

Exploring the use of a learn-based exergame to enhance physical literacy, soft skills, and academic learnings in school-age children: a pilot study.

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Table of Contents

Original Manuscript.....	5
Supplementary Files.....	26
Figures	27
Figure 1.....	28
Figure 2.....	29
Figure 3.....	30
Figure 4.....	31
Multimedia Appendixes	32
Multimedia Appendix 1.....	33
Multimedia Appendix 2.....	33
CONSORT (or other) checklists.....	34
CONSORT (or other) checklist 0.....	34

Exploring the use of a learn-based exergame to enhance physical literacy, soft skills, and academic learnings in school-age children: a pilot study.

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Abstract

Background: There's ample evidence that most children don't get enough physical activity. To address this major public health problem, the French government has imposed 30 minutes of daily physical activity (DPA) at school, but without providing any supplemental resources or concrete guidance. Considering both children's interest in video games and the need for teachers to complete their curriculum, using a learn-based exergame that combines physical activity (PA) and learning, seems particularly relevant.

Objective: The first objective of this study was to evaluate the feasibility of implementing 30 minutes of DPA through exergaming among school-age children. The second objective was to examine the effects of an exergaming program on physical literacy, academic learning, and soft skills (motivation, self-efficacy, and concentration).

Methods: This interventional study using the Play Lü® exergame platform, with a pre-post design, included 79 children aged 8.9 years (SD=1.2) from grade 2 (7 years old) to grade 5 (11 years old). Play Lü® requires the players to throw balls against the wall to reach a target or to activate an object while providing an interactive game area for educational activities linked to specific learning themes. At the request of teachers, the learning theme in this study was mathematics.

After four habituation session phases, students took part in 30 minutes DPA sessions with Play Lü® for 3 weeks. Before (T0) and after (T1) the program, students completed a self-evaluation booklet to assess their level of physical literacy, academic performance, and soft skills (e.g. motivation, concentration).

Results: First, the implementation of this exergaming program was welcomed by the school's administration, teaching staff, and parents. Second, after the program, we observed increased scores in physical literacy (+3.8%, $W=933.0$, $P=.002$, $rrb=-0.39$ [-0.58, -0.16]) and motivation in mathematics (+9.86%, $W=381.5$, $P=.005$, $rrb=-0.44$ [-0.66, -0.16]). In addition, it's important to note that some measures progress differently across learning levels and age groups.

Conclusions: The use of learning-based exergaming is particularly well suited to the implementation of 30 minutes of DPA during school hours.

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Original Manuscript

Original Paper

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Abstract

Background: There's ample evidence that most children don't get enough physical activity. To address this major public health problem, the French government has imposed 30 minutes of daily physical activity (DPA) at school, but without providing any supplemental resources or concrete guidance. Considering both children's interest in video games and the need for teachers to complete their curriculum, using a learn-based exergame that combines physical activity (PA) and learning, seems particularly relevant.

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Results: First, the implementation of this exergaming program was welcomed by the school's administration, teaching staff, and parents. Second, after the program, we observed increased scores in physical literacy (+2.6(3.6%), $W=933.0$, $P=.002$, $r_{rb}=-0.39$ [-0.58, -0.16]) and motivation in mathematics (+0.7(9.8%), $W=381.5$, $P=.005$, $r_{rb}=-0.44$ [-0.66, -0.16]). In addition, it's important to note that some measures progress differently across learning levels and age groups.

Conclusions: The study's results indicate a positive impact of learning-based exergaming on physical literacy and motivation in mathematics among school-age children.

Keywords:

Learning supports; exergaming; physics playground; educational games; primary school; children.

Introduction

Background

Regular exercise and physical activity (PA) have been shown to benefit children's physical and social health, as well as their academic performance [1–3]. For children, the World Health Organization (WHO) recommends a minimum PA practice of 60 minutes of daily moderate-to-vigorous PA (MVPA) [4]. Yet, in France, only 41.8% of children reached these recommendations [5]. In other words, nearly six children out of ten are physically inactive. In this context, the French national health strategy [6] has set as a major objective the implementation of a comprehensive policy of prevention and health promotion. As a result, since September 2022, primary schools have been required to provide 30 minutes of daily PA (DPA) to promote PA and encourage the development of children's motor skills and physical abilities. Distinct from the teaching of physical education (PE), the 30 minutes of DPA can take a variety of forms, adapted to the context of each school. They can be split up and combined over the various school and extra-curricular periods. This was extended to all elementary schools after 2 years of testing in 11,000 volunteer schools [7].

Given the significant amount of time children spend in school throughout their childhood, schools represent an ideal setting to achieve maximum impact concerning improving PA levels [8,9]. Furthermore, several studies suggested that combining PA with academic activities can improve children's health and cognitive functioning, which could subsequently lead to children's academic performance improvement [10–12]. Attention, in particular, which is a prerequisite for learning, is often targeted during classroom-based PA [13]. However, other variables such as motivation and self-efficacy (referring to the child's perception of his/her own capabilities), are well known to influence children's school performance and acquisition [14–17] and could be influenced by a more entertaining approach to learning via exergaming.

Despite all the benefits of implementing regular PA at school, in a systematic review, Nathan and colleagues [18] have highlighted several barriers such as environmental context and resources with a “lack of time in the curriculum”; goals with “competing curriculum demands of other subjects”, or “physical activity considered a lower priority than other subjects”; or their beliefs about capabilities such as the lack of teacher expertise and confidence delivering PA, and their intentions with “a lack of teacher motivation to implement PA” [18]. By contrast, they have also raised several facilitators. Among them, the knowledge domain can play a facilitating role, for example, “sufficient knowledge about PA and health to effectively conduct PA” [18]. This dimension could be explored through the notion of physical literacy (PL), which corresponds to “the motivation, confidence, physical competence, knowledge and understanding to value and take responsibility for engagement in physical activities for life” [19]. Indeed, PL is particularly important in early childhood, a crucial period for the development of fundamental movement skills [20] and the adoption of PA habits. Physically literate individuals are more physically active, spend more time playing sports, and are less sedentary. PL is a multi-level concept that is increasingly taken into consideration in the field of public health as it is a key determinant of PA habits across the lifespan [21].

One of the factors behind children's low PA levels, but also high levels of sedentary behaviors, is screen time use. Indeed, 71.7% of French boys and 58.5% of French girls aged 6-10 spend more than 2 hours a day in screen time [22]. Between 8 and 12 years old, 1.5 hours of daily screen time is attributable to video games [23]. Over the last decades, video games have emerged as one of the most popular forms of global entertainment. Given children's keen interest in video games, it seems particularly appropriate to use gamification to encourage their PA. To stay active while enjoying the pleasures of video games, a worthwhile alternative is exergaming. Indeed, exergaming or active video gaming (AVG) requires bodily movements to play the game and encourages PA to focus on children's interest in the game's dynamic and stimulation. Our approach to exergaming takes into

account a health dimension and can be associated with the conceptualization proposed by Oh and Yang [24], defining exergame as “a video game that promotes (either via using or requiring) players’ physical movements (exertion) that is generally more than sedentary and includes strength, balance, and flexibility activities”.

