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Pilot Study and Gamification Analysis of a Theory-based Exergame

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Abstract

A theory-based exergame was developed for tweens to promote their self-efficacy towards physical activity and increase their physical activity levels. We used protocols from both health science and gamification research in piloting the exergame. First, we assessed the usability and feasibility of the exergame and conducted a preliminary exploration of its effectiveness. After technical improvements were made based on our findings, we reiterated the pilot study and analysed the gamification elements of the exergame by using Octalysis analysis. The overall findings suggest that a theory-based exergame can positively influence the self-efficacy of tweens towards physical activity. The exergame showcased theoretical strength, achieved using diverse gamification elements but its overall game design and usability can be further improved. The study concludes that health-related components of the purpose of intervention must be incorporated in parallel with the engaging design of the game, taking into utmost consideration the theories, evidence as well as the needs and perceptions of its target users. This study provides valuable insights on future development and evaluation of gamified health interventions.

Keywords: *exergame, physical activity, self-efficacy, gamification, Octalysis analysis*

1 Introduction

Physical activity (PA) is defined as any bodily movement via skeletal muscles leading to energy expenditure [1] and is associated with significant health benefits in children particularly on their physical health [2-4] and psychosocial well-being [2][5-8]. It also influences a child's social development, learning as well as cognitive skills [9-11].

A physically active lifestyle tends to track from pre-adolescence stage or tweens and eventually into adulthood [12][13]. Studies have shown that despite the known beneficial effects of being physically active, children's PA levels are still low [14] and this phenomenon increases dramatically throughout the adolescence stage [15-17].

Globally, three out of four children (11 to 17 years old) do not meet the PA level recommendations set by the World Health Organisation [18]. Between 2001 and 2016, insufficient PA levels of children in high-income countries increased from 31.6% to 36.8% [19]. Studies in Finland concluded that despite the support of government agencies over the years in promoting PA among children and adolescents, their PAs are still below the recommended levels [20].

Physical inactivity has become one of the most challenging issues in public health [21] and the fourth leading risk factor for lifestyle-related deaths [22]. It significantly contributes to the rising numbers of Diabetes Mellitus type 2, musculoskeletal diseases, depression, and being overweight which consequently can lead to obesity [23][24]. In Finland, a recent study showed that 27% of two- to 16-year- old boys and 17% of girls are at high risk of obesity [25].

Innovative and child-friendly interventions are needed in promoting PA among the younger population. The availability of our current technology can provide us with the opportunity to develop and implement digital health-promoting interventions [26-28].

The majority of children spend time playing digital games [26-29] and mobile games are the most popular of its forms [30]. They offer a conducive channel to engage children in health promotion [31][32] and a healthy lifestyle in fun and effective ways [27][33-39]. Evidence shows that health games can increase energy expenditure [33][36] and improve cardiovascular functioning [34]. It may also help in regulating Body Mass Index (BMI) to recommended levels [33][34], promote healthy eating habits [35], and increase self-efficacy as well as self-esteem [38]. Moreover, it can be useful for the rehabilitation of children with special needs [36][39].

The use of digital games to promote health such as exergames has increased over the years due to its potential to provide evidence-based health interventions to its target users [35][38][39]. Exergames or active video games [40][41] are digital games combined with physical exercise to induce physical activity [42]. In this paper, we present the findings of our pilot study for the developed theory-based exergame – Movenator, exploring its usability, feasibility, and acceptability. We also conducted a preliminary exploration of its effectiveness on increasing PA levels as well as PA self-efficacy to tweens. Furthermore, the gamification design of the exergame was critically evaluated based on Octalysis framework [43][44].

2 Development of the Exergame

Movenator is an exergame developed for tweens by a multidisciplinary group of researchers from nursing and computing sciences. The theory of self-efficacy [45-47] was used as the theoretical foundation of the content of the exergame. Previous studies and empirical evidence in addressing the needs and perceptions of children and adolescents were also considered.

We performed an iterative development process from 2015 to 2017 that consisted of three phases. In the first phase, we performed a systematic review of evidence and identified a guiding theory of health game interventions promoting children's physical activity and self-efficacy.

In the second phase, we did a focus group interview study for tweens (n=35) to collect information on the target group and guide the overall design of the exergame. The study explored the tweens' perceptions pertaining to the elements of a digital game that promotes physical activity and their motivating factors to increase their PA levels.

