Motivational Impacts and Sustainability Analysis of a Wearable-based Gamified Exercise and Fitness System

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Abstract
Recent years have been hailed by many as the *era of the wearables*. Meanwhile, gamification in the area of health and fitness has rapidly emerged as a popular field of research. This paper reports the early results of a long-term (70-day) study of using wearable activity trackers and gamification to promote exercise and being more active. The research is being conducted to investigate the motivational effects of using sensor-based games to promote daily exercise, as well as how different methods of releasing the application and its updated features may affect user's enthusiasm and the game's life-cycle. From the data we have collected so far, we can see the gradual emergence of clear pattern based on our periodically updated application. The initial results seem to support the notion of using gradual addition of features or changes as means of sustaining the participants' interest and usage.

Author Keywords
Gamification; fitness; exercise; wearable device; motivation; game sustainability.

ACM Classification Keywords
K.8.0 [Personal Computing]: Games

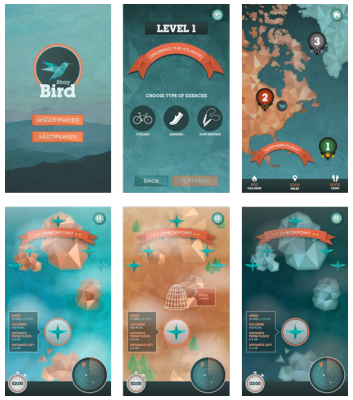

Figure 1. Screen shots from our original application. From left to right, row one: choice of player mode, choice of exercises, landing screen; row two: level1 view, level2 view, and level3 view.

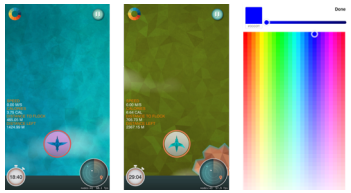

Figure 2. Screen shots from our updated application. From left to right: customized bird color for level1, customized background color for level2, color picker panel view.

Introduction

Gamification of exercise and fitness has rapidly emerged over the past few years as an effective method of promoting fitness and wellness. By utilizing game-based dynamics and motivational factors in a non-game context [1] [5], mobile applications, along with wearable devices, have proven to be efficient platforms for exercise and fitness due to their wide adaptation, continuous accessibility to users [3], and aspects of entertainment.

On the other hand, the rise of inertial measurement unit (IMU) equipped activity trackers has enabled millions of people to easily monitor their physical activities. Consequently, we suggested that off-the-shelf wearable devices have considerable potential to be utilized in gamification of exercise and fitness. We illustrated that this approach helps towards achieving their fitness goals by making exercise more fun and engaging, accessible, and rewarding [7].

In our previous work, we utilized this concept through the design and implementation of a smartphone game application, which used wearable devices as input systems [6]. We conducted a short-term user study and used combinations of different exercises and types of wearable devices to evaluate the usability and outcomes of our system. The results showed that based on existing technologies and user needs, the idea of employing wearable activity trackers for gamification of exercise and fitness is feasible, motivating, and engaging.

In this paper we extend the application with more comprehensive questions and experiments, followed by a 70-day long-term user study (currently in progress), to conduct an in-depth investigation of the motivational impacts of using our system for promoting exercise. In order to have people maintain a constant habit or routine, applications should be designed with not only desirable usability but also durability, which will provide users with sustainable motivation and engagement over time [2]. Consequently, we update the application regularly by adding new features, and evaluate the effect of such time-based updates. In our ongoing user study, we also aim to investigate how different ways of releasing the application or updates to users may affect the users' behaviors towards the game. Therefore, we divided our participants into three groups where the first group receives the game with only very basic features, the second group receives full features of the game, and the third group starts from only basic features but will have different features gradually unlocked every 10 days. The behavior patterns of each group is monitored, and early results are presented in this paper.

Application Design and Implementation

The iOS application *StrayBird*, initially implemented for our previous work [6], is used in this study. We added a series of features to the original single-user single-level game in [6], as shown in Table 1. The iOS application communicates with wearable activity trackers (TI Sensortag) in real-time and utilizes the data received from its sensors (inertial measurements) as inputs to the game. Players can play the games in three modes: running, cycling or rope skipping to control the movements of the game character. The story of the game is based on a bird that has fallen behind its flock. The objective is to regroup with the flock before the time runs out and before the group reaches its destination. There are also physical and environmental parameters that may affect the movement

Figure 3. The wearable device used in this study.

