Gamification of Older Adults' Physical Activity: An Eight-Week Study

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Abstract

Designing fitness programs to combat a sedentary lifestyle and foster older adults' motivation and goal-setting is not yet well-understood beyond point-based systems. To improve older adults' (over 50 years) health and wellness, we studied a gamified physical activity intervention over eight weeks in an experiment (N=30) with three conditions (gamified, non-gamified, control). Our qualitative analysis showed the gamified group exhibited more engagement and interest in performing physical activity facilitated by technology. Results from our quantitative analysis indicated significance in the perceived competence dimension compared to the non-gamified and the control group. Perceived autonomy was significant for the non-gamified group against the control group. The findings from qualitative and quantitative analysis show motivation, enjoyment, and engagement were higher in the gamified group. This provides support for successfully facilitating older adults' physical activity through gamified technology, which helped us create guidelines for older adults' adaptive engagement.

1. Introduction

Older adults are trying to lead healthy lifestyles because humans, specifically in Western societies, are living longer than at any other time in history [1] while maintaining physical and mental wellness. Participation in recreational activities, such as playing digital games or technology-supported exercising contributes to improving older adults' quality of life [41].

Game-based technology that makes mundane tasks more interesting and playful by appealing to our emotions is becoming more popular. This is also known as gamification, which is the process of using game design principles [30] in non-game contexts [16,26]. Research suggests that gamified fitness applications are one way to engage people in regular physical activity (PA) [40]. However, not all older adults are physically active in the same way, and they often face more substantial cognitive and physical challenges compared to a younger population.

This paper addresses the problem of investigating the disenchantment of older adults with PA, reasons for their lack of engagement with PA, and contributes motivational affordances for PA technology. We conducted an experimental eight-week study that was a synchronous, three-condition (gamified, non-gamified, control), with a total of 30 participants. Results of the qualitative analysis indicated that technology facilitation of PA was prevalent in the gamified and the non-gamified groups of participants. From a technology artifact perspective, results also indicated granular categorizations for PA motivation, setting up goals, feeling of accomplishments, rewards, and tracking of PA. Quantitative analysis of the data also yielded significant differences between the groups with higher engagement for gamified and non-gamified groups. These results indicated that technology facilitation of PA can be achieved through the usage of motivational affordances as behavior change technologies using the gamification construct.

2. Related Work

Older adults' motivation for PA and their attitudes and perceptions towards PA technology are both critical for our investigation. Thus, we reviewed literature on PA motivation, and gamified PA interventions facilitated by technology for older adults. **Motivational affordances**, a term that is used interchangeably with gamification elements (like challenges, actions, achievements, reward mechanisms, and social interaction elements [23,51]), are elements supporting intrinsic and extrinsic PA motives [24–26] in our study. We investigate the impact of motivational affordances through gamified technology for older adults.

2.1. Motivation for Physical Activity

Older adults' PA motivation is greatly influenced by their age-related impairments (decreased motor skills, balance issues, poor posture) and health-related challenges (coronary disease, osteoporosis, arthritis, emotional loneliness, minimized cognitive functions) [12,19,53]. Motivation to engage in PA is influenced by their own personalities, attitudes towards technology

and social interaction [37]. Currently, we lack guidelines for designing and tailoring PA programs for older adults from a motivation-and-goals systems view compared to rewards-based systems [25,31,48].

Much research on older adults and PA motivation is available; however, research that triangulates older adults' PA, PA motivation, and motivational affordances is limited. This investigation fills that gap. While older adults above age 65 have been categorized as seniors or elderly, many studies on physical activity interventions have qualified older adults to be 50 years and older [34–36,57]. One of the many reasons for this is because many individuals ≥50 years are physically inactive and do not meet the national guidelines for PA [5]. Motivation of older adults to participate in PA has been studied by many researchers [2,9,12,45,53,54]; however, limited research has been done on motivation as part of technology facilitation for older adults' PA.

A long-term efficacy study of computer-tailored PA interventions for older adults carried out on adults over 50 years' age were effective in inducing long-term behavioral changes of older adults [55]. Efficacy of print-based interventions were stronger than web-based interventions over a 12-month period in adults over 50 years of age indicated the need for improved web-based interventions for better sustainability [49]. Research indicates the increase in population aged 50 to 64 years to be more adept at using web applications and technology artifacts [29,33,44]. Thus, novel strategies like gamification should be explored in PA domains.