In the third phase, we performed technical development of the exergame. The principles of user-centred approach were adopted to design the user interfaces (UI) and game flow. The iterative process included a wireframe version testing of the initial prototype among a representative sample of target users (n=10) in a controlled setting. The testing protocol explored the target users' perceptions of the game content and challenges affecting functionality and comprehension of the exergame. Based on the results of this phase, we produced the final prototype of the Movenator exergame and used it in the pilot study.

The main idea of the exergame is to encourage players to be physically active by using game elements such as level progressions, points accumulation, rewards, goal setting, monitoring, building the player's own game space and competition. In the exergame game space, the players aim to build community structures for an island inhabited by penguins. The players can design their own game characters and build up teams to earn and collect In-App Currency (IAC). To earn IAC, the players need to perform physical exertions or activities (e.g. walking or running a set of distances) while their mobile phone is with them.

The PA levels are measured through various sensors available on the mobile device. The health objective of the game is to increase the player's PA levels by rewarding success progressions in the exergame. The exergame provides vicarious experiences, positive feedback, and fun for players, which are all important sources for self-efficacy [47]. Figure 1 shows four excerpts of the exergame's visual display (character creation, game space, earning and spending IAC and building community structures).

Character creation | Game space | Earning and spending IAC | Building community structures

Figure 1. *Visual display screenshots of the exergame*

3 *Piloting the Exergame*

The study design (Figure 2) consists of 1) Pilot study I: pilot usability-feasibility study and preliminary exploration of effectiveness, 2) improvement of the exergame based on the results, 3) Pilot study II: reiteration of pilot usability-feasibility study and preliminary exploration of effectiveness after the improvement of the exergame, and 4) Gamification analysis based on the Octalysis framework. Permission to conduct the study and ethical approvals were acquired from the City of Turku and the University of Turku Ethics Committee prior to the commencement of the studies. Informed consent from all study participants and their parents or legal guardians was obtained for each study in respect to their voluntary involvement, anonymity, dignity, and integrity.

3.1 Pilot study I

We assessed the usability and feasibility of the exergame and conducted a preliminary exploration of its effectiveness on promoting self-efficacy towards PA and increasing PA levels. We used a randomized controlled trial (RCT) design with mixed methods. Using a RCT design on pilot studies provides opportunities to determine and prepare for the possible challenges in conducting a large-scale evaluation study in the future. It focuses on the assessment of the feasibility pertaining to the acceptability of the intervention, the design process as well as determining the calculation of effect sizes in terms of sampling [48].

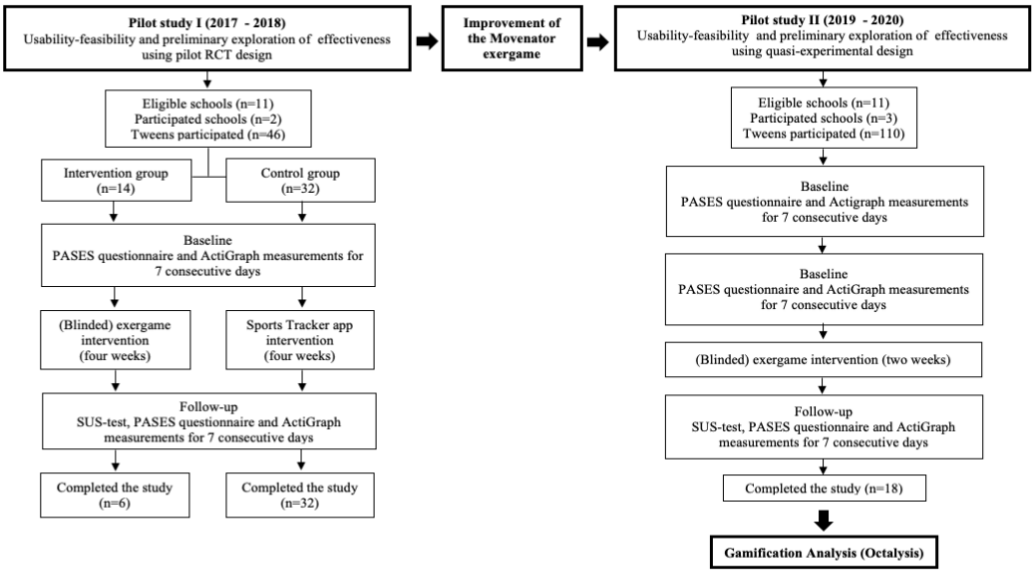

Figure 2. *Study design*

3.1.1 Recruitment and randomization

The recruitment was done by the researchers in a school-level within the municipality of Turku. The set eligibility criteria were based on (1) having more than 500 enrolled students on average, (2) equivalent socio-economic district, and (3) with no physical activity programs in progress. We recruited study participants ages nine to 13 years old. Based on earlier studies, PA levels start to decrease significantly during the puberty stage of children [49]. In Finland, the highest percentage of PA level decrease was detected on children ages 11 to 15 years old. Based on the recommendations of the Finnish Ministry of Social Affairs and Health, PA interventions for this demographic should be earlier than the detected decline period of PA levels [50]. The children should have no physical barriers for performing physical activities and were able to communicate in Finnish.