Game Type	%
Simulation	6
Sport	14
Strategy	11
Racing	12
Sandbox	1
RPG	8
Adventure	6
Puzzle	2
Action	11
FPS	9
Combat	3
MMO	6
Card	3
Casual	5
Education	3

Table 2. The preference ratio of different types of games.

behavior of the bird and flock, for example a bird net may appear to catch the bird and the player has to reach a certain speed in order to break the net. Another example is a thunderstorm that may occur and threaten the flock. The game features a mission-based structure and point-based system. Higher levels can be unlocked when missions have been achieved. The achievement system is also designed to encourage players during the gameplay. Multiplayer mode brings in leaderboard and challenge box that allows players to compete with each other. Figure 1 presents several screens from the application. Additionally, the ability to customize character and background colors is implemented in the application (see Figure 2). We used HockeyApp [4] to distribute different versions of our application to participants, and to receive user feedbacks.

User Study Design

36 participants were recruited for our study. They were all provided with a TI Sensortag wearable device (see Figure 3) to take home. The wearable could be worn on the wrist or ankle (depending on the exercise they choose; for example, for cycling the sensor should be worn on the ankle). The wearable then connects to the game application on iOS that we distributed to the users. No particular set of instructions was provided, and users were allowed to explore the system on their own.

The users were then randomly divided into three equal groups of 12. To users in group 1, we only provided very basic features of the game such as a single level (level 1) version of the game, as well as single player mode. Users in group 2 were provided the the full version of the application, including the ability to customize colors, as well as all 3 levels of the game, and multiplayer mode with leaderboard and challenge box, etc. Users in group 3 started with the same application as those in group 1, but have been gradually receiving updates (once every 10 days), until they eventually end up with an application that is identical to those group 2 after 70 days. The update schedule is shown in Table 1.

Day	Updates
Day 1	Single level, single player
Day 11	Add customized bird color
Day 21	Add multiplayer leaderboard and challenge-box
Day 31	Add level 2 (with bird net)
Day 41	Add customized background color
Day 51	Add achievements
Day 61	Add level 3 (with thunderstorm)

Table 1. Automatic updates schedule used for group 3.

For data collection, we use Google Analytics API to track users' detailed behavior data, including each screen view and tapped event with associated timestamp, each exercise session they performed with their performance, as well as their feedbacks and comments. We also provide both pre and post-study questionnaires for all participants. The pre-study questionnaire gathered detailed information about the users such as gender, age, and other important information such as existing training, fitness, and exercise routines, past injuries, and more. The post-study questionnaire will comprehensively evaluate participants' experience during the study.