Given that children spend most of their time at school, that they have a particular appeal for video games, and that exergaming seems to have beneficial effects on school learning [25], the use of exergaming at school would appear to be the ideal solution for promoting PA, LP [26–28] and learning [29]. Furthermore, it seems that using a technology-based learning environment at school can increase soft skills such as motivation and concentration on academic tasks [30]. Similarly, it has been shown that incorporating technology into an instructional intervention can improve students’ sense of self-efficacy [31] which is a key variable for academic learning. Exergames, in particular, have been found to promote cognitive functions, motor skill training, enjoyment, and motivation to play of school-age children [32], but also to improve self-efficacy over traditional exercises [33]. Supporting this idea, it has been shown that exergaming (e.g., Nintendo® Wii Games [34]) incorporated into PE classes combined with health messages has a higher potential to enhance PA-related attitudes and behaviors than regular PE classes, especially in elementary school children [28]. An interesting exergaming tool for reconciling learning and DPA is the Play LÜ exergame platform (LÜ® Interactive Playground, Québec, Canada) [35]. This technology allows to change traditional sports-school atmosphere into an interactive learning environment through interactive wall projection and a synchronized sound system. LÜ Playground activities are designed to improve children and adolescents’ learning by allowing them to respond to questions in specific fields (e.g., mathematics, history, natural sciences) by throwing balls against the interactive wall. This tool would therefore allow the practice of PA within non-physical education curricula and thus ensure the 30 minutes of DPA among primary school children. Moreover, given the associations demonstrated in the literature between cognitive functioning, soft skills, learning, and PA, it also seems essential to assess whether an exergaming program can improve these different variables.

Objectives, research questions, and hypotheses

The first objective is to study the feasibility of implementing 30 minutes of DPA through exergaming. Given that exergaming combines the interests of children (for video games) and teachers (for learning and respecting the curriculum), while promoting PA, we hypothesize that it will enable effective implementation of the 30 minutes of DPA in schools.

The second objective of this study is to evaluate the effects of an exergaming program on PL, academic learning, and soft skills (motivation, self-efficacy, and concentration). We hypothesize that implementing a DPA program involving exergaming on a specific academic course combined with information on health-promoting behaviors daily could increase children's PL (hypothesis 1) and increase academic performance (hypothesis 2). Indirectly, allowing students to work on an academic subject more entertainingly through exergaming could improve students' motivation in the academic discipline (hypothesis 3), Improve their sense of self-efficacy in the subject (hypothesis 4), as well as their concentration in class and the academic subject (hypothesis 5).

Methods

Population

This study was conducted with children aged 7 to 11 as part of the implementation of the 30 minutes

of DPA policy. The study was designed as an interventional study with a pre-post design. It included children from grade 2 (7 years old) to grade 5 (11 years old) in a mid-sized city school in the southern part of France who had never benefited from any intervention in the field of exergaming. Before the project, the study and objectives of this research project were presented to the school administration and then to the teachers. This pilot study took place in a small school with one class per level and one teacher per grade, each of them ($n=4$) with no experience of exergaming and volunteering to take part in the research protocol. This school was selected for its pre-existing collaboration with the research team and middle-school students (8th grade), as well as for the availability of a space that could be used to install the LÜ® mobile setup over a period of several weeks.

Subsequently, parents of the classes concerned were informed that their children would be part of a research protocol on 30 minutes of DPA during school time. A request for parental consent was sent via the school administration to each parent. In the event of parental refusal (only 3 parents refused), children's data were not analyzed. A habituation phase was then proposed, and the teachers were able to learn about the various potentialities of the LÜ® tool, as well as the implementation of the 30 minutes of DPA by the project team. The intervention then began and lasted 3 weeks, and pre- (T0) and post-intervention (T1) assessments were conducted.

During the enrollment period, 102 children were eligible (Figure 1). However, due to the absence of parental consent ($n=3$) or the absence of children at evaluation time 0 ($n=6$) or time 1 ($n=11$), the analyses were carried out on 79 children. This final sample was made up of 34 girls and 45 boys with a mean age of 8.9 years ($SD=1.2$).

INSERT FIGURE 1 HERE

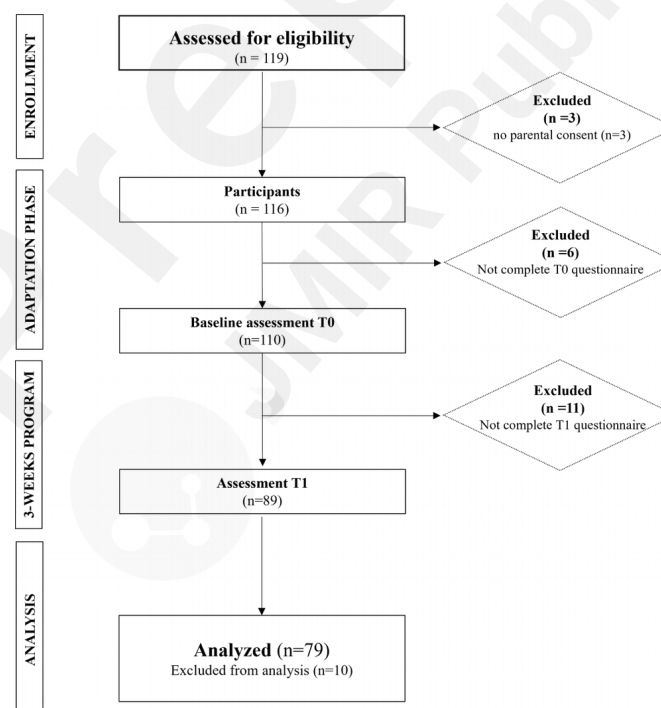


Figure 1. Study flow chart.

Classes measures

All the teachers expressed the wish to work on mathematics (geometry and arithmetic). A planning schedule was drawn up with the classes concerned so that the sessions could be scheduled during math lessons.

Teacher's measures

At the end of the program, teachers were asked the following questions:

“On a scale from 0 to 10, how would you rate:

1. your students' motivation for mathematics before the program?
2. your students' concentration for mathematics before the program?
3. your students' motivation for physical activity before the program?
4. your students' motivation for mathematics today?
5. your students' concentration for mathematics today?
6. your students' motivation for physical activity today?”

Children's measures

At T0 and T1, students completed a questionnaire consisting mainly of analog visualization scales or checkboxes on different variables of interest (PL, motivation, self-efficacy, and concentration) which are described in the following sections. In addition, exercises adapted according to grade level were proposed in the target subject (mathematics) and a control subject (French).

Physical literacy

PL was assessed using the Physical Literacy Assessment for Youth Self (PLAY Self), designed for children 7 years and older to explore children's perceptions of their PL [36]. PLAYself demonstrated robust psychometric properties, with good fit statistics, internal reliability, and a lack of item bias and problematic local dependency [37]. For a better understanding of the different dimensions of PL in the PLAYself questionnaire, the forms are available in English [38] and French [39] versions. The adaptation of this form within the evaluation booklet of this pilot project is available in Appendix 1.

PLAYself consists of 22 questions divided into four subsections:

1. *Fitness*: children's perceived fitness level with “disagree (1)/agree (2)” response categories to a single item.
2. *Environment*: measures of six different environments in which children can do sports and activities (e.g., “How good are you at doing sports and activities in the gym?”) on a 5-point Likert scale ranging from “never tried” (1) to “excellent” (5)
3. *Physical literacy self-description*: twelve statements about doing sports and activities based on cognitive and affective factors (e.g., “It doesn't take me long to learn new skills, sports or activities”), where the children are asked to rank how well they agree on a 4-point Likert scale ranging from “not true at all” (1) to “very true” (4);
4. *Relative Ranking of Literacies*: children's ranking of the importance of literacies in school, at home with family, and with friends (e.g., “Math and numbers are very important in school”) each on a 4-point Likert scale ranging from “strongly disagree” (1) to “strongly agree” (4);

The first section is informative while, with the other three subsections, a score can be calculated as well as a total score for PLAYself. The total PLAYself score is the average across the scores of each

subsection excluding the fitness question. The higher the score (0—100), the higher the self-perceived PL.

