 50% (5); Gcompris 40% (4); ABC Autism40% (4).
Tablet	**23**	Human Body 46,2% (6); Animal Farm for Kids 38,5% (5); Bini ABC 38,5% (5); Word shape 38,5% (5); Sonic the Hedgehog 38,5% (5); ABC Autism 30,8% (4); Gcompris 30,8% (4); Word Adventure 30,8% (4); Coloring Book 30,8% (4).
Mobile Phone	**20**	Minecraft 44,4% (5); Troll Master 44,4% (4); Merge Home 33,3% (3); Mini Market 33,3% (3).

Of the 12 game sessions carried out, 3 case studies are analyzed, with 3 children and their respective activities in a single session.

Game situation - challenge 1, level 1: positive and negative particle cannons are used so that the player can fire, one at a time, and take the black triangle to the green circle, thus obtaining metals and resources necessary to progress in the game. Figure 1 shows a successful situation. If the player fails, he can continue to play without any penalty.

Figure 1: The player obtained 1 metal after achieving the goal of reaching 2

Description: Student 9 (A009); School (E004); (1st year); 6 years

Figure 2: addition math symbol

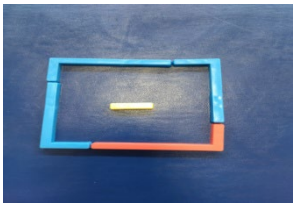

Figure 3: subtraction math symbol

Figure 2 and 3 - Session 1-Challenge 1/Level 1: In the digital game there are two particle cannons, one shoots negative particles (subtraction) and the other shoots positive particles (addition).The researcher placed numbers and pieces of different colors and geometric shapes on the rug. The child was asked to create the mathematical symbol for addition (+) and for subtraction (-), which appears on the cannons. He could select, up to 3 colors.

Results obtained: The child understood the verbal instruction of accomplishment and selected three different colors, as requested “I like these colors”. Selected different colors of symbols from the game; A good spatial organization was observed, and has commented: “I am making a square with large pieces and the sign is small. Poor little thing". The recognition and realization of geometric shapes and mathematical symbols present in the digital game were visible, with good time management and good body posture. He showed pleasure, good interaction with the technique and presented a fluent speech.

Description: Student 2 (A002); School (E003); (3rd year); 8 years

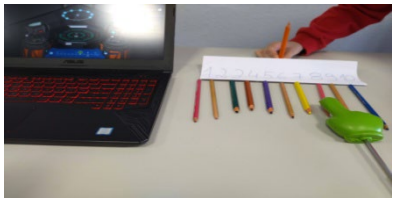

Figure 4: Digital game: challenge 1

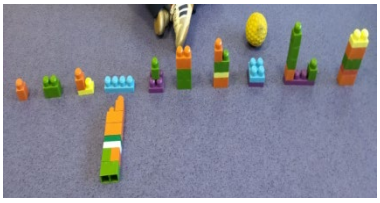

Figure 5: Psychomotor game: count up/down

Figure 4 and 5 - Session 6- Challenge 1/Level 1: The number line given by the game indicates the numbers from 1 to 10. The triangle (bottom line of the line) indicates the amount that the game gives us and the green circle (upper line of the straight line), indicates the value intended as a result. When performing the digital game, the student presented specific difficulties in reasoning and in understanding the increasing and decreasing sense of numbers, on the number line. To better perform the mathematical operation, he got up and with the help of the material seen in fig.4. He positioned himself behind the straight line (something he could not do in the video game) and was able to tell if the operation was addition or subtraction (there are 8, but the intended result is 6), and did on the floor, as seen in Fig.5, the number line using puzzle pieces with an indication of the value given by the game, in another calculation, represented by the puzzle pyramid, and the intended value as the result indicated by the yellow ball.

Results obtained: The student successfully completed the task. He delivered a simple but understandable speech; presented atypical motor agitation and deficit in attention and concentration “today I am tired, I did not sleep well”; Difficulty in carrying out the mathematical calculations, it was necessary to do reinforcement on the table, with motor experience, to understand the increasing and decreasing direction and thus carry out the calculation; He managed to transpose the number line correctly from 1 to 10.

Description: Student 4 (A004); School 4 (E004); (4th year); nine years old

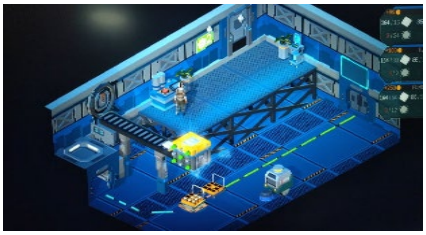

Figure 6: Digital game: Challenge 2

Figure 7: Psychomotor game: multiplication

Figure 6 and 7 - Session 8 - Challenge 2**:** the player heads to the machine that will release the metals. Upon release, the metals fall to the mat and trigger a number of lights. After observing the value, the calculation can be by multiplication (ex: 2 metals x 2 lights=4) or addition (2 metals, each one is worth two lights 2+2=4). Then the student must select how many carts he will use (ex: for result 4 the student can choose 4 carts that only carry 1 material or 2 carts with a capacity for 2. After selection, the carts move forward and collect the sprockets in the present case 4. The pieces are transported out of the metallurgy and the player moves on to the next challenge, which is not used in this research project. After playing challenge 2, the child was asked to replicate an account that he had made during the game session on the computer. The student selected the material and set up the route by himself and without assistance. He opted for a simple multiplication operation 2x2=4. As can be seen in Fig. 7, the student creatively simulated the game and was efficient in choosing the carts, having opted for 2 cars of 2 instead of 4 cars of 1.

The student successfully completed the task and was able to transform the digital game in a psychomotor game. He was very motivated and committed, saying that “I like this game. It's very cute”; He walked the route as if he were “inside” the digital game, imagining where the machine in digital game is located to activate the challenge and adopting the operator's movement. Later on the student walked into “his game” space to operate the account, moving correctly and freely.

4. Discussion

From the results obtained from the psychomotricity sessions presented, at the level of verbal communication, there was a variety of verbalizations rich in detail, for example: "We should have more games like this". There were some difficulties in terms of issues related to the body, reasoning and logic, organization and planning, memory, concentration and attention, stereotypes, mathematical concepts of subtraction and multiplication and communication in 3 cases of the sample. The digital game contributed in a very positive way to the dynamization of psychomotricity sessions. Realizing the variety of games and exercises that it was possible to carry out based on the digital game was really interesting and challenging both for the students and for the TSEER. This constituted an excellent pedagogical tool, which allowed to enhance the creativity of the TSEER and of the students. It was an element that enhanced and facilitated interdisciplinarity, essential for the integration and inclusion of children with ASD and/or dyscalculia. The individualized one-to-one work also represented a positive and facilitating element of learning. The psychomotricity sessions also proved to be an excellent complement to the game. Observing students' freedom of movement, communication, thinking, reasoning, relationships, and participation was exciting. The adoption of differentiated pedagogical practices is a good way to support them in learning and progress.

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