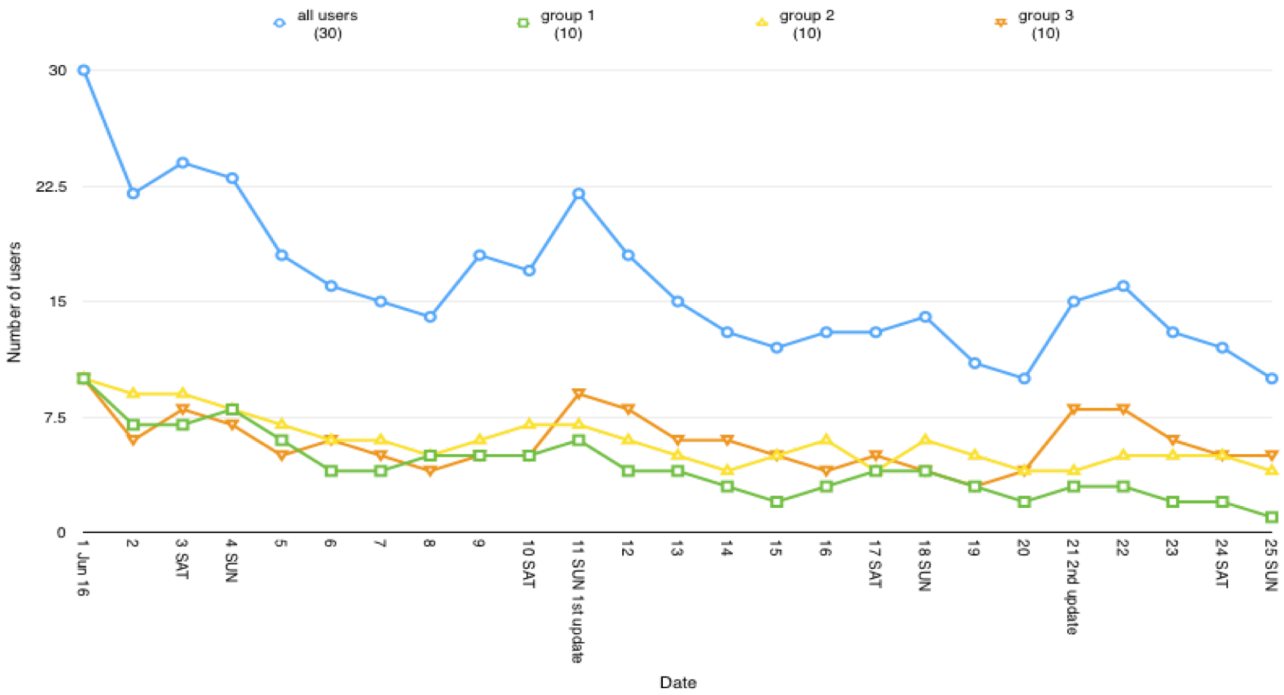

Figure 4. Early result of active users. Each unlock date and weekend has been marked out.

Early Results

Out of the 36 volunteers who participated in this study, 22 were males and 14 were females. Their average age was 24.30 with the standard deviation of 4.61. Their average hours of exercise per week was 3.65 hours with a standard deviation of 2.76, while the average hours per week spent on playing games was 6.19 for pc/console games (with a standard deviation of 9.01) along with an 4.15 hours per week spent on playing smart-phone games (with a standard deviation of 6.61). 14 out of 36 participants (38.9%) previously (or currently) owned an activity tracking wearable device.

We also asked about what types of video game they often like to play and provide them with multiple choices. The result is shown in Table 2, and is consistent with our initial thought that sports-related games are probably more suitable for this user group and this type of activity, although this is not conclusive.

During the first 25 days of the study, some interesting trends have emerged from the collected data. Figure 4 shows the number of active users. It can be seen that the local peaks mostly appear with either on weekends or when application updates for group 3 have been sent

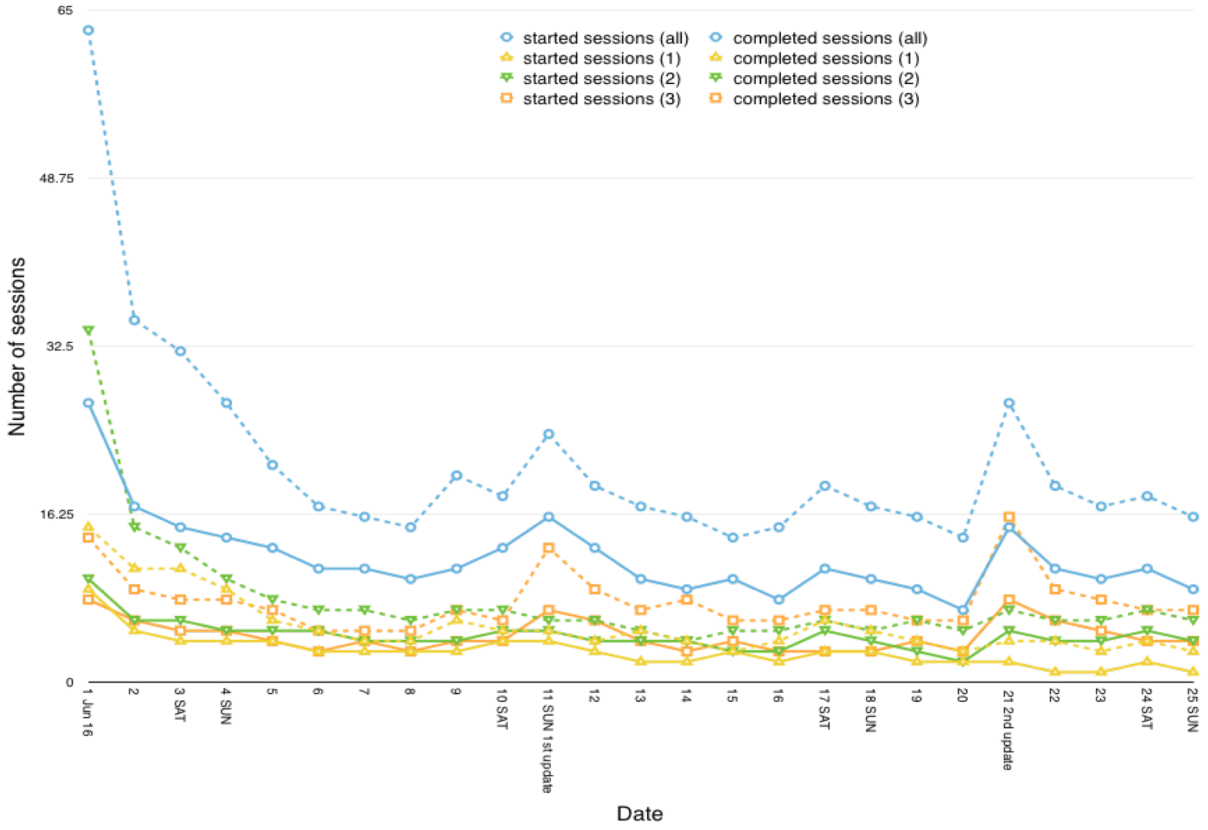

Figure 5. Early results for workout sessions. Dotted lines represent the total number of started sessions, where solid lines show only those that were completed.

out. After 25 days, group 3 maintains a higher user retention rate compared to the other two groups.