The randomization was also done in a school-level by drawing lots to avoid intervention contamination which can potentially occur when done in a participant-level. The participating schools were coded as “intervention school” and “control school”. In the intervention school, the participants used the Movenator exergame; whilst in the control school, the participants used the Sports Tracker app [51]. The participants were very familiar with the Sports Tracker app and has been commonly used during physical education (P.E.) classes in primary schools in Finland to monitor their PA exertions such as jogging, running or cycling. Hence, the app was used as treatment as usual for the control school.

3.1.2 Data collection

The data were collected from 2017 to 2018. The baseline data for the participants’ PA levels and PA self-efficacy were collected one week before the intervention using the Physical Activity Self-Efficacy Scale (PASES) [52] and ActiGraph GT3X+ accelerometers [53].

After the baseline data were collected, the intervention school participants downloaded the Movenator exergame onto their smartphones. Whilst the participants from the control school downloaded the Sports Tracker app. The study facilitators assisted with the downloading process and privacy settings of the app.

During the four-week intervention period, the participants were instructed to use the Movenator exergame at their discretions without restraints and the same applied to the participants from the control school in using the Sports Tracker app. The follow-up data were collected immediately after the intervention period using the System Usability Scale (SUS) test [54], acceptability questionnaire, PASES questionnaire and the ActiGraph GT3X+ accelerometers.

3.1.3 Measures

The usability of the exergame was measured using the System Usability Scale (SUS) test which was translated into Finnish language. The SUS-test is a valid and reliable tool for evaluating the usability of applications, products and services. The scale contains 10 items which the participants rated in Likert scale between one (strongly disagree) to five (strongly agree). The total SUS-test score ranges from 0 to 100 [54].

The acceptability of the game was measured using a qualitative questionnaire developed for the purpose of the study. The questionnaire included seven questions about the participants' experience and perceptions about the game.

To measure the initial effectiveness of the exergame intervention, the participants' PA levels were measured using ActiGraph GT3X+ accelerometers. The ISO-approved and water-resistant device measures the acceleration or vibration of raw motion exerted by the user [53]. The participants were instructed to use the accelerometer at all times when they are awake, for seven consecutive days in both baseline and follow-up. No pause criteria were set in using the ActiGraph GT3X accelerometer. We used the cut-points developed by Freedson, Pober and Janze [55] in calculating for the sedentary, light PA and moderate to vigorous physical activity (MVPA) levels.

The PA self-efficacy was measured by an eight-item PASES questionnaire (Figure 3). The PASES questionnaire was forward-backward translated to the Finnish language using ISPOR-protocol [56]. The participants rated each item in the questionnaire between one (strongly disagree) to five (strongly agree).

3.1.4 Data analysis

The average SUS-test scores for both the game and the Sports Tracker app were calculated using an Excel spreadsheet. The results were then interpreted based on the corresponding values as suggested in the SUS Adjective Rating Scale [57].

The qualitative data pertaining to the acceptability of the Movenator exergame were analysed deductively and the data were categorized based on attractiveness, suitability, perceived appropriateness as well as satisfaction and ideas for further development.

The quantitative data for the PASES PA levels and PA self-efficacy were analysed using non-parametric tests because of the limited sample size. The statistical analyses were performed using IBM SPSS software (version 25) with a value of $p<0,05$ to indicate statistical significance. The differences between the intervention and control schools were analysed using Wilcoxon signed ranked test.

Physical Activity Self-Efficacy Scale (PASES) questionnaire

Saunders et al., 1997

(Modified from the version of Motl et al., 2000)

Please circle the number that is closest to how much you agree or disagree with each statement.
Remember that **physical activity can refer to any kind of playing, games, sports or exercise that makes you move and to breathe faster.**
There are no wrong answers. (PLEASE CIRCLE ONE NUMBER FOR EACH STATEMENT.)