2.2. Gamified PA Interventions

While prior research indicated the relevance of intrinsic motivations in traditional PA [13,38], preliminary studies investigating motivations of older adults' towards technology-facilitated PA, indicated the impact of intrinsic motivations for successful gamified PA [31]. In digital gaming for seniors, game preferences and motivations to play the game were true-to-life scenarios, cognitive training, and improving their reflexes [46]. Furthermore, in-person and electronically mediated interventions through persuasive games [52] and interpersonal communications [50] are effective for influencing and motivating health behaviour to participate in more PA [47].

The benefits of gamified applications as referenced above range from increased motivation [7], improved monitoring daily activities, and tracking of goal-attainment [47]. Furthermore, gamified applications afford to connect individuals via a community [52].

Current research does not identify specific motivational affordances for older adults to participate in PA or daily exercise using gamified technology. An understanding of these motivational affordances specific to older adults is important for developing technology to foster increased adherence to PA through gamification. We further this understanding of PA motivation by identifying intrinsic, extrinsic, and feedback elements of gamified PA technology.

3. Research Design

Our main research questions were:

How can gamification elements be used to foster the intrinsic and extrinsic motivations for physical activity and daily exercise routines among older adults? How can customization of gamification elements be done for PA applications for this demographic?

In the related literature, a minimum effective exercise program for habit formation was six weeks [3,32,42]. Therefore, we designed our PA intervention for older adults (50+) over an eight-week study period in a synchronous, three-condition study (N=30). Participants were randomized to one of three conditions:

Group 1: Physically active and use of a gamified physical activity app (Spirit50)

Group 2: Physically active and use of a pedometer

Control: Physically active

Baseline current PA was assessed using the International Physical Activity Questionnaire (IPAQ) [28]. All participants filled in a questionnaire once a week, for eight weeks, which combined the following scales (dependent variables):

1 Measuring the enjoyment and engagement of the participants over the eight-week period using the self-report Intrinsic Motivation Scale (IMI),(45 item, 7-point Likert scale, 1 = not at all true, 7 = very true) [15,38]
2 Measuring the motivation aspect of the participants over the eight-week period using the self-report Psychological Need Satisfaction in Exercise Scale instrument (PNSE)),(24 item, 7-point Likert scale, 1= not at all true, 7 = very true) [58]
3 Measuring exertion using the Rating of Perceived Exertion scale (RPE) [4] after each session

Participants were also interviewed once a week for the period of the study. They had the option of being interviewed over the phone, Skype, or answering the interview and the self-report questions online.

3.1. Participants

Participants aged 50+ years, with an active lifestyle as defined by the Dietary Guidelines for Americans, 2014 (https://goo.gl/sruHW6) were recruited from the community. We refer to individuals living in this manner as *active lifestylers*. Recruitment was conducted through e-mails, flyers, social media postings and in person. Interested participants were informed about the eight-week commitment and told that they would be randomly allocated to one of the three study conditions.

Each participant answered the questions from the Physical Activity Readiness Questionnaire (PAR-Q) [59] document, which was used to determine their current PA levels and their eligibility to participate in the experimental study. Additionally, the long-form version of the IPAQ, a validated instrument [22,28] was used to determine the current PA intensity for all participants. A demographic questionnaire was used to collect data regarding participants' age, gender, and educational levels. Participants were not paid for taking part in the study and could opt-out from the study at any time during the eight-week program. The inclusion criteria were (1) adults over 50, (2) active lifestyle, (3) ability to use computers and mobile devices.

3.2. Procedure

Group 1: Spirit50 (Gamified Application): We compared existing gamified PA technology and selected Spirit50 because it was specifically tailored for older adults. Spirit50 was specifically designed for adults over 50 years of age and incorporated the following gamification elements: goal definition (quest), daily challenges (sub-goals), goal progression meter, points and badges (stars) as motivational affordances.

The initial and weekly meetings with participants from this group was carried out in the LiveLabs[1], a modern and technologically advanced mobile usability lab located at the Humber College, Toronto, Canada. All participants assigned to Group 1 were invited individually to the usability lab and provided with a login and password for spirit50.com. They were allowed to choose their long-term goals, barriers to doing PA exercises and answer questions regarding their current health situations. These selections enabled the application to identify a low, medium, or high intensity exercise routine for an eight-week period and offer specific goals that they would have considered to work on. To establish a common ground for comparison, all participants in this group were directed to select this specific goal - "Get up and down off the floor with ease". This provided the participants with an eight-week PA program tailored for this specific goal. The participants then proceeded to use the application and cycle through the exercise routines as per the instructions provided on the screen.