Academic achievement

To measure academic achievement, exercises in French and mathematics were retrieved from the national program by level following teacher school year progression. The test evaluated students' academic knowledge and skills related to specific subject areas, including French and mathematics. The test was grade-specific; did not contain any bias regarding age, gender, or ethnicity; and was scored as a percentage of achievement in French on one side and mathematics on the other.

Motivation, self-efficacy, and concentration

Motivation and self-efficacy were assessed by two items each, one for mathematics and the other for French. For motivation, children were asked: "How much do you enjoy doing [mathematics/French] exercises?". For self-efficacy, children were asked: "How well do you think you did on the [mathematics/French] exercises?". Concentration was assessed by three items, one for mathematics, one for French, and a more general one targeting concentration in class. For this variable, children were asked: "How easy is it to concentrate in [class/mathematics/French]?" We used a simple question per variable to reduce the time needed to complete the entire protocol. The items were formulated as clearly as possible to be adapted to the children's age and to ensure that they measure the core component of each variable. For all items, children were asked to respond using a 10cm long visual analog scale representing their own feelings and marked by extreme labels at 0cm (e.g., very hard) and 10cm (e.g., very easy), which appeared as reliable response option in children's questionnaires [40].

Procedure

Habituation phase

On Thursdays in March 2023, students had four LÜ® 30-minute habituation sessions, spaced one week apart, enabling them to familiarize themselves with the interactive gymnasium. Activities linked to the academic development of the LÜ catalog were proposed, targeting Languages (i.e. Minewörd), Mathematics (i.e. Wäk and Newton, Constello and SphYnX App), Science and Technology (i.e. Brüşh and Grüb), History (i.e. Störia) and Arts (i.e. Pixël). With mathematics accounting for 1/5 of the school program in each grade, and the LÜ catalog offering more mathematics-related applications (except PE, which was not at the center of the project), the 4 teachers wanted to work on mathematics during the 3-week DPA immersion phase (Figure 2).

INSERT HERE FIGURE 2

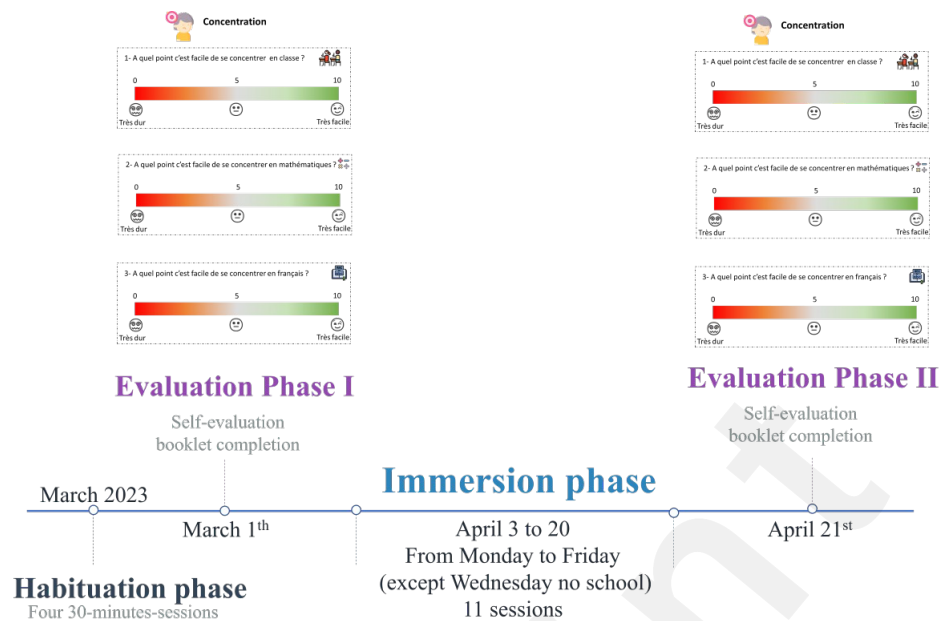


Figure 2. Timeline project.

Immersion phase

After the habituation phase, students took part in daily 30-minute DPA sessions using the Play LÜ® exergame platform and working on a single subject selected by the teacher (Figure 2).

The Exergame Setting

For this research protocol, the LÜ mobile equipment owned by the research team was made available to the school for this pilot project and was installed in a designated space for the duration of the project. The Play LÜ® exergame platform (LÜ Interactive Playground®, Québec, Canada) has the potential to overcome the limitations of a physical room. With Play LÜ®, the participants are immersed in the games displayed on a giant projection wall (6 X 3 meters). The principal mechanism of Play LÜ® requires the players to throw balls against the wall (e.g., to reach a target or to activate an object; Step 1 in Figure 3). In addition, this mobile platform offers an interactive game area for educational activities linked to specific learning themes (calculations, puzzles, etc.). For this research protocol, a work area with a daily changing activity circuit has been implemented behind the LÜ Mobile® (without the interactive wall). With class compositions ranging from 26 to 30 students, this "with" and "without" interactive wall configuration is essential to keep students active during the 30-minute session. So, once the ball has been sent to the interactive wall (Step 1), the student must go behind the mobile LÜ towards the back of the room (Step 2) to carry out various exercises to promote different motor skills (e.g., jumping, throwing, balancing), and perform other exercises on the way back (Step 3). At the end of the circuit behind the LÜ (Step 2 and 3), the student waits his turn in front of the interactive wall (Step 4).

INSERT FIGURE 3 HERE

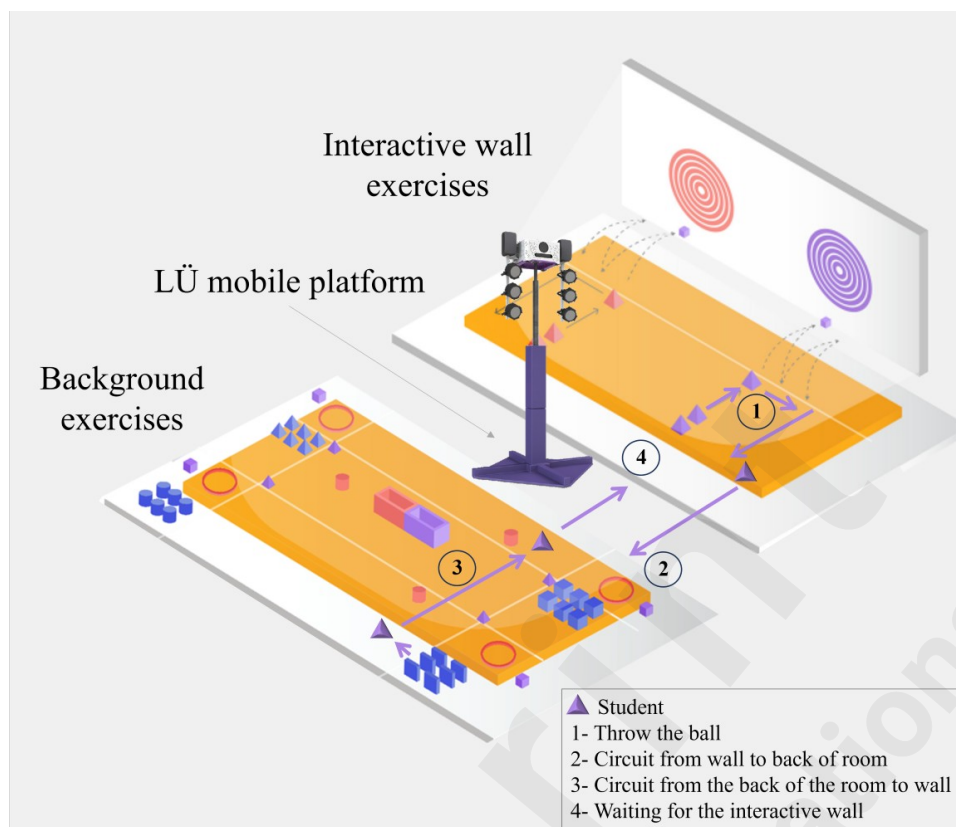


Figure 3. Practice environment implementation.