		Strongly disagree	Somewhat disagree	Neither agree or disagree	Somewhat agree	Strongly agree
1.	I can be physically active during my free time on most days.	1	2	3	4	5
2.	I can ask a parent or another adult to do physically active things with me.	1	2	3	4	5
3.	I can be physically active during my free time on most days instead of watching TV or playing video games.	1	2	3	4	5
4.	I can be physically active during my free time on most days even if it is very hot or cold outside.	1	2	3	4	5
5.	I can ask my best friend to do physically active things with me during my free time on most days.	1	2	3	4	5
6.	I can be physically active during my free time on most days even if I have to stay home.	1	2	3	4	5
7.	I have the coordination I need to be able to be physically active during my free time on most days.	1	2	3	4	5
8.	I can be physically active during my free time on most days regardless of how busy my day is.	1	2	3	4	5

Figure 3. *PASES questionnaire*

3.2 Pilot study II

The Movenator exergame was technically improved based on the findings from the first pilot study. The second pilot study reiterated the assessment of the exergame's usability and feasibility as well as the preliminary exploration of effectiveness in promoting tweens' PA levels and PA self-efficacy.

The study used a quasi-experimental one-group design in consideration of the time required in implementing the study and needed resources. We compared the PA levels and PA self-efficacy between two periods (baseline and follow-up) upon using the Movenator exergame.

The recruitment procedure and eligibility criteria were carried out in the same way as with the previous pilot study and ethical considerations were adhered to. We collected the data from 2019 to 2020 from the study participants and we shortened the intervention period to two weeks to make the participant retention more manageable. The measures and data analysis for usability and feasibility of the Movenator exergame were explored as with the first pilot study.

3.3 Octalysis Analysis

To assess how well the exergame utilizes different gamification elements and whether the exergame could be classified as a gamified application, the gamification design of the exergame was evaluated using Octalysis [43][44]. The Octalysis framework encompasses game design elements that serve as core drivers towards the engagement of users in gameplays. It consists of eight core drives that trigger our inherent human characteristics that lead to the motivation of accomplishing certain activities. The core drivers are presented in Figure 4.

