FitBird: Improving Free-weight Training Experience using Wearable Sensors for Game Control

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Abstract
Strength training improves overall health, well-being, and sports performance. However, the training process is often repetitive, making the experiences boring and tiring after going through the long-term session. This paper proposes FitBird, which uses wearable sensors to map existing strength training motion to game designs to enhance entertainment level during exercising. We chose 1:1:1 as the time intervals proportion of three distinct phases during exercises repetition: 1) Eccentric: muscle lengthening, 2) Isometric: same muscle length, and 3) Concentric: muscle shortening, and integrated this tempo for the well-known game - FlappyBird as the training guidance. We evaluated the proof-of-concept prototype with 12-person study that participants conducted strength training while using our system. The results showed that FitBird significantly improve user's entertainment level during strength training and was preferred by most of the users.

Author Keywords
Sports/Exercise; Gamification

CCS Concepts
•**Human-centered computing** → *Field studies; Interaction design;*

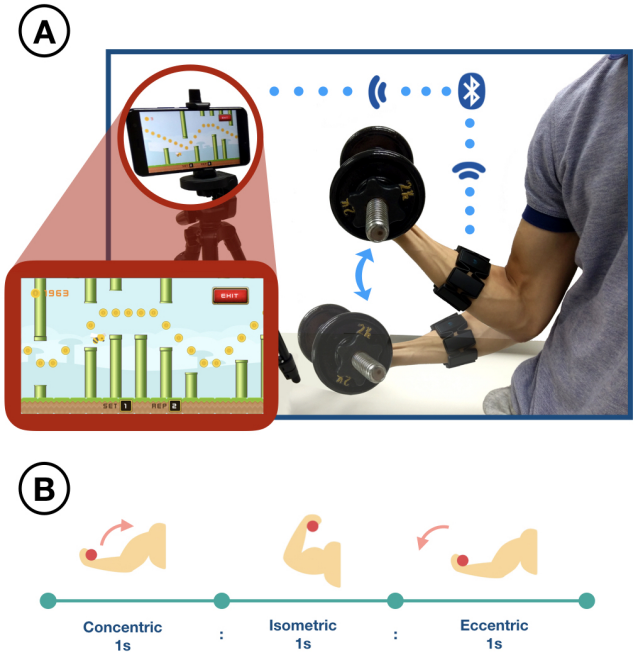

Figure 1: (a) FitBird maps bicep curl to FlappyBird in real time to raise game entertainment level. (b) Tempo is the ratio of the time intervals among the three phases in a repetition: 1) Concentric: muscle shortening, 2) Isometric: maintaining the same muscle length, and 3) Eccentric: muscle lengthening.

Introduction

Strength training improves overall health, well-being, and sports performance. The World Health Organization (WHO) specifically recommends that *"muscle-strengthening activities should be done involving major muscle groups on 2 or more days a week"* with aerobic exercises in order to improve cardio-respiratory and muscular fitness, bone health, and to reduce the risk of depression and noncommunicable diseases (NCD), such as heart disease, stroke, cancer, chronic respiratory diseases and diabetes, which are the leading cause of mortality in the world [10].

Despite the benefits, strength training often consists of repetitive movements, leading to dullness and tediousness. In this work, we tried to enhance exercise's entertainment level by gamifying the training motion. To better understand user's thoughts on doing strength training while playing games, we first conducted a 29-person field survey. Through the investigation, we found that there were 69% of participants expecting and feel interested with the possible interaction that combines strength training and game control input.

Based on our preliminary survey results, we proposed FitBird, which maps strength training motion to game control mechanism to better enhance entertainment level for exercises. As shown in Figure 1a), we implemented a prototype using the MYO [5] inertial measurement unit (IMU) readings of bicep curls to control the well-known FlappyBird game [2]. Instead of tapping on screen to fly the bird up, we modified the game control to continuously reflect the progress throughout a repetition, i.e. the maximum and minimum muscle contractions are mapped to the highest and lowest positions of bird respectively.

Besides position mapping, strength training programs also contains variables that include the number of *sets, repe-*

titions, rest time, weight, and tempo [3, 11]. *Tempo*, as shown in Figure 1b), describes the interval ratio of the three distinct phases of an exercise repetition: 1) Concentric: muscle shortening, 2) Isometric: maintaining the same muscle length, and 3) Eccentric: muscle lengthening. We applied even distribution of time on each phase for our game system based on the *strength* goal proposed by American College of Sports Medicine (ACSM) [3, 11]. In order to indicate the specific tempo, there were several pipes and coins set as the guidance in our game interface, while the number of sets and repetitions were displaying below (shown in Figure1a)).

To evaluate our system, we conducted a 12-person study to compare FitBird with no gaming feedback on the entertainment level provided during strength training. Our results showed that FitBird significantly improved entertainment level compared with no-game condition (8.0 vs. 3.5 on a scale of 10, $p < .01$), and was preferred by most of the users (91.7% for game vs. 8.3% for no-game).

Related Work

Gamification [4] is always used to be added into a non-gaming system to improve user experience. Our work aims to integrate gamification elements into strength training routines. We review the related work combining strength training exercises and games.