Daily session exercises with Play LÜ

During the 3-weeks immersion phase, sessions were structured in the same way, with at the beginning a warm-up using the Gröove® application (Figure 4), which can be assimilated with AVG Just Dance® (Nintendo®; [41]); then a core session promoting mathematics learning adapted to each grade, with a section in front of the interactive wall with the Newton® application for arithmetic and Puzz® application for geometry (i.e., with picture geometric form or rules), and a section without the interactive wall consisting of motor skills circuit (for example, throwing, jumping, balancing) enabling the child to be as active as possible (Figure 4). During break times (mainly while waiting for their turn on the interactive wall), the children had access to posters presenting active health behaviors with their favorite heroes according to age (i.e., The Minions®, Miraculous®, successful French singer or Youtuber depending on students' ages). The session ended with a 3-minute meditation for a return to peace and quiet using the Gaïa® application (Figure 4).

INSERT FIGURE 4 HERE

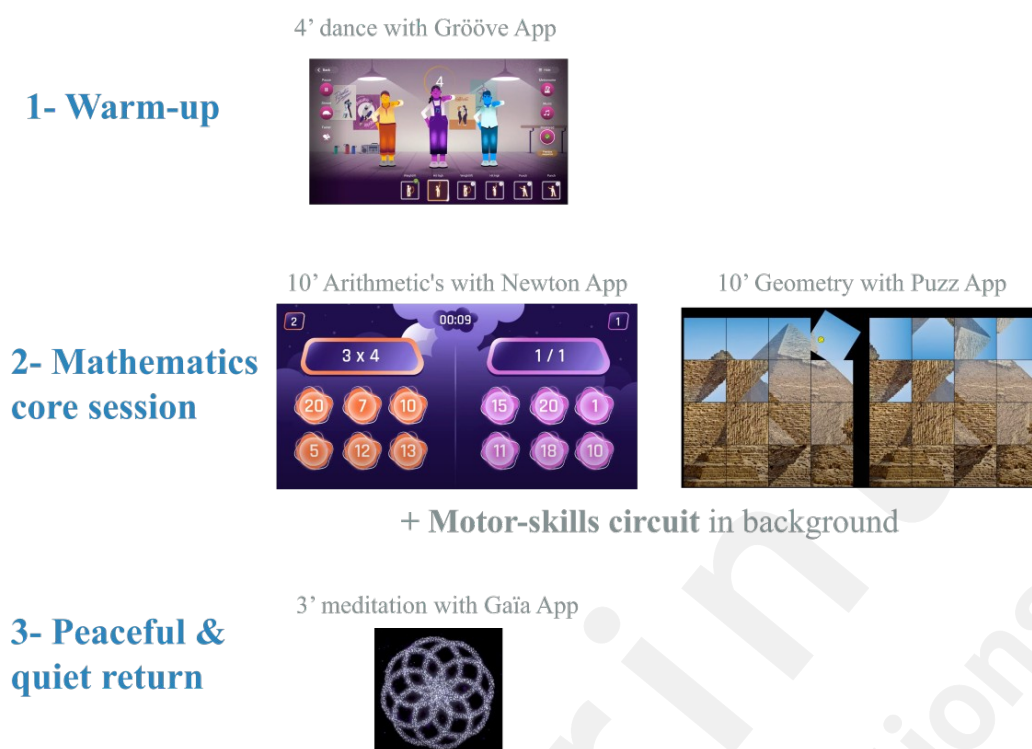


Figure 4. DPA core session details

Focus on LÜ applications

The Play LÜ® exergame platform allows the use of applications (with or without the customization) that can be used to meet general or specific learning objectives. The applications used during the immersion phase and their pedagogical benefits are summarized in Table 1.

Table 1. Play LÜ applications.

	App description	Learning objectives		
		Academic development	Physical and motor development	Socio-cognitive development
Gröëve 4'	This is a perfect warm-up and allows to develop gross motor skills	- Movements - Dance	- Coordination - Cardiovascular endurance	- Cognitive flexibility - Inhibition
Newton 10'	Newton is a fun way to combine physical activity and math with the customization of equations by grade	- Arithmetic	- Manipulation (throw the ball and aim at the target)	- Inhibition
Puzz 10'	Throw the ball at a piece of the puzzle to rotate it and allow it to create an active knowledge competition.	- Puzzle created with geometry-related images - Spatial orientation	- Manipulation (throw the ball and aim at the target)	- Task engagement
Gaïa 3 to 5'	This application helps your students cool down after they've been active.	- Health and healthy habits	- Proprioception	- Emotional regulation

The customization of pre-existing games in LÜ was carried out on the Newton® and Puzz® applications about mathematics learning. For the Newton® application, the difficulty of the operations proposed depended on each grade (for example, addition and subtraction calculations for grades 2 and 3, and multiplication calculations for grades 4 and 5). For the Puzz® application, the images to be assembled were linked to the geometry program (for example, polygons and non-polygons for grades 2 and 3, and complex polygons for grades 4 and 5).

Evaluation phase

Before (T0) and after (T1) the 3 weeks of DPA (Figure 2), students completed a self-evaluation

booklet to assess their level of PL, academic performance, and soft skills that could be impacted by the program (e.g., motivation, concentration, self-efficacy).

At the end of the 3-week immersion phase, the students retook the same questionnaire, with only minor changes to the exercises (e.g., 12 + 18 replaced by 14 + 15), but with the same instructions and level of difficulty. Following this, a short interview was conducted with the teachers during the lunch break, asking them to assess the changes observed in their classrooms.

All DPA sessions were carried out by sports science students specializing in adapted PA and health, under the supervision of a qualified teacher of adapted PA and health.

Statistical Analysis

Power analyses were conducted using G*Power. For a pre-post comparison, with a medium effect size (.50), an alpha error probability of .05, and a power of .95, we obtained a total sample size of 45. We then adjusted to the number of participants available in the schools (which allowed us to reach the sample size of 45).

As our data did not follow a normal distribution and given the characteristics of our sample, the intervention impact was tested with nonparametric within-group comparisons (T0 vs. T1; Wilcoxon tests, bilateral p-values) for all participants, then by school-grade grouping. Effect sizes were expressed as the rank biserial correlation (r_{rb}) and its 95% confidence interval. We also provided the score differences between T1 and T0 and expressed them as a percentage of improvement. Data were analyzed using JASP® software (0.17.2.1 version).