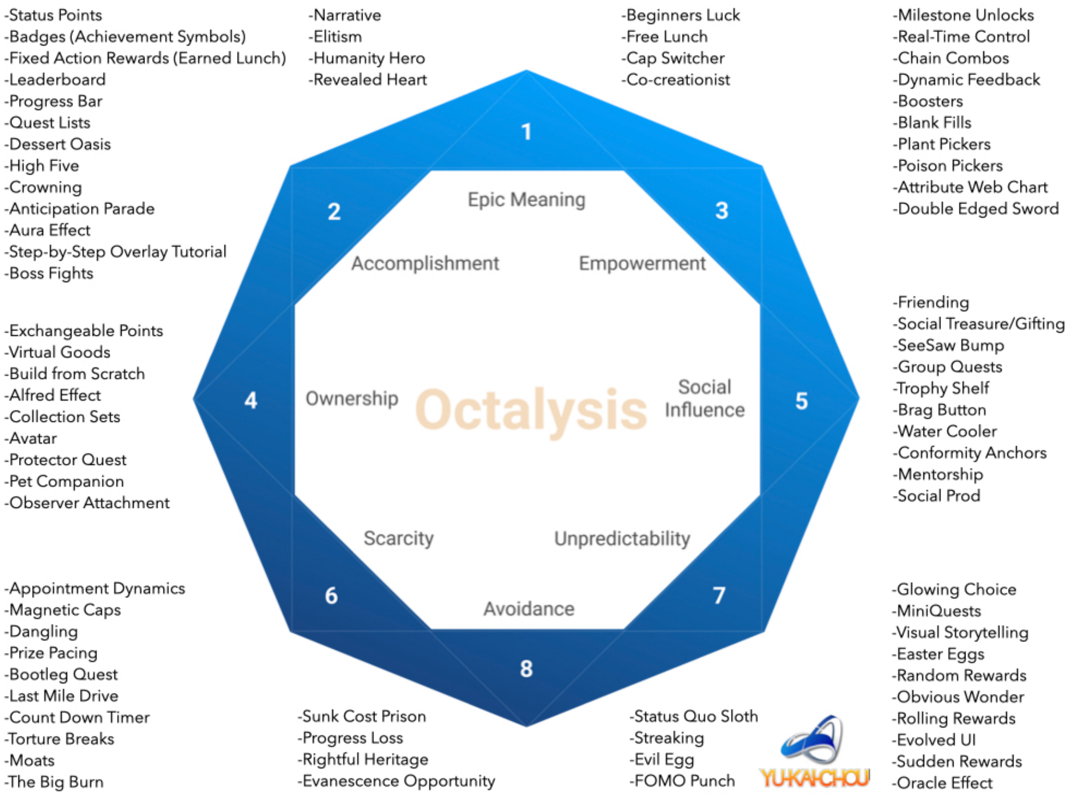

Figure 4. *The Octalysis Framework by Yu-kai Chou [43, 44]*

In conducting the Octalysis analysis, the presence of each of the core drives (Table 1) are identified in the game and to be scored on a scale of 0 to 10 based on the subjective judgment and experience of the evaluators [58]. The raw core drive scores are squared, and the sum is calculated to get the total Octalysis score.

The high or low score does not directly indicate as either good/ bad or desirable/ non-desirable result. Scores can be interpreted to identify the presence of the core drives in the exergame. The presence or absence of the core drives is a design choice rather than a necessity, which depends on the goals of the gamification and intent of the game developers.

The evaluators familiarized themselves with the Movenator exergame and conducted the Octalysis analysis individually. They discussed their individual findings and assessments together and formed a consolidated evaluation about the gamification design of the exergame's final version.

Table 1. *The eight core drives of the Octalysis Framework*

Epic meaning and calling	Person believes they are doing something greater than oneself or was "chosen" to take the action.
Development and accomplishment	Internal drive for making progress, developing skills, achieving mastery, and eventually overcoming challenges.
Empowerment of creativity and feedback	Users are engaged in a creative process where they repeatedly figure new things out and try different combinations.
Ownership and possession	Users are motivated because they feel like they own or control something.
Social influence and relatedness	Incorporates all the social elements that motivate people, including mentorship, social acceptance, companionship, and even competition and envy.
Scarcity and impatience	Wanting something simply because it is extremely rare, exclusive, or immediately unattainable.
Unpredictability and curiosity	Constantly being engaged because you do not know what is going to happen next.
Loss and avoidance	Motivates us to avoid something negative from happening.

4 Results

4.1 Pilot study I

Two out of 11 recruited schools participated in the study, with which 46 out of 190 total number of eligible enrolled tween students confirmed their participations. Initially, there were 14 tweens in the intervention school. However, due to the unforeseen technical issues with the Movenator exergame app, data from six participants (two girls, four boys) were only included in the analysis. The technical issues were detected at the beginning of the study. The exergame was using the built-in accelerometer on some smartphone models for counting the steps of the participants and it caused the exergame app to crash.

Thirty-two tweens completed the study in the control school (16 girls and 16 boys). Overall, 38 tweens completed the study. The age median in the intervention school was 11.00 whilst in the control school, it was 12.00 (Table 2).

Table 2. *Results of participants*

School	n	Girls	Boys	Age median
Intervention	6	2	4	11.00
Control	32	16	16	12.00
Total	38	18	20	11.00

The average SUS-test score of the Movenator exergame was 62.50. This result can be interpreted as “OK” based on the SUS-test Adjective Rating Scale [59]. The Sports Tracker app garnered an average SUS-test score of 74.11 which was “Good”. The participants further commented that the game was not too cumbersome to play and that it was easy to use. The participants in the intervention school, however; were less interested to use the exergame frequently in comparison to the participants in the control school using the Sports Tracker app.

The participants evaluated the acceptability of the exergame objectively (Table 3). The participants gave positive feedback on the penguin theme of the exergame. Majority of the negative feedback arose due to encountered technical issues. The participants also presented proposals for further improvement. The possibility to move more widely in the game area and more tasks in the exergame were common suggestions. Based on the study results, the participants also experienced that the exergame encouraged them to be physically active.

Table 3. *Results of acceptability of the exergame from pilot study I*

Attractiveness	**Suitability**
+ Nice game layout + Funny penguin characters - Did not like the characters - Monotonous	+ Easy to use + Nice to play + Does not need much spare memory - Did not work at all
Perceived appropriateness	**Satisfaction and ideas for further development**
+ Inspired to be physically active	+ Funny - Boring - More bonus levels and tasks in the game - More routes and roads to the game world - Possibility to move more widely in the game - Bigger prizes and better graphics

Physical activity levels decreased in both schools from baseline to follow-up (Table 4). The difference between light physical activity in the baseline (p=0.028) and follow-up (p=0.002) was statistically significant in both schools. The decrease in moderate-to-vigorous physical activity (MVPA) was statistically significant in the control school (p=0.003), but not in the intervention school (p=0.249). The sedentary time increased in both schools. However, the difference was statistically significant in the control school (p=0.0001). The doze of the intervention remained low; the median gaming time was 39 minutes in a four-week intervention period.