Once each participant had completed all aspects of the exercise routines, they were provided a paper format of the combined questionnaire with the above scales and were interviewed. All participants were encouraged to login to Spirit50 from home or work to review and follow through on the daily routines planned by the Spirit50 application. Each participant was allocated a scheduled time to meet every week for testing the exercise routines as they progressed through the program. Post-session interviews and answering the IMI and PNSE questionnaires were conducted each week for the eight-week period.

Group 2: Pedometer (Non-Gamified): Participants in this group were provided a standard clip-on pedometer and asked to continue their physical activities as normal. Participants were provided the questionnaire and interviewed in-person once on a weekly basis or online.

Control: Participants were asked to go about their normal activities and were provided a printed format of the questionnaire once each week for the eight-week period. Interviews for this group were conducted via phone, in person, or via Skype. Participants who were unable to meet in-person were provided a link to the survey questionnaire on a weekly basis with a session number, participant ID, and a group number. They were asked to provide answers to the interview questions in long-form questionnaire answers online.

3.3. Interview Protocol

The interviews were semi-structured and were geared towards understanding their experiences when participating in PA for the week. It was focused on eliciting answers related to *motivation* to do PA, *triggers* facilitating PA, barriers, *accomplishment* and *setting up of goals* for PA, *rewards* and *tracking* of PA. These questions relevant to the research question, were as follows:

1 What was your *motivation* to do the physical activities or exercises this week?
1.1 Were there any *triggers* that helped, you be motivated to do these this week?
2 With regards to physical activity, how do you set up or *decide on goals* to help you do PA or exercises?
3 Were there any accomplishments or *feeling of accomplishment* this week (completion of a task is also an accomplishment)?
4 With regards to PA, were there any *fears or barriers* that you faced this week?
5 Were there any *rewards* (tangible or intangible) that you received or felt/received this week?
6 What kinds of *tracking* information or feedback would you have liked to receive?

4. Data Collection and Analysis

Data were gathered as qualitative information from responses to interview questions and quantitative scale data from the motivation questionnaires.

[1] LiveLabs Usability Lab – Humber College

Data Analysis - Interviews

With three groups of participants, 10 participants in each group for eight-week sessions, we had 240 instances of data collection points. There were 100 audio recordings of interviews from participants from the three groups. Each recording spanned an average of 15 minutes. In addition, answers to interview questions were provided in written format and online or via emails. The audio recordings were transcribed to text using Transcribe[2], an online transcription tool. Once transcribed, the answers were collated under the six interview questions listed in the Interview Protocol section. This resulted in six Excel spreadsheets under the following interview questions: motivation to participate in PA, setting up goals to participate in PA, fears or barriers to participate in PA, accomplishments, rewards, and tracking.

Since its inception in 1967 [21], grounded theory (GT) has bifurcated into two methodical approaches: Glasser's traditional method and the Strauss et al. approach [27,56]. While Glasser's traditional method is recognized as the original GT method which had a more inductive method, many researchers have used the Strauss method because of its flexibility with respect to deductive and inductive analysis, ease of data management and code saturation [17,27,56]. In this study, we used the GT analysis as proposed by Strauss where code saturation was achieved by coding until no new code emerged [8,11]. While a study using *Fish n Steps*, an interactive computer game to promote PA used this method for data analysis [39], other studies also adapted this method for analyzing qualitative data [6,10,18]. For our study, GT analysis was used to code the transcripts line by line and break up the data into its component parts or properties [8,11]. Open coding was done on each sentence of the transcripts to identify the meaning of the interview data into phrases that represented each sentence by the participant [11]. Characteristics of the meaning of these codes were also notated in the Excel file identifying the properties of the code. These codes explicated actions to meanings [8,20] of participant responses. The above process was done for all participant responses for each of the six questions. These properties and open coding for the six questions are indicated in the supplementary materials.

The next step was to identify any relationship between open codes, which would then be aggregated into a higher category. This process is identified as axial coding or the process of relating categories to sub-categories [8,11]. Axial coding was done for all the six interview question responses. The interview responses were then sorted based on the group number and axial codes to gather interview responses and to evolve characteristics of the categories.