Ethical Considerations

This pilot study was an experiment in human and social sciences in the field of health and therefore did not involve the competence of the Committee of Protection of the persons according to article R1121-1 section II subsection D of the French Code of Public Health. Before the start of the study, a favorable opinion was obtained from the president of the University of Nîmes ethics committee. He verified that the study was conducted in accordance with institutional and national ethical standards, as well as the Declaration of Helsinki (2008). Moreover, this study was integrated into the school's activities and projects, and the protocol was validated by the school administration.

Consent to participate

Concerning consent and information, first, the study was presented to the school's teaching staff and administration who have given their approval to take part. Next, an online information notice and online informed consent with the names and university affiliations of the experimenters were requested from the parents of all children in the classes involved in the study before the beginning. Finally, the information and informed consent of the children and their teachers were collected face-to-face. Recruitment was based on voluntary participation, with no compensation for participants. Participants were informed that they could withdraw their consent at any time, whether at the request of the child, parent, or teacher.

Specific measures taken towards the public

To assure safety and security, all activities took place during class hours, under the supervision of the teacher, and the exercises were led by an associate professor specializing in public health and physical activities and two 3rd-year students in adapted physical activities from the University of Nîmes. The expertise of the three animators enabled them to adapt the physical activities to the

children's abilities, to prevent any risk of injury. Moreover, the number of animators made it possible to provide individual support when needed. Finally, to guarantee the security of the data, they were all stored on a secure university computer, and the printed versions were kept in a secure cupboard in a university office.

Results

Feasibility DPA and exergaming

Concerning our first objective, which was to study the feasibility of implementing 30 minutes of DPA through exergaming, our results showed that implementing exergaming during school time is entirely feasible. First, as far as the parents were concerned, all but three were in favor of their children taking part in the project. Second, as regards the teachers, they all agreed to take part in the project. Thirdly, all scheduled sessions (n=11) were carried out, with no sessions canceled. External constraints, such as educational visits or other activities, could have led to cancellations, but the teachers expressed a desire not to miss any sessions and agreed to exchange schedules with other classes when constraints arose, demonstrating their interest.

Effects of exergaming program

On all cohort

Concerning our second objective for the whole cohort, the intervention of 3-weeks of DPA led to increased scores in PL (in accordance with hypothesis 1) and motivation in mathematics, the subject covered in the intervention (in accordance with hypothesis 3). Marginally, there was a general improvement regarding concentration in class whereas we expected (hypothesis 5) this increase to be observed also for mathematics (Table 2). In addition, contrary to our assumptions, we did not observe any changes in academic performance (hypothesis 2) or feelings of self-efficacy (hypothesis 4) in mathematics. Surprisingly, the intervention also favored French learning (which was not covered in the intervention): academic performance, concentration, and self-efficacy in French were higher after the intervention.

Table 2. Descriptive analyses of variables of interest and before (T0) vs. after (T1) the 3 weeks of DPA comparisons for the whole cohort (N=79) ^a.

	T0 M (SD)	T1 M (SD)	T1-T0 (% of improvement)	W	P	r _b [95% IC]
Physical Literacy						
	70.8 (13.6)	73.4 (13.3)	+2.6(3.6%)	933.0	.002	-0.39 [-0.58,-0.16]
Academic achievement						
In mathematics	63.6 (32.5)	60.8 (31.0)	-2.8(-4.4%)	1440.0	.35	0.12 [-0.13,0.37]
In French	59.3 (26.2)	65.0 (27.9)	+5.7(9.6%)	858.0	.05	-0.26 [-0.50,-0.00]
Motivation						
In mathematics	7.1 (3.6)	7.8 (3.0)	+0.7(9.8%)	381.5	.005	-0.44 [-0.66,-0.16]
In French	5.3 (3.2)	5.6 (2.9)	+0.3(5.6%)	1222.0	.48	-0.09 [-0.34,0.16]
Concentration						
In the classroom (general)	5.5 (3.0)	6.0 (2.7)	+0.5(9.0%)	934.5	.07	-0.24 [-0.48,0.01]
In mathematics	7.0 (3.2)	7.2 (2.8)	+0.2(2.8%)	580.0	.16	-0.21 [-0.48,0.08]

	In French	5.6 (2.7)	6.4 (2.8)	+0.8(14.2%)	838.0	.01	-0.34 [-0.55,-0.09]
Self-efficacy							
	In mathematics	6.8 (2.8)	7.2 (3.1)	+0.4(5.8%)	887.5	.30	-0.14 [-0.40,0.13]
	In French	6.1 (3.1)	6.7 (2.8)	+0.6(9.8%)	728.5	.02	-0.32 [-0.54,-0.05]

^a Significant differences are specified in bold.

In Grade 5

Focusing specifically on each grade (see Appendix 2 for full details), participants in Grade 5 were those most affected by the intervention.

Grade 5 showed an increase in PL (+5.6(7.9%); $W=9.0$, $P<.001$, $r_{rb}=-0.91$ [-0.96, -0.78] hypothesis 1), math motivation (+1.1(20.0%); $W=15.5$, $P=.007$, $r_{rb}=-0.77$ [-0.91, -0.43] hypothesis 3) and math concentration (+0.8(12.7%); $W=21.5$, $P=.01$, $r_{rb}=-0.68$ [-0.88, -0.27] hypothesis 5) scores. Regarding French classes (even though they were not targeted by the intervention), grade 5 demonstrated higher motivation (+0.8(17.7%); $W=60.0$, $P=.05$, $r_{rb}=-0.48$ [-0.76, -0.03]), and self-efficacy (+1.5(29.4%); $W=45.0$, $P=.02$, $r_{rb}=-0.57$ [-0.81, -0.14]) scores after the intervention. They also tended to get higher academic achievement scores in French (+7.3(11.4%); $W=53.0$, $P=.09$, $r_{rb}=-0.44$ [-0.75, -0.03]). Contrary to hypothesis 1, grade 5 academic achievement scores were lower after the intervention in mathematics (-10.7(-13.6%); $W=192.0$, $P=.006$, $r_{rb}=0.66$ [0.29, 0.85]).

In Grades 2 to 4

The other grades also benefited from the intervention but to a lesser extent. After the intervention, grade 2 increased their PL scores (+5.2(7.1%); $W=28.0$, $P=.03$, $r_{rb}=-0.58$ [-0.84, -0.11] hypothesis 1), and marginally their academic performance in math (+15.1(33.7%); $W=18.5$, $P=.06$, $r_{rb}=-0.59$ [-0.86, -0.06] hypothesis 2). Grade 3 increased their math concentration (+0.5(7.5%); $W=50.5$, $P=.04$, $r_{rb}=-0.51$ [-0.79, -0.07] hypothesis 5). Regarding French classes, grade 2 marginally increased their self-efficacy scores (+1.0(14.4%); $W=24.0$, $P=.07$, $r_{rb}=-0.54$ [-0.83, -0.01]), grade 3 significantly their academic performance (+16.8(40.1%); $W=68.0$, $P=.01$, $r_{rb}=-0.58$ [-0.80, -0.21]) and grade 4 marginally their concentration (+1.1(20.7%); $W=25.0$, $P=.09$, $r_{rb}=-0.52$ [-0.82, 0.01]). Deleteriously, grade 4's academic performance in French declined following the intervention (-15.0(-19.8%); $W=103.5$, $P=.01$, $r_{rb}=0.72$ [0.33, 0.90]).