Table 4. *Results of the PA levels from pilot study I*

	Intervention			**Control**		
	Baseline (median)	Follow-up (median)	p-value	Baseline (median)	Follow-up (median)	p-value
Light physical activity	59.1min	40.7min	0.028	55.min	46.4min	0.002
MVPA*	139.8min	96.3min	0.249	128min	107.6min	0.003
Sedentary time	18h 7min	19h 2min	0.463	17h 34min	19h 11min	0.0001
Step count	5977	3961	0.463	6721	6561	0.010

**Moderate-to-vigorous physical activity*

Based on the results of the PASES scores (Table 5), there was a positive intervention effect in the intervention school, but the effect was not statistically significant (p=0.244).

In the control school, there was a statistically significant decrease in the PASES score (p=0.001).

Table 5. *Results of PASES score from pilot study I*

	Intervention			Control		
	Baseline (median)	Follow-up (median)	p-value	Baseline (median)	Follow-up (median)	p-value
Total Score	25.00	28.00	0.244	37.00	35.00	0.001

4.2 Pilot study II

A total of 18 tweens (8 boys and 10 girls, age median = 10.00) completed the study prior to the COVID-19 pandemic restrictions in Finland.

The participants assessed the usability of the Movenator exergame and garnered an average SUS-test score of 64.86, which can be interpreted as “OK” based on the SUS Adjective Rating Scale. They found it to be fun to play the game and that the penguin characters were funny in a good way. Although, some found the graphics to be dull and needing improvement on quality (Table 6).

The Movenator exergame was developed for android devices; thus, the students with iPhones which are running on iOS were not able to download and play the exergame. This issue was not improved during the technical development of the exergame due to unmet resources. On the other hand, most participants found it fairly easy to play the Movenator exergame; but some suggested that there should be an in-game tutorial that the game characters can introduce what the game is all about, how it is meant to be played and what the objectives are.

All participants agreed that the idea of the Movenator exergame can encourage them to be physically active, most especially during their idle times. They further expressed that the exergame needs to be improved in terms of graphics quality, more building options as well as character and game functionalities such as for characters to be able to get inside the buildings they built and zooming functions for the game so they can see their characters and buildings up close.

Table 6. *Results of acceptability of the exergame from pilot study II*

Attractiveness	Suitability
+ funny characters - dull graphics - boring background - cannot edit characters	+ easy to play - not available in iOS - did not work - no in-game tutorial
Perceived appropriateness	**Satisfaction and ideas for further development**
+ encourages users to be physically active + the objective of the game is good	+ can be fun to play when there is nothing to do - needs more building options to build - improve graphics quality and game attributes - characters can get into buildings they built - needs more background variations e.g. icebergs - zoom in and out functions

As with the first pilot study, the PA levels of the study participants decreased from baseline to follow-up (Table 7). The differences were statistically significant for light physical activity (p=0.005), moderate-to-vigorous physical activity (MVPA) (p=0.006) and Step count (p=0.002) as well as the increase in sedentary time (p=0.005) from the baseline to follow-up.

Table 7. *Results of PA levels from pilot study II*

	Baseline (median)	Follow-up (median)	p-value
Light physical activity	68.45min	57.25min	0.005
MVPA*	159.30min	122.67min	0.006
Sedentary time	17h 58min	19h 20min	0.005
Step count	8565	6236	0.002

**Moderate-to-vigorous physical activity*

The results of the PASES score indicate that the Movenator exergame had no intervention effect towards PA self-efficacy at all (Table 8). The difference between baseline and follow-up was not statistically significant (p=0.641).

Table 8. *Results of PASES score from pilot study II*

	Baseline (median)	Follow-up (median)	p-value
Total Score	35.50	35.50	0.641

4.3 Gamification analysis

The evaluators (TJ, TM) assessed the Movenator exergame based on the eight core drives of the Octalysis framework. The drivers were categorized into two groups – low and high scoring drivers (Table 9). Based on the analysis, the Movenator exergame uses diverse gamification design elements from both positive motivators (e.g., empowerment) and negative motivators (e.g., scarcity and impatience). The more detailed analysis presented below shows that the gamification design is not balanced, and the gamification elements implemented in the exergame do not uphold players' motivation for very long in practice.