Data Analysis – Questionnaires

The data from the weekly report of the IMI engagement and enjoyment) and PNSE (motivation) and RPE questionnaire were analyzed using SPSS. We had 10 participants in each group giving us a total of 80 responses (240 items for 3 groups) in each group.

5. Results

5.1. Participant Demographics

All participants qualified to participate in the eight-week study though the PAR-Q instrument. Additionally, the IPAQ instrument helped to identify the current baseline intensity levels of participants based on metabolic equivalent tasks (MET) recorded by participants' during the past seven days prior to the start of the eight-week study. Essentially, the MET score of an activity is multiplied by the minutes of the performed activity and is expressed in multiples of the resting metabolic rate [28]. The MET scores from the long form questionnaire established PA levels of participants over the past seven days across four domains: work, active transportation, domestic and garden (yard work), and leisure time. Table 1 shows details of participant information from the three groups.

The IPAQ quantifies MET scores of activity levels and is categorized as low, moderate (at least 600 MET-minutes/week) and high (physical activity of at least 3000 MET-minutes/week) [22,28]. It indicates the PA levels of participants in all the three groups to be categorized as high PA, labelling them *active lifestylers*.

	Gamified (N=10)	**Non- Gamified (N=10)**	**Control (N=10)**
Age	Mean = 60.5; SD = 6.87	Mean = 63.1; SD = 8.44	Mean = 68.8; SD = 6.66
Gender	F= 4; M=6	F= 3; M=7	F= 3; M=7
MET minutes/ week	Mean=4235.4; SD= 870.5	Mean=4785.8; SD= 1103.4	Mean=5521.9; SD= 2348.5

Table 1: Participant demographics

5.2. Findings from Qualitative Studies

Exploring the relationships between open codes led to evolving axial codes for the six interview questions: motivation, setting up goals, feeling of accomplishment, fears and barriers, rewards, and tracking of physical activity. Comparison of the axial codes emerging for the

[2] https://transcribe.wreally.com/

three groups are shown in the supplementary materials. The following is a summary of the findings from the emergent axial coded from the gamified group.

Motivation for PA: Accomplishing a goal, aging well, challenged by activity, easy access to resources, enjoying outdoors, experience, fear of being unhealthy, focusing on appearance, focusing on motivational affordances, for a healthy lifestyle, freedom of usage, fun and recreation, influenced by the app, inspirational influencers, limitations of resources, mental wellbeing, routine/lifestyle, social connections, spontaneous and subconscious activity, treatment for a health issue.

Setting up Goals: Combining exercise types, committing time for activity, enjoying combination of activities, focusing on goals | on appearance | on motivational affordances, improving health outlook.

Feeling of Accomplishment: Adding new challenges, influencing activity through app, completing difficult challenges, feeling of mental satisfaction, feeling the burn, feeling validated for efforts, improving body conditioning, improving confidence, improving health condition, improving ability, increasing independence, inspiring motivational affordances, inspiring performance, progressing through activities, seeking external resources, social interaction.

Fears and Barriers: Challenging health conditions, fearing inability, fearing appearance issues, having psychological challenges, limiting resources, fearing lack of performance, fearing social interaction.

Rewards and PA: Completing an activity, having freedom of usage, having intangible rewards, having tangible rewards, feeling of mental satisfaction, having self-awareness, having sense of accomplishment, improving confidence, influencing characteristics of the app, improving health condition, inspiring motivational affordances, seeing results of efforts, social activity

Tracking of PA: Challenging tracking issues, indicating completion status, improving body form, showcasing motivational affordances, making social connections, needing feedback, measuring physical activity.

5.3. Findings from Quantitative Analysis

Answers from participants for the PNSE, IMI and RPE scales, collected over an eight-week period were compared between the three groups (group 1 = gamified, group 2 = non-gamified, group 3 = control).

Overall Tests between Groups: Data were non-normal and binned into groups using the grouping variable and tested using the Kruskal-Wallis test.

Kruskal-Wallis Test (PNSE)

While for the PNSE scale, motivation was significantly affected by the interventions for the dimensions related to perceived competence [H(2) = 28.77, p <0.5], perceived autonomy [H(2) = 8.76, p <0.5], and perceived relatedness [H(2) = 17.60, p <0.5], was higher in group 1 (gamified) than the other two groups (non-gamified and control). The Jonckheere - Terpstra test revealed a significant trend between the groups in the perceived competence (J = 6491, z = -5.33, r = -.34) and the perceived relatedness dimension (J = 8064, z = -2.63, r = -.17). The negative value of the z-statistic indicated a rising trend toward the gamified group (i.e., a trend of descending medians as the coding variable increased).