On teachers' perceptions

Concerning the results obtained from teachers, 3 out of 4 teachers observed an improvement in their students' motivation for mathematics after the program (in Grade 2, $T_0 = 5.5$ vs. $T_1 = 7.5$; in Grade 3 $T_0 = 7.0$ vs. $T_1 = 7.5$; in Grade 5 $T_0 = 8.0$ vs. $T_1 = 8.5$), and one teacher observed no change (in Grade 4, $T_0 = 6.0$ vs. $T_1 = 6.0$). In addition, 2 out of 4 teachers observed an improvement in their students' concentration for mathematics after the program (in Grade 2, $T_0 = 6.0$ vs. $T_1 = 6.5$; in Grade 4, $T_0 = 3.0$ vs. $T_1 = 5.0$), and the other two teachers observed no change (in Grade 3, $T_0 = 6.0$ vs. $T_1 = 6.0$; in Grade 5, $T_0 = 6.5$ vs. $T_1 = 6.5$). Finally, about students' motivation for PA, only one teacher observed an increase (in Grade 2, $T_0 = 8.0$ vs. $T_1 = 9.0$). It should be noted that two of the teachers who observed no change (in Grades 4 and 5), had already identified the maximum motivation score before the start of the program. The last rated the motivation of its students at 9.0 before and after the program.

Discussion

Principal Findings

Since September 2022, primary schools have been required to provide 30 minutes of DPA. In this pilot study, the implementation of an exergaming program as part of the 30 minutes of DPA policy was welcomed by the school's administration, parents, and teachers with an increase in perceived motivation for mathematics.

Second, after the program, we observed that children increased scores in PL and motivation in mathematics after 11 learn-based exergaming sessions.

Exergaming implementation

Although this reform is recent in France, it had already been introduced in other countries, several years ago. Indeed, the DPA school policy has been implemented since 2005 in Canada to promote active lifestyles for children in school settings [42], and in the province of Ontario, all elementary school children receive DPA during instructional time [43]. Yet, ten years later (in 2015), it was revealed that only half of Ontario teachers were meeting this expectation [44] and this number dropped to 23% five years later in Martyn and colleagues' evaluation [45]. The Canadian experience underscores the need to explore effective and sustainable methods for implementing the 30 minutes of DPA in schools. Consequently, this pilot study shows that exergaming can be used as a valuable tool in the deployment of DPA at school.

The efficiency and usefulness of exergaming

Our second objective was to find out whether an exergaming intervention could actually be effective, as well as being perceived as useful. We hypothesized that implementing a DPA program involving exergaming on a specific academic course could have an impact on different aspects of the child's experience. Firstly, in line with hypothesis 1, our results showed a significant increase in the PL of the entire cohort, with significant increases of over 7% for both Grades 2 and 5. This result is all the more important as it has been highlighted that elevated PL leads to greater PA participation, resulting in positive physiological, social, and psychosocial adaptations, and thus improved physical, mental, and social health [46]. In other words, PL could play a role across the lifespan in promoting positive health. Therefore, exergaming seems to be an effective and useful instrument to promote PL. This observation is in line with Sun's review [47], which highlighted that AVG could contribute to enhancing children's PL, in particular on the motivational aspect of exergaming making it possible to provide a variety of opportunities to develop or reinforce basic motor skills among children.

Secondly, concerning motivational aspects, in line with hypothesis 3, our results showed that an overall positive effect on students' motivation towards the discipline worked. Indeed, we found an increase in math motivation (target subject) with a significant increase of almost 10% for the total cohort, while motivation for French (control subject) was not impacted. It seems that allowing students to work on mathematics more entertainingly, i.e., by throwing balls onto calculation operations, helps to increase their appeal in this course.

Thirdly, contrary to hypotheses 2, 4, and 5, our results showed no increase in academic performance, motivation, and sense of efficacy in mathematics. Yet, results showed an increase in these variables in French, even though this subject was not directly targeted in the sessions. Although interpretation is limited without a control group that did not benefit from the intervention, it is conceivable that the participants benefited from additional motivational resources provided by the 30 minutes of DPA toward learning at school, in accordance with the results of Vazou and collaborators motivation and self-efficacy [16]. An argument in support of this explanation may be the marginal increase in general concentration in class for the total cohort as it has been observed in Taras' review which noted an immediate increase in concentration in students following PA [48]. This overall

concentration may have benefited all subjects, especially those frequently considered less difficult than mathematics (i.e., French).

Finally, it is important to note that the positive effects of the intervention can be found in all school grades, even if a greater benefit is observed in Grade 5. As the ability to apply skills or knowledge learned during one activity to another activity is evidence of a transfer process, older children are likely to be more sensitive to it [49]. Indeed, in this study's intervention, the children were learning with different tasks and objectives (in DPA exergaming and their normal lessons). The transfer of skills from one to the other is therefore not obvious (even if the "mathematics" cue is common to both) and remains a particularly demanding cognitive process for which the children need to be motivated. Decreases in academic performance in French and mathematics (Grades 4 and 5) may be explained by constraints in the classrooms: the teachers were rotated during the semester, and the last data collection took place the day before the vacations (the participants being less involved overall in the academic exercises required). However, the marginal increase in mathematics performance in Grade 2 and the increase in French performance (overall cohort and Grade 3) demonstrate the importance of continuing testing this intervention.

The practical implication in the educational context

Learn-based exergames can be powerful allies in the implementation of DPA policy at school. For schools and educational teams, the first obstacle could be the associated cost. In France, the Ministry of Education has launched a call for projects entitled "Pour un socle numérique dans les écoles élémentaires" ("for a digital base in elementary schools") [50] to equip the schools of tomorrow. In this context, it is necessary to create links between the worlds of research and education. Researchers need to present them with the advantages (i.e., academic performance, self-efficacy, motivation, PL, PA, sedentary behavior), but also the constraints (i.e., update, group management, security) of this type of practice, to make them as efficient as possible in different teaching situations. Indeed, as part of the 30 minutes of DPA policy in elementary school, one of the major difficulties is sustaining the actions and motivation of teachers, as presented in the Canadian study [44,45]. Once the equipment has been acquired and installed in a fixed position (ceiling-mounted model), one of the solutions for maintaining motivation among teaching teams would be to integrate PA professionals into the internship framework. This option not only enables teachers to benefit from the specific skills of the trainees but also to position themselves as observers of the class, to be able to work on specific notions during physical education teaching [18].

Limitations

In the context of this pilot study, which focused mainly on implementation feasibility and learning, it would have been interesting to consider the children's physical fitness (i.e., muscular strength, agility, and cardiorespiratory fitness) and general state of health. Indeed, a French longitudinal study with a 3-year follow-up of children aged 7.7 at the start of the study showed that the physical fitness of French youth decreased between childhood and early adolescence [51].

It would also have been interesting to compare the effects of this program with a control group. For example, it would have been worthwhile to compare the scores of the experimental group with exergaming and targeted school exercises to two control groups: the first one with no physical activity and no school exercises, and the second one with no physical activity but with school exercises identical to the experimental group (e.g., on a tablet computer). To verify the validity of the results, it would also have been necessary to vary the targeted school exercises (e.g., mathematics and French; randomizing their inclusion in the intervention to ensure that the most difficult material is not the only one tested). Moreover, this study was carried out in a single school with a single class

per level. It would be worthwhile increasing the size of the cohort by increasing the number of classes per level in different schools. Furthermore, our program was of limited duration (3 weeks), a longer program (at least one trimester) with more DPA sessions would undoubtedly have increased the effects we observed and allowed additional benefits to be observed. In future studies, it would be interesting to compare the effects of a short program like ours with those of a longer program and could shed light on the effects' duration through time (in particular following longer interventions).