Having a similar concept, Richards et al. developed *Brain & Brown* [12, 13, 14], a strategy card game for strength training. The main goal of the game is to defeat the opponent using the offensive and defensive powers of available characters in the cards. After organizing their team, players need to perform exercises to use their characters' skills. Each card has its own specific exercise on it, and the amount of power is dependent on how well the exercise was performed. This game will give the feedback to make players check if the exercise is performed correctly. While this work contributed in correcting exercise form by giving feedback after exercise, FitBird provided real-time feedback of correct tempo.

About to commercial product, *eGym* [1], an existing company producing training machines, integrates exercise equipments with instant visualization of training data, and also includes some gamification elements to reward users for having correct speed. However, the gamification elements are simply an interface that displays visual guidance, while we try to map existing commercial game design to improve entertainment level.

In the aspect of entertainment level, *SymGym* combines video game controller with resistance training machines, and is able to play simple classic games, such as Pac-Man or Asteroids. Based on the same concept, we added *tempo* as part of gameplay, which was not provided by *SymGym*.

Field Survey

We conducted a survey to explore the needs of game for strength training. The 29 respondents (age 18-29, Mean = 21.5, SD = 2.49, 9 females) helped us finishing the survey. The training experiences of respondents varied from beginners, intermediate, and athletes. Training frequency ranged from 1 to 5 times a week, with each training session ranging from 30 to 90 minutes.

Methodology

We created an online questionnaire and invited people that have fitness habit to fill the form. We asked respondents to describe their views in detail. There are mainly three questions in the survey:

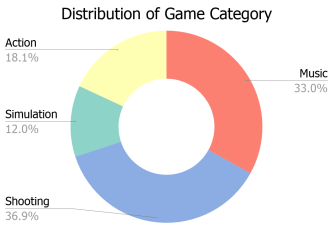

Figure 2: Distribution of game category that mentioned in the survey.

1) What is your opinion on playing games when doing strength training?
2) What kinds of games that you want to play when doing strength training?
3) If there is a game that can play when exercising, what functions do you expect?

Results

For the idea of playing games in strength training, 69% of the respondents expressed their desire to try the game interface when exercising to enhance their sense of entertainment. The game categories that the respondents mentioned include music, shooting, simulation, and action game, and the distribution is shown in Figure 2. About the expected functions, we summarized the opinions of the respondents below:

- **Progress counter:** With multi-repetition sets exercise, people may forget how many repetitions they have conducted, and the counter helps users visualize their training progress.
- **Mobility:** Although almost all of the respondents said they would play the game at the gym, there were still a few respondents expressed they would play the game at home to avoid embarrassment. Therefore, portable aspects and the ability to let the user's setup the game anywhere is also vital for some user group.
- **Agency during rest period:** Between sets, people usually have nothing to do and feel boring. The gamification design in rest time not only increases training motivation, but also provides something to do to kill boring time.
- **Achievement system:** Exercise needs to be encouraged. The achievement enables the users to fulfill their accomplishment.

Prototype Design

We modified FlappyBird, a classic game where players use tap or click to control a bird to fly through pipes, as our prototype. This sample prototype involves linear movement on the up-down axis and controlled by doing bicep curls (shown in Figure 1a)).

Modifications in FlappyBird

First we canceled the gravity in FlappyBird so that players' forearm motions have complete control over the bird's position. Original punishment was also modified from direct death to loss of coins to ensure that exercise wouldn't be interrupted. Through the arrangement of pipes and coins, whose positions were automatically generated according to the speed of background scrolling, the game provided a path that indicated the 1s:1s:1s tempo, which composed of three distinct phases of an exercise repetition, concentric, isometric and eccentric, for players to follow.

Implementation

Due to our prior successful experience using real time API and the smooth signals it provided, the inertial measurement unit (IMU) in MYO [5] is used to sense players' motions and control the bird in the game. As shown in Figure 1a), through SDK released by Thalmic Labs [6], the game system can obtain orientation data from the sensor via Bluetooth. Developed using Unity, our prototype is able to run on multiple platforms, including PC and android mobile phone.

Gameplay
As shown in Figure 3, players need to follow the tempo according to their motion by collecting the coins and avoid hitting the pipes. With the current state of training information displayed below, they can keep track of how many sets and repetitions they have done.

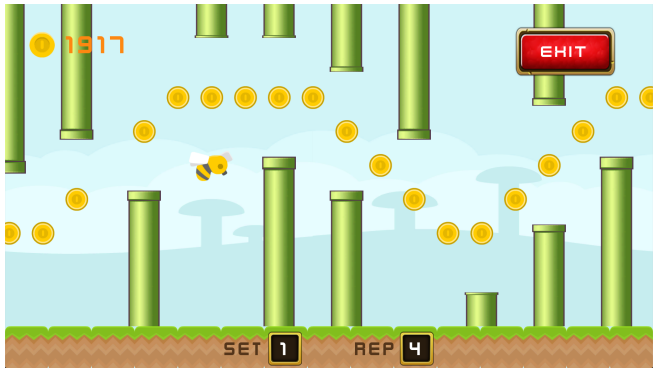

Figure 3: Game flowchart of our FitBird prototype modified based on FlappyBird.