The Octalysis score showed that the Movenator exergame can be deemed as a gamified solution. It has a balanced white hat and black hat gamification. Although, the presence of left brain core drives is stronger than the right brain ones. It means that the evaluators' experience with the exergame is more extrinsic in nature, and this may affect the engagement of users eventually once the goal is removed or lessened.

Table 9. Octalysis score of the exergame

Low scoring drivers	High scoring drivers
Curiosity and unpredictability = $0^2 = 0$	Development and accomplishment = $4^2 = 16$
Loss and avoidance = $1^2 = 1$	Scarcity and impatience = $5^2 = 25$
Epic meaning and calling = $2^2 = 4$	Empowerment of creativity and feedback = $6^2 = 36$
Social influence and relatedness = $2^2 = 4$	Ownership and possession = $8^2 = 64$
Octalysis Score	150

4.3.1 Curiosity and unpredictability

Drivers for curiosity and unpredictability are not present at all in the exergame. Instead, all goals and elements are at least visible if not in use from the beginning. Also, there is no in-game story to unravel. Tweens also noted this absence during the evaluation studies, that it was boring, and nothing has really unravelled during gameplay. The players wanted something new to happen as they progress on with the exergame.

4.3.2 Loss and avoidance

Loss and avoidance are just barely present in the exergame. It might be possible that sunk cost prison mechanic could have some effect, but the exergame lacks longevity in terms of gameplay for it to take real effect on the players. Being physically active speeds things up, but it is presented in positive manner instead of being a requirement, and if users do not comply, they will lose resources or progress. Players also have the power to decide all the goals personally, so the exergame is not forcing them to act towards any specific goal.

4.3.3 Epic meaning and calling

Epic meaning and calling is somewhat present in the exergame, as the basic idea of the game is to get players to be more physically active. This can be related weakly to humanity hero mechanic. But as the game has no storyline, it is more of a “Sims-type” game. In the feedback, the exergame missed the advantages of having a storyline to provide the players with meaning, immersion and engage themselves for continuous usage.

4.3.4 Social influence and relatedness

Social influence and relatedness are not directly present in the exergame. As an experience, it is purely a single-player game. The exergame indirectly supports a metagame where players can move around in a group. Otherwise, it does not promote social gameplay.

4.3.5 Development and accomplishment

There are a lot of lower-level mechanics in place such as challenges, level, points, and rewards. But as the game does not set goals or challenges for the players, it impedes the notion of progress and feeling of accomplishment.

4.3.6 Scarcity and impatience

Players’ progression is prevented by the initial lack of resources, which are earned by being physically active or waiting. Basically, resources build up at a constant speed which depends on which strategy the player chooses. The exergame also does not limit how much the players can move during gameplay, so there is no limit on how many resources you can get. All functionalities the player can use during the game are open from the beginning, so nothing new can unravel during the gameplay. Tweens noted that rewarding was nonchalant – you get the same prize every time without anything special. To the players, it felt like you "get things automatically" and it is nothing out of the ordinary. Nevertheless, the elements of scarcity and impatience are somehow present.

4.3.7 Empowerment of creativity and feedback

Drivers for the empowerment of creativity and feedback are at the core of the exergame design. As the exergame does not set goals for the players, they have all the freedom to create what they want and when they want. According to user comments in the evaluation studies, the city building was the best part of the game. Though they did wish for more building-type options to choose from. They also noted that they would like to be able to customize the penguin characters and be able to enter the buildings they built. The reverse effect of the exergame design is that there are no changes in the game content based on their progress. Moreover, the players’ choices do not really affect the gameplay, so the outcome stays the same no matter what they end up doing. They can build what they want and where they want. They can decide their own goals and there is no gameplay boost nor level-specific building variations. The players’ choices do not affect their gameplay outcome.

4.3.8 Ownership and possession

Ownership and possession have the strongest presence in the exergame’s overall design. There are no preselected elements and players can start building their town from scratch. The players are responsible for all these decisions. These decisions ensure that the players own and is also responsible for everything they see and can use in the game.

The exergame is a single-player experience, so all decisions to be made by the player are protected from external influences such as from other players that are in the same multiplayer environment. On the other hand, as everything is open for the player, there are no meaningful choices. As the game progresses, they can get every type of building and penguin as the earlier decisions do not exclude anything off. This can potentially make the decision-making process made by players meaningless.

5 Discussion

Developing health games demands a rigorous process and needs to follow user-centred design principles to produce an age-appropriate, effective and sustainable digital intervention tool [57][59-61]. The design of the game should be based on theory, evidence [62] as well as the consideration of the needs and perceptions of its target users [63]. Provided that the engaging components of the game are design pre-requisites, the health-related components of the purpose of intervention should be incorporated in parallel with the development planning of the game. For example, to promote physical activity of children, relevant theories on health behaviours and physical activity should be considered early on prior to its actual development in addition to its game design framework. In our study, the Movenator exergame showcased theoretical strength that was achieved using diverse gamification elements but was lacking on overall game design, functionality, and usability. Prior to implementation, prototypes should be tested rigorously and evaluated objectively following a suitable framework in its intended implementation settings with its target users [27][32][35]. It is crucial to put consideration on both its engaging mechanics and purpose of intervention.

The two pilot studies have shown that the usability of the Movenator exergame can be better. Although the SUS-test score slightly improved after the technical adjustments, it is still below the recommended average score of 68 [59]. Moreover, digital games developed as a health intervention should be made available across commonly used device platforms (e.g. Android and iOS smartphone devices), as they are meant to cater to all its target users. However, this is not the case with Movenator.

The participants found the exergame as an encouraging way for them to be physically active. However, in both conducted preliminary explorations of effectiveness, there were no positive intervention effects on participants' PA levels. Instead, it decreased in both schools from baseline to follow-up. These findings are indicative of a low intervention dose. The technical issues encountered with the Movenator exergame substantially diminished its immersive characteristics. Thus, the participants were not as engaged as much as the gamification was intended for. At baseline, most participants were using the accelerometers at least three days in a week. But at follow-up, almost half of them were not using the accelerometers as much as recommended. This low compliance affected the reliability of the PA level measurements. This study would have been able to provide more meaningful insights on whether the children had been really physically active while using the Movenator exergame if measurements had been made during the intervention.

There was a small positive intervention effect on PA self-efficacy based on the participants' PASES scores. However, this was not detected in the reiterated pilot study.

The Octalysis framework focuses on the aspect of gamification function, providing value to its users rather than on mere entertainment factor alone. The analysis showed that the exergame's main purpose to promote physical activity to tweens is somewhat detached from the gaming content. The basic mechanics for gaining in-game resources by physical exertion or moving is the only component connecting these elements to each other. As the exergame also gives players some in-game resources without requiring them to actually move, this makes it possible to sever that connection. Based on the Octalysis analysis, the exergame is heavily skewed towards extrinsic experience. If the goal that the players can set up is removed or reached, the players might lose their motivation to continue with the exergame.

The implementation of this study was reduced by the device platform availability of the Movenator exergame. The technical issues could not be fixed during the study; thus, many study participants discontinued their participation. It required time and monetary resources to adapt the exergame to iOS platform. The data were collected only for those who were able to play the game. The other schools in the municipality refused to take part in the study due to other ongoing studies and projects. During the preliminary exploration of effectiveness, we managed to collect data from 18 participants amidst the COVID-19 pandemic. The pandemic has significantly affected our study and the participation of tweens. Due to lockdown restrictions, schools were closed, and we were not able to collect all data from other participants. Therefore, the study needs to be ended.

6 Conclusion

Gamification and serious games possess a promising potential to be used as high-impact and child-centred intervention tools for children. The continuous efforts of researchers in both health sciences and gamification research can eventually achieve effective ways to address, empower and enable children to prosper in various health-related challenges.

This study gave important information about developing and piloting an exergame to promote self-efficacy and increase the PA levels of tweens. Our findings can contribute to the literature and provide direction for future undertakings on gamification and serious games as health intervention tools. The Movenator exergame encourages its users to be physically active. It has the scope to make impacts on the improvement, limitations and challenges of the implementation of health-related gamification and serious games.

Our study suggests that gamified and serious games used as health intervention tools, need to utilize a combination of multi-disciplinary protocols for its development and evaluation. Conducting a gamification analysis in addition to pilot usability-feasibility and primary exploration of effectiveness will contribute to its rigor. It will shed light to substantial information on gamification mechanics, immersive characteristics as well as its effectiveness as a health intervention tool.

The exergame needs to be made available across the most common mobile operating systems (OS), for both Android and iOS. A large-scale randomized controlled trial (RCT) with power-estimation sampling needs to be conducted to explore the true effectiveness of the exergame.

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