Perspectives

Future studies could explore possible diffusion effects of enhanced DPA interventions with or without exergaming on various PA indicators (e.g. physical fitness, increased mobility by accelerometry, sedentary time and breaks, increased implication in PE curricula at school). It would also be useful to conduct a longitudinal study to measure the impact of exergaming on PA and fitness levels but also on the evolution of overweight and obesity in children.

Furthermore, it could be relevant to precise, in future studies, interventions' effects on students' academic performance, motivation, and self-efficacy either on specific academic courses during interventions or on general attitudes and performances in different courses. Finally, specifying various students' profiles concerning these measures (e.g. depending on the initial level of PL and PA, depending on age/grades) could provide information on subgroups of children benefiting most from such exergaming interventions. In addition to student characteristics, it might also be useful to consider teacher characteristics (e.g., attitude toward exergaming) to better understand the individual and environmental factors likely to moderate the effects of such interventions.

Conclusions

As part of DPA's 30-minute implementation, the use of learn-based exergaming has shown very interesting results in increasing PL as well as student motivation toward mathematics. Furthermore, supporting pedagogical teams with qualified teachers in PA has proven to be beneficial for both students and staff.

With this encouraging pilot study, it is necessary to continue investigations by increasing the number of students per grade and to carry out research over a longer school period with a control group to confirm these results regarding the use of learn-based exergame with Play LÜ within the framework of DPA.

Acknowledgments

We would also like to thank the school (administration and teaching staff) for allowing us to carry out this type of pilot study.

Conflicts of Interest

None declared

Abbreviations

DPA: Daily Physical Activity

PA: Physical Activity

PE: Physical Education

PL: Physical Literacy

MVPA: moderate-to-vigorous PA

WHO: World Health Organization

Contributions

AG conceptualized and supervised the project, and contributed to the data collection and processing, project administration, and writing of the original draft. FL, GB, ECV, and EC conceptualized and supervised the project and were involved in reviewing and editing the manuscript. FL contributed to the statistical analysis.

AP was involved in DPA implementation supervision and PL during the session. ED and NAB were students in adapted physical activities who carried out the DPA sessions as part of their end-of-year internship.

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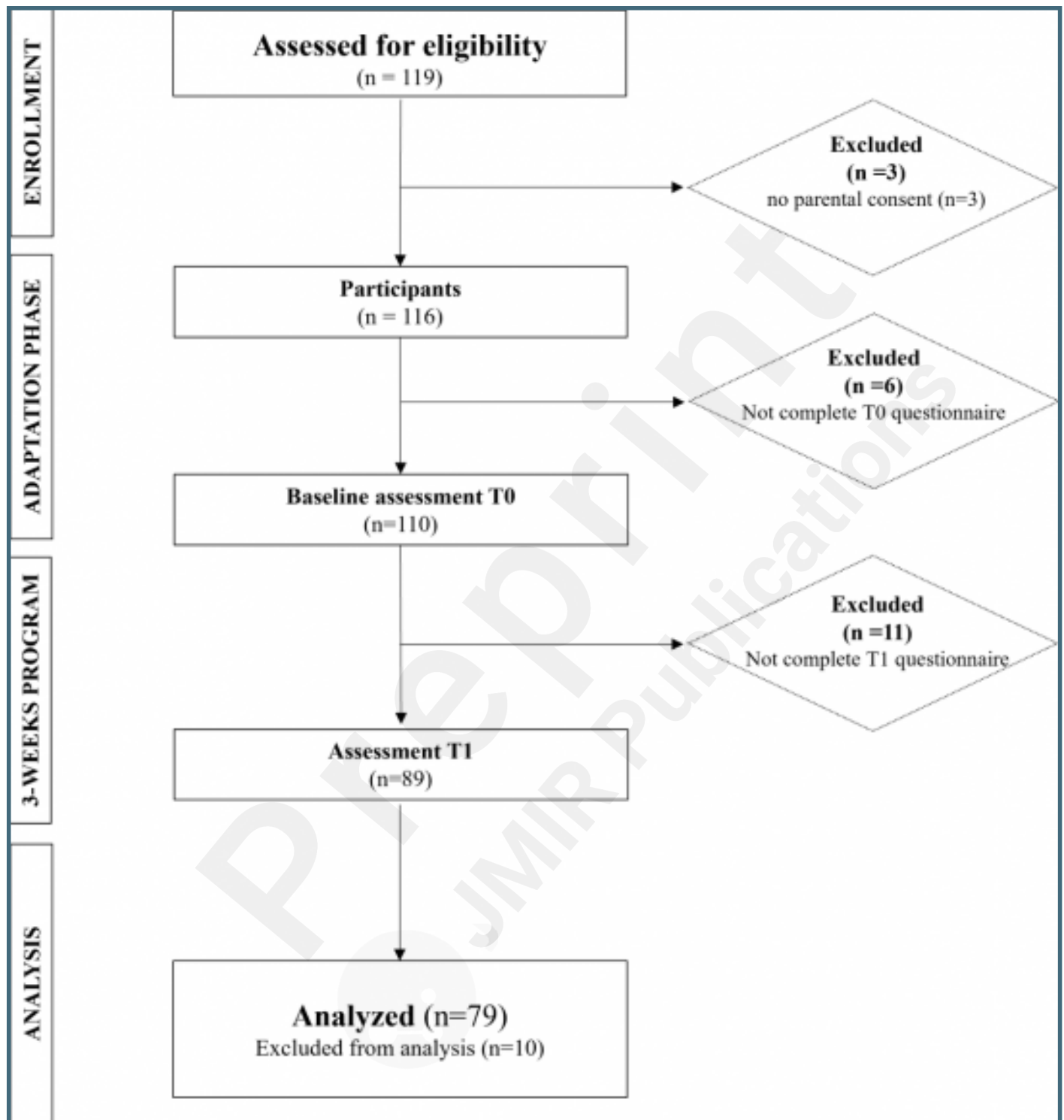
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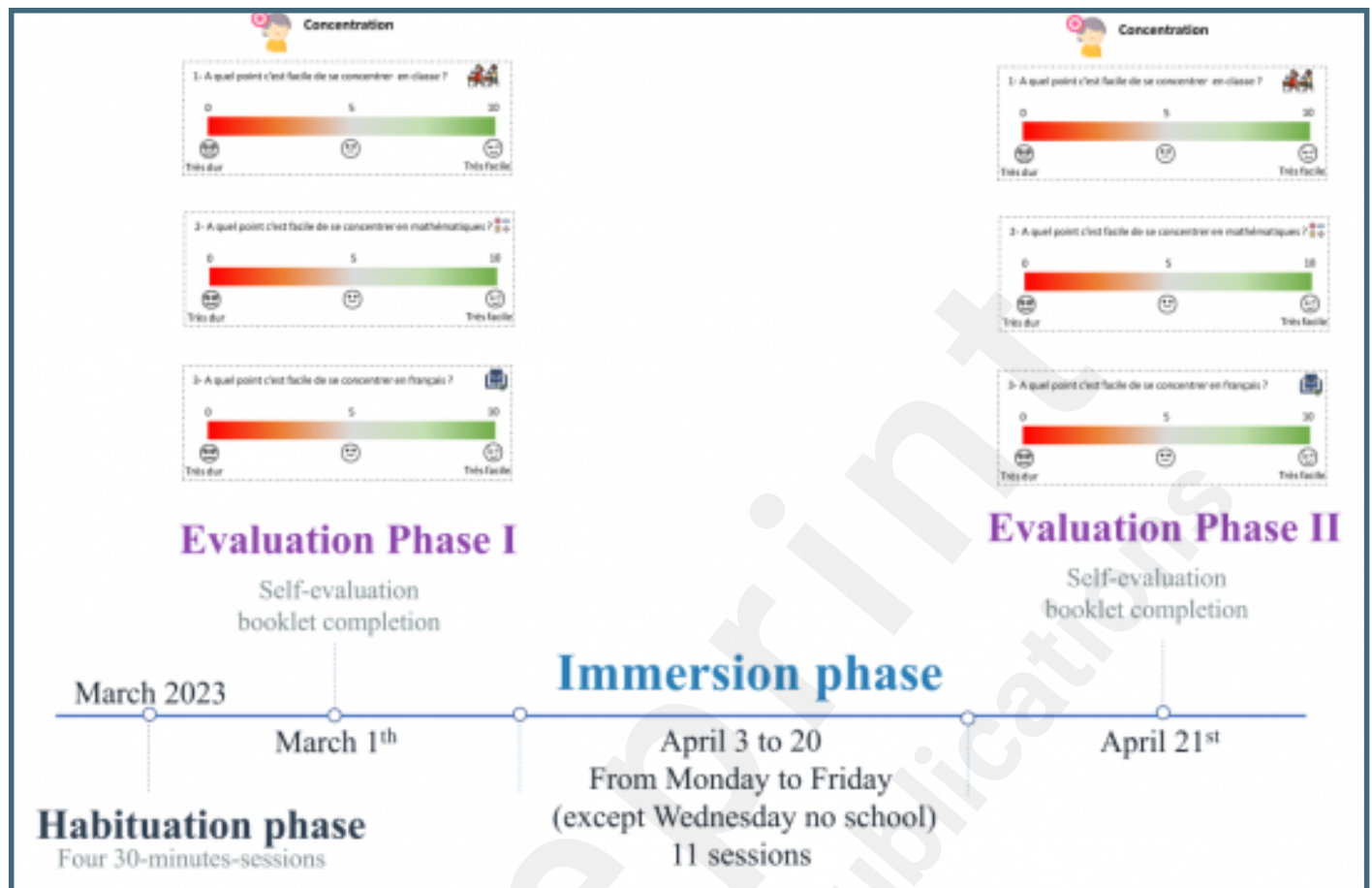
Supplementary Files