Evaluation

To evaluate the entertainment level of FitBird, we conducted an user study to let user do strength training while playing with our system.

Participants
We recruited 12 participants (age 17-23, Mean=21.9, SD=1.73, 6 females) at local university. 3 of them don't have exercise habits, while others exercise at least twice a week, including swimming, playing volleyball and badminton. 10 of them have experiences in strength training, but only 5 participants still keep the habits.

Setup
The study was conducted in fitness room at local university to better simulate the distracted environment when doing strength training as usual. Participants were asked to wear a MYO on their forearm of habitual hand, standing with the screen placed at the same height as their line of sight.

Task
1RM, repetition maximum, is refer to the maximum amount of weight that one can do in one repetition. Participants were required to execute bicep curl on their habitual hand with the loading of 50% of 1RM, which is lighter than the guidelines suggested for reducing fatigue and increasing security. We also invited professional trainer to assure the posture user perform is correct to avoid any sports injury during the study. For the two conditions, exercising without playing the game and playing with FitBird, they would perform the bicep curl for 8 repetitions in 1 set, and there was a two-minute rest between the two set. The conditions were counter-balanced and assigned to the users.

Procedure
Before the study, a preliminary test was performed to measure participants' 1RM, and the appropriate weight was calculated by online RM calculator. After that, participants would perform the task, and rate entertainment level of each conditions in 10-point Likert Scale (1 representing boring, 10 representing interesting). Finally, participants had chance to experience the whole game and give some feedback about the game. The entire study took about an hour, including executed the tasks, rest between sets, and interview section.

Results
The results of rating in entertainment level by participants are shown in Figure 4. Our system provided significantly higher entertainment level compared with no-game condi-

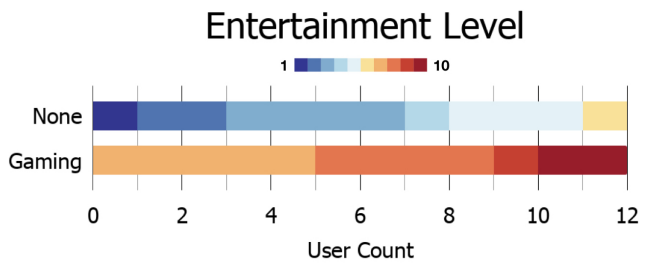

Figure 4: Distribution of entertainment rating on a 10-point scale. In the chart, blue color represents boring and red color represents interesting.

tion (AVG(SD): 8.0(1.13) vs. 3.5(1.51), $p < .01$, $t = -8.28$, by running t-test). FitBird had also won the favor of most participants. 91.7% of participants preferred FitBird interface vs. 8.3% for no gaming feedback.

Qualitative Feedback

We collected some qualitative feedback from participants after they experienced the whole game. They expressed pros and cons of our system, as summarized below.

They found the control of the game intuitive, which helped them keep the tempo without much consideration. (P4, P12) *"Getting coins means high tempo accuracy, and missing coins means I lose the tempo. It's easy to get started,"* said P12. About the game mechanism of collecting coins, it increased players' motivation of exercising through its instant positive feedback. (P5, P10, P11) P11 even said that *"The experience is good especially when I lower down the dumbbell because I think it's the most difficult part and the real-time feedback helps me well. I achieved the muscle control which I thought couldn't finish through the guidance of the game."* The idea of putting a store during rest time won the favorite of players. It made the game more entertaining since they could try different characters and skills. (P1, P3, P4, P6, P8) *"Purchasing in the store give me a sense of accomplishment,"* said P4.

They thought that the diversity of the game was insufficient. (P1, P2, P5, P10) *"The background is too monotonous." "Maybe the background can be replaced to buildings sometime." "Too few skills in the store."* P5 also expressed that *"After buying all items in the store, I will lose my interest."* In the aspect of safety, in order to collect coins, the posture may be incorrect and cause injury. (P10, P11) P11 stated that *"I admit that I will twist my wrist in order to get coins, but I think the injury maybe related to the loading."*

They hoped to increase obvious degree of the hint. (P1, P2, P10) *"Maybe it can remind me when I am close to the finishing line." "MYO vibrate when I hit the pipe."* P1 also indicated that *"Can use the entire screen instead of the character or other game objects to give the hint."* In security mechanism, P5 proposed the idea *"The game can detect improper usage, then displays warnings, and interrupts the game."* Furthermore, they hoped the game can apply to more training exercises. (P9, P11, P12) *"Expect that I can choose the game of other strength training motions,"* said P9.

Conclusion and Future Work

To summarize, FitBird is a system that utilizes wearable orientation sensor to map bicep curl to FlappyBird, which significantly increased the enjoyment of training process. Building on this, we will try to make some variances in fixed tempo to improve entertainment level more. Furthermore, we also will expand our study to evaluate how this system could improve the training effectiveness, such as estimated error rate [8, 7, 9] and tempo accuracy for different training goals (e.g., Hypertrophy, Strength).

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