Figure 5 presents additional data regarding game-play where the number of sessions started and number of sessions completed are illustrated. It is observed that the weekends and updates have affected the workout session curves as well. Additionally, the second update (adding multiplayer, leaderboard, and challenge-box) performs slightly better than the first one. As group 3 can now access multiplayer mode, there are 12 more people in the community so users from group 2 also show higher levels of engagement. Moreover, Pearson correlation coefficient was computed to assess the

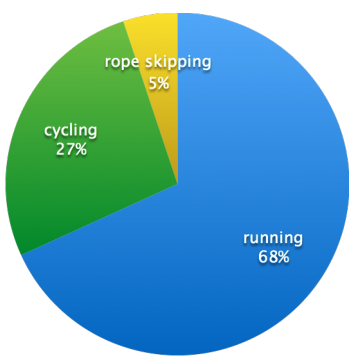

Figure 7. Exercise choice percentage.

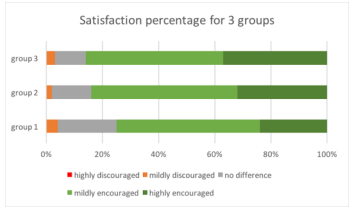

Figure 8. Satisfaction percentage for three groups.

relationship between the number of each group's daily started workout sessions and completed workout sessions. For all three groups there were all positive correlations between the two variables. For group 1, r = 0.862, p = 3.057e-08; for group 2, r = 0.893, p = 1.917e-09; and for group 3 r = 0.902, p = 7.450e-10. (where r value represents the sample Pearson correlation coefficient and p value measures the significance of the r value). From the result we can see user's engagement and game-play are highly linked. Moreover, a simple linear regression was calculated to investigate the trend of user's engagement based on the growth of time. (the number of completed sessions were used in this calculation to represent user's engagement). Figure 6 shows time series plots of number changes (decrease rates) of the completed sessions with the estimated regression line (where slope of group 1 is -0.172, slope of group 2 is -0.112 and slope of group 3 is -0.035). From the result we can tell the consistent updates could so far increase the usage of the application to some extent.

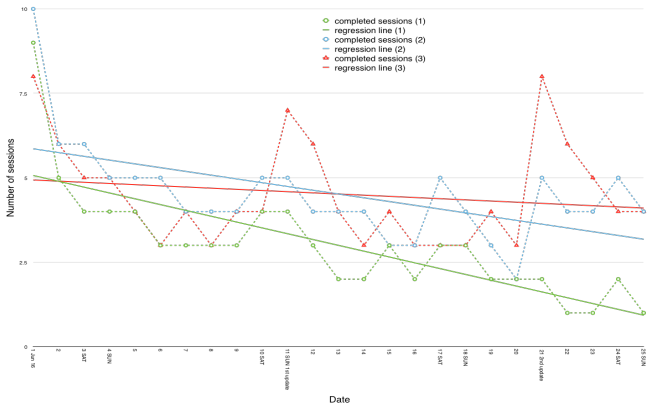

Figure 6. Plots of regression lines for all three groups.

Figure 7 shows participants' choice of exercise type, in which running is the most popular exercise. Figure 8 shows the feedback that we collected using a 5-point Likert scale for all three groups regarding the level of encouragement by the system towards more exercise. We can see most users felt positively regarding this gamified exercise experience.

Conclusion

In this study, we extended an existing application with a set of more diverse features to evaluate the motivation impacts and sustainability of a wearable-based gamified exercise and fitness system. We have reported early results of an ongoing long-term (70-day) user study. Early data shows that engagement and game-play are highly linked, and the consistent updates (gradual addition of new features) have so far resulted in increased usage of the application.

A more detailed analysis of the experience along with detailed statistical analysis of the results will be carried out once the experiments are concluded and additional data are available.

Moreover, feedback from participants indicated that most users would like this kind of application to support outdoor activities as well, and some stated they would prefer real-time competition mode. These ideas are possible directions for our future research. We will also focus on utilizing player modelling techniques to better understand users from different perspectives. A comprehensive gamified fitness advisor and recommendation system can be further developed.

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