Figures

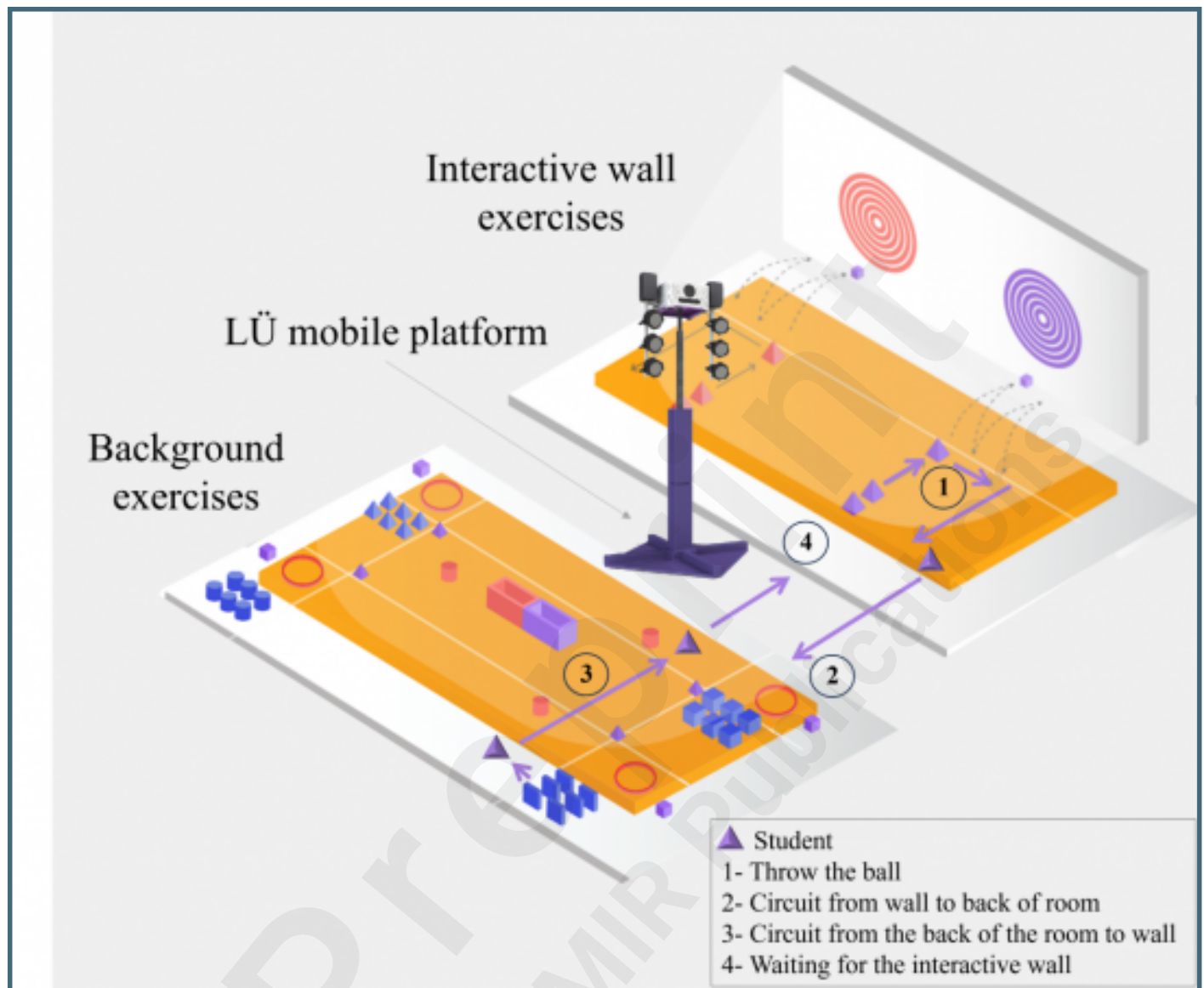
Study flow chart.



Timeline project.



Practice environment implementation.



DPA core session details .

1- Warm-up

4' dance with Gröove App



2- Mathematics core session

10' Arithmetic's with Newton App



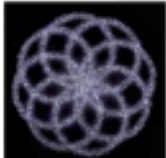
10' Geometry with Puzz App



+ Motor-skills circuit in background

3- Peaceful & quiet return

3' meditation with Gaïa App



Multimedia Appendixes

PlaySELF adaptation questionnaire.

URL: <http://asset.jmir.pub/assets/98171c232892b279fbedb12d72186410.pdf>

Tables Grade 2 to Grade 5.

URL: <http://asset.jmir.pub/assets/f61e2c4dad377bbdf226b3a0a1d15095.docx>



CONSORT (or other) checklists

CONSORT-eHealth.

URL: <http://asset.jmir.pub/assets/f33f9dde4e8286c1e3b17f0821c0cbdc.pdf>