Kruskal-Wallis Test (IMI)

All effects are reported at p <0.5. Engagement was significantly affected by the interventions: interest/engagement (H(2) = 12.45), perceived competence (H(2) = 39.65), effort/importance (H(2) = 6.21), pressure/tension (H(2) = 12.56), perceived choice (H(2) = 12.5), value/usefulness (H(2) = 6.43), relatedness (H(2) = 10.42). The Jonckheere-Terpstra's test revealed a significant trend in the data: the negative value of the z statistic indicated a trend of descending medians as the coding variable got bigger, which indicated a rising trend toward the gamified group. Significant trends were seen in the following dimensions: Interest/Enjoyment: J = 7602, z = -3.42, r = -.22; Perceived Competence: J = 5824, z = -6.46, r = -.41; Effort/Importance: J = 8272, z = -2.28, r = -.14; Perceived Choice: J = 11616, z = 3.45, r = .22; Value/Usefulness: J = 8116, z = -2.60, r = -.16

Kruskal-Wallis Test (RPE)

The comparison for RPE showed significant exertion between the groups H (2) = 24.3, p < .05. The Jonckheere -Terpstra's test revealed a significant trend in the data: J = 12277, z = 4.618, r =.30. The positive z-statistic indicates a rising trend of medians as the coding variable increased, indicating that the participants in the gamified group (group 1) felt lower exertion compared to the participants from the control group (group 3).

6. Discussion

We discuss the findings from the qualitative and quantitative analysis with reference to older adults and PA. Sample responses from the qualitative analysis are shown in supplementary materials.

Technology Facilitation of PA: To understand older adults' enjoyment and experiential aspects of using technology for PA, we examined the relevance of technology in the context of PA motivation, setting up goals, feeling of accomplishments, fears and barriers, and rewards, and tracking.

Qualitative Analysis: By investigating the influence of gamification elements in PA technology, this experimental study extends the prior work of using web-based interventions to promote PA by sedentary older adults (55+), supporting improved behavioral changes and effective changes in PA of older adults (50+) [29,49,55]. Based on qualitative analysis, we illustrate the evidential chain [43] indicating the justification of

gamified PA technology for older adults (Figure A1 - supplementary materials). While qualitative analysis has been used by researchers for hypothesis testing, the analysis shown in Figure A1 (c.f. supplementary materials) provides evidence of technology influencing PA. This correlates with the results of the quantitative analysis that gamified PA applications would increase participant engagement and motivation in PA activity

Quantitative Analysis: From the quantitative analysis, overall needs satisfaction for exercise (PNSE) indicated significance for perceived competence, perceived autonomy and perceived relatedness. The Jonckheere-Terpstra test, used to compare trends between the groups, also revealed rising medians towards the gamified group for dimensions relating to interest/enjoyment, perceived competence (for interventions), effort/importance, perceived choice and value/usefulness. This result is also similar based on the axial codes that emerged from the qualitative analysis indicated in the evidential chain mapping (Figure A1, sup. Matl.) that the gamified group participants showed interest and enjoyment by the following: improving on their deficiencies, increasing challenges progressively, indicated perceived competence through increasing challenges progressively, feeling of the ability to do more and increasing difficulty levels, feeling importance of effort/importance by feeling validated for their efforts, measuring progress and improvement in body conditioning. Perceived choice was afforded by the ability to select goals and challenges, self-regulation of routines and flexibility of usage. Furthermore, value/usefulness was afforded by feeling energetic, wanting to do more, improved confidence and improving ability.

The results of the follow-up tests in the quantitative analysis for needs satisfaction for exercise (PNSE) indicated significant results between the gamified group and non-gamified for perceived competence, and between the gamified and control group for the same dimension. This was also similar to the axial codes emerging from the qualitative analysis indicating that participants in the gamified group felt that a scheduled program with daily achievements and challenges with motivational affordances like points and stars (rewards) helped them feel that there was validation of their efforts, and provided constant monitoring of their progress.

The Spirit50 app had minimal social interaction options included for testing and therefore it was surprising to note that the gamified group indicated significant difference from non-gamified and control group for the relatedness dimension. In comparing the qualitative data from the gamified group, many participants indicated that they could see the potential of social interactions with other online participants of the app and in their own daily life.

7. A Theory of Motivational Affordances for Older Adults'

Older adults are interested in various aspects of gamified technology because specific elements within the system provided advantages such as: keeping on track with regular PA, ability to recognize their limitations with exercise intensities, challenge themselves to do more, feel validated for their efforts and be rewarded for their task completion stages. While older adults have limited understanding of terminologies such as gamification and motivational affordances, they do respond to triggers such as: setting up of attainable goals, on-the-spur of the moment challenges and pushing themselves to do more PA. Additionally, the quantification of PA using pedometers also pushed older adults to walk more, add new challenges in their routine walks or treks adding to the degree of difficulty of their activity and also increase the time spent on such activity. Furthermore, the presence of motivational affordances also provides older adults with the choice of monitoring of their progression, keeping track of their achievements, and giving them an improved sense of control of their efforts for PA.

Based on the findings from analysis of qualitative data, we illustrate the elements are crucial for facilitating engagement and enjoyment in PA for older adults through gamification. We propose the term *adaptive engagement* which means: *tailoring of older adults' engagement through customization and personalization of motivational affordances for PA.* Based on the clustering of motivational affordances [23,51], we categorize emergent motivational affordances into intrinsic, extrinsic, and feedback elements.

Table 2: Adaptive engagement guidelines 1

Intrinsic Motivation Elements	**Guidelines**
Attainable goals	Understanding the ability that is specific on an individual level should be the focus of PA goals (quests).
Challenges mirroring ability	Increasing challenges progressively to reflect the individual's ability so that it inspires confidence and provides a sense of accomplishment.
Increased agency	Challenges and levels should provide older adults with the feeling of a sense of being in control of their bodies based on their own physical limitations.
Choice of types of exercises	Combining activities to provide exercise and PA that improve endurance, flexibility, strength training within an indoor and outdoor environment.

Intrinsic Motivation Elements	Guidelines
Choice of intensity increases or decreases	Gamification of PA activities should have provisions of trying out new challenges or change the intensity level so that the activity feels like a challenge or have the potential of downgrading the challenge.
Inspiring curiosity	Gamification elements should provide the opportunity to provide a mystery PA module for older adults to try out for a new reward.
Interjecting unpredictability	The opportunity to do random PA activities to increase levels and rewards fosters the element of engaged participation.
Facilitating spontaneity and instantaneous gratification	Include elements that allow for spontaneous PA and instantaneous gratification in the form of feeling the burn, completion, achievement as internalized rewards.
Freedom of usage and habit formation	Allowing the possibility of activities to be done anywhere and anytime with simplicity and memorability to help with habit formation.
Facilitating competency	Providing challenges that help promote health benefits and increased mental satisfaction.
Social facilitation	Providing the possibility for older adults to share and post achievements, challenges with specific routines.

Table 3: Adaptive engagement guidelines 2

Extrinsic Motivation Elements	Guidelines
Attainable rewards	Challenges should provide the opportunity of instantaneous rewards while scaffolding to inspire active participation. It gives older adults the feeling of satisfaction that certain tasks and milestones are achievable based on their ability, rewarded and measurable.
Validation of efforts	While receiving points and stars seemed frivolous, its attainment after doing PA activity provided a sense of validation of one's efforts.
Progression reflecting ability	Progression should show the competence of older adults in being able to do a specific level to afford a sense of accomplishment.
Progression reflecting efforts	Combining activities to offer exercise activities that provide endurance, flexibility, and strength training within an indoor and outdoor environment.
Highlighting achievements	Providing badges and points that help to showcase their achievements and completion of difficult challenges.
Intangible rewards	Rewarding ability to perform the tasks and complete the tasks and providing the opportunity for bragging rights, recognition, as well as achievement levels will contribute to engagement and enjoyment of the PA activity.
Tangible rewards	Facilitate usage of experience points earned to be redeemed for ancillary contexts such as diet plans, fitness plans, fitness gear, books and competitions.

Table 4: Adaptive engagement guidelines 3

Feedback Cycle Elements	Guidelines
Correctness of form	Real-time feedback on posture correction, gait and correctness of stance when doing the exercise routines is a difficult technology challenge but was desired by many older adults for increased participation.
Performance characteristics	The possibility of providing feedback on reps and steps, speed of completion, and tracking metrics such as calorie burn, heart rate, weight loss provides increased engagement
Encouragement through praise	Real-time feedback in the form of praise and checkmarks for task completion through the gamification app will help to reassure older adults
Visual representation of progression	Progression representation of daily, weekly and monthly indicating competence in all or specific activities in a graph format is more easily understandable by older adults
Onboarding and education	Older adults should have the opportunity to overcome challenges with understanding game, gaming and gamification terminology through training and education modules of the gamification app

Implications of the Study Findings

The GT analysis on 'Motivational Affordances for Older Adults PA' provides numerous vantage points for technology facilitation

Older adults' perspective: This theory provides a better understanding of PA motivation and the relevance of specific gamification elements in the context of PA. This highlights empirical evidence that older

adults care about motivational affordances (gamification elements) to an extent that it encourages PA [5]. As indicated in a prior study [7], intrinsic motivation attributes such as feeling good, feeling of accomplishment, satisfaction of doing the routines, confidence in ability to initiate the task of participating in exercise routines contributes towards habit formation and can lead to adherence and maintenance of regular physical activity. While being rewarded in the form of badges, points, experience points, and scores are a few examples of tangible rewards, the improvement in appearance, weight loss, and better-looking skin are also examples of tangible rewards, thus adding to prior studies [19,39]. Intangible rewards can range from accomplishments of feeling good, feeling energetic, praise, recognition, and improved confidence in ability to regulate one's healthy behaviour to mention a few [35,38]. Motivational affordances provided by gamification technology assists with remembering to do the exercise routines, quantifying physical activity metrics through tracking steps, and providing feedback on calorie intake and calories burned throughout daily activities thereby fostering a sense of accomplishment [29,33,44].

Implications for Research and Technology Design: This theory also provides empirical evidence that tailored PA interventions for older adults improve their engagement and enjoyment. This means that this experimental study supports health behaviour change through gamification elements [35,38]. The specificity of intrinsic, extrinsic, and feedback elements emergent from GT provides guidelines for developing and designing gamified PA technology for older adults.

8. Limitations and Future Work

In the context of gamification as well as quantified health applications, threshold data is rarely adjusted to older users [53]. For example, general fitness goals, such as taking 10,000 steps a day, may not be suitable for older adults with age-related mobility impairments [53]. Therefore, applications will need to adapt such features in the interest of addressing concerns related to both motivation and safety for older users.

Concerns about placebo effects in games [14] are also critical to determine what is mediating the observed behaviour. In this experimental study, participants in the gamified and non-gamified group may expect to have more engagement because of the presence of new features in the technology artifact (i.e., a novelty effect). Older adults are also prone to stick to habits, therefore wearing out effects of novelty and interaction paradigms for this demographic need further investigation. There were also the occasions when participants from the gamified and non-gamified forgot to perform their weekly tasks because of their daily-life activities. There was also the possibility of risk of a participant not willing to do the specified daily PA on specific days' due mood swings (P11) and general lethargy (P08) in specific weeks. This posed the limitation of participants not adhering to the exercise plan of a weekly basis for the 8-week intervention period. Three participants dropped out of the control group and new recruitment had to be done of the study protocol prior to the eight-week period. Additionally, older adults' perception of games, gaming, and gamification compared with younger adults in the context of PA, needs further investigation.

9. Conclusion

Motivational affordances or gamification elements have been used in many areas for increasing the engagement and motivation of consumers or users in the domains of marketing, education, health and wellbeing, and crowdsourcing to mention a few. There has been limited research in the use of gamification elements to facilitate motivation and engagement of users in a physical activity setting, especially for the older adult demographic. GT analysis from qualitative data show relevance of motivational affordances within the gamified and non-gamified group in performing PA facilitated by technology over an eight-week period. Results from quantitative analysis indicated significance in the perceived competence dimension compared to the non-gamified and the control group. Perceived autonomy was significant for the non-gamified group against the control group. This congruence between the findings from the qualitative and quantitative analysis indicates that gamification elements can serve as factors to foster PA motivation, enjoyment and engagement. Furthermore, the findings also indicated that enjoyment and engagement is less in groups with traditional PA interventions than due to the usage of gamification elements in PA technology. This experimental study showed that the usage of motivational affordances through gamified technology can be used to foster intrinsic motivation among older adults for PA. Our guidelines for adaptive engagement are important research contributions to better understand PA technology for older adults.

10. Acknowledgements

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11. References

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