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Smarter Phones for Healthier Lifestyles: An Adaptive Fitness Game

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Monster & Gold, a context-aware and user-adaptive game, takes into account users' heart rate, age, fitness level, and exercise phase to help them exercise at the optimal intensity to gain cardiovascular benefits.

Sedentary lifestyles are increasingly common, especially in western countries. Such lifestyles are contributing to a dramatic increase in obesity, which can ultimately cause cardiovascular disease, diabetes,[1] and cancer.[2] So, both cardiologists and oncologists recommend regular exercise.

Various devices support exercise both indoors (for example, stationary bikes and treadmills) and outdoors (for example, heart rate monitors and step counters). However, because they provide limited motivational support, they tend to interest only users who are already motivated to exercise.

Combining motivation and exercise, *fitness games* can act as persuasive tools.[3] They can trigger decision-making (for example, a user responds to a game event by promptly performing an exercise). They can also guide users through a process (for example, leading them through an exercise sequence at a particular intensity). Moreover, games that adapt to users can provide tailored information and increase self-efficacy.[4,5]

Mobile phones will likely become a major persuasion platform.[6] They're ubiquitous and well suited to persuade users to exercise regularly. Researchers have already developed fitness applications for mobile devices that train users while they exercise outdoors,[7] let them share information about trails,[8] and enhance motivation through social dynamics.[9]

Unfortunately, most fitness games are for indoor use on PCs or consoles. Consequently, users don't obtain the benefits of open-air environments or the persuasive functionalities of mobile phone applications. Also, many mobile fitness games don't adapt rules to users' fitness levels and current exertion, so users must control the exercise intensity themselves (see the “Related Work in Fitness Games” sidebar).

So, we created Monster & Gold, a context-aware, user-adaptive fitness game for mobile phones. Monster & Gold trains and motivates users to jog outdoors at the correct intensity. Evaluations of the game have led to improved game design and have confirmed the game's beneficial effects on training and motivation.

Related Work in Fitness Games

In the past few years, researchers have devoted increasing attention to outdoor fitness games. For example, Fish'n'Steps maps the number of steps a user takes to the growth and emotional state of a virtual fish in a tank.[1] The fish's appearance changes depending on whether the user's total steps exceeds predefined targets. The fish will be happy if its user has reached his or her daily goal or sad if the user hasn't. The game tries to promote positive social dynamics by showing in the same tank the fish of different users on a team and by displaying competing teams' rankings. A 14-week study with 19 users showed that users' enthusiasm decreased after the first two weeks, but the game helped users establish healthier lifestyles. Fish'n'Steps can count users' steps both indoors and outdoors through a wearable pedometer. However, the game runs on a stationary kiosk, so users can't monitor their progress continuously.

NEAT-o-Race in the NEAT-o-Games suite overcomes this limitation by running on mobile phones.[2] (NEAT stands for *N*on-*e*xercise *A*ctivity *T*hermogenesis.) It captures the amount of energy a user spends (using an accelerometer to measure user motion) and maps it to the speed of an avatar in a virtual race. The user who spends the most energy wins the race and earns points to spend in other games in the suite. Two user evaluations showed that players were engaged by the games and exercised more.

Both Fish'n'Steps and NEAT-o-Race try to estimate how much a user exercises, but they can't distinguish among different kinds of exercise such as walking, cardiofitness, or strength training. UbiFit Garden infers such information from 3D accelerometer and barometer data.[3] It maps different exercise types onto different kinds of flowers that populate a virtual garden on a mobile phone. To have a rich, varied garden, users must perform many varied exercises; the game displays butterflies when users meet particular goals.

Whereas the previous games motivate users primarily through rewarding visualizations and social dynamics, Fitness Adventure relies on an interactive story to motivate people to walk outdoors.[4] The game exploits a GPS device that tracks the user's movement in a town. When the user reaches particular places, the story proceeds, asking the user to find an object to help an old professor in his research.

Unfortunately, none of these games detect users' heart rate and thus can't monitor exertion. To the best of our knowledge, the only mobile fitness game that exploits users' heart rate is 'Ere Be Dragons.[5] The game is also aware of users' location and requires them to move around, keeping their heart rate in a particular range, to discover an uncharted territory. If the heart rate is in the optimal range, the landscape flourishes. If the rate is too low, the landscape becomes impoverished. If the rate is too high, the landscape becomes a dark forest. However, the game can't adapt its rules and dynamically increase or decrease the required exercise's intensity, as various desktop games do.[6,7] Users must control exercise intensity themselves to keep their heart rate in the optimal range to succeed in the game. This is acceptable for experienced users but less suited for untrained people who are unfamiliar with fitness exercise.

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Monster & Gold

To determine the user's heart rate, Monster & Gold processes pulse data, provided by a Bluetooth pulse oximeter clipped on the user's ear. It determines the user's position and speed through the mobile phone's internal GPS.

On the basis of the expert knowledge of a sport physiologist and a professional trainer, the game aims to help users achieve cardiovascular benefits. More precisely, because cardiofitness exercises are aerobic, users should jog at a moderate intensity—a heart rate between 50 and 75 percent of their maximum heart rate (*HRMax*)—for 30 to 50 minutes. Each session should consist of three phases:

- warm-up—5 to 10 minutes at 50 to 60 percent *HRMax*,
- main exercise—20 to 30 minutes at 65 to 75 percent *HRMax*, and
- cooldown—5 to 10 minutes at 50 to 60 percent *HRMax*.

The game should adapt to help users reach the optimal intensity for each exercise phase by continuously measuring heart rate and triggering context-aware game rule adaptations. Moreover, because *HRMax* varies considerably with users, particularly with age, the optimal intensity should vary in a user-adaptive way.

Whereas the previously mentioned durations are suitable for people training regularly, the actual duration should vary by user. For example, less-fit users will likely get tired and potentially reach dangerously high heart rates earlier than fitter users. So, the game should adapt exercise duration by considering users' overall fitness, including how often, how long, and how effectively they've been exercising during the past weeks, as well as their current exertion.

Game Rules

While users jog outdoors, the game displays a one-way virtual trail (see Figure 1) that moves as if they were jogging on it. The distance run in the virtual trail is proportional to the distance run in the real world. The game resembles a GPS navigation system, but instead of real-world points of interest (POIs) such as churches and restaurants, users find virtual monsters, gold, potions, and shields, which last a few seconds, then disappear.

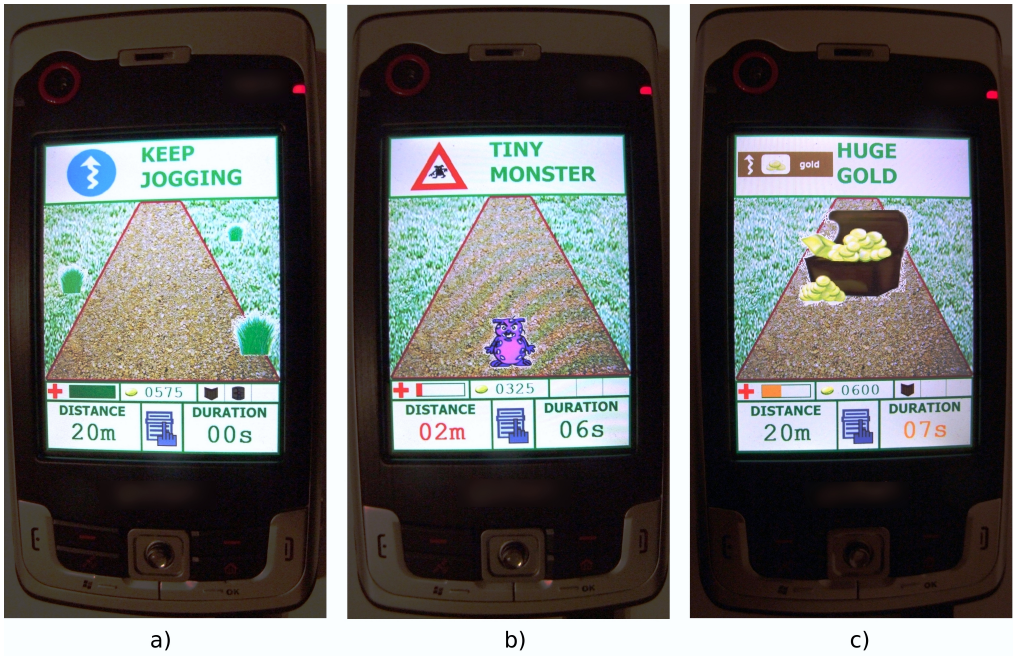


Figure 1. Monster & Gold's GUI during (a) a proceed-on-trail task (PROC), in which users should just keep jogging; (b) a monster reach-or-avoid task (ROAV), in which users should slow down to avoid the monster; and (c) a gold ROAV, in which users should maintain their speed (if optimal) or speed up (if suboptimal) to obtain the treasure chest.

The goal is to score gold points (GPs) without losing health points (HPs). To collect GPs, users must maintain or increase their speed to pick up gold on the virtual trail before the gold disappears. To preserve HPs, users must slow down until monsters vanish, because hitting a monster decreases HPs. Users can recover HPs by picking up potions, and they can repel monsters if they've picked up shields.

POIs are tiny, medium, or huge. Tiny gold consists of a few coins, medium gold consists of three gold bars, and huge gold is a treasure chest. The more gold, the more GPs; the larger the monster, the more HP damage. Likewise, larger potions recover more HPs. Each of the three shields can repel one monster of corresponding size before breaking. Users can own only three shields at a time—one of each type.

The game alternates between two tasks:

- a proceed-on-trail task (PROC), in which users should just keep jogging, and
- a reach-or-avoid task (ROAV), in which they should speed up or slow down to reach or avoid a particular POI.

When a ROAV starts, the POI is at a specific distance from the user and lasts a set amount of time before disappearing. The system determines the POI type, distance, and duration after checking whether the user jogged at the optimal intensity in the last PROC. By considering the user's mean heart rate (*MeanHR*) during the PROC, the user's age to estimate her *HRMax* (using the well-known equation $HRMax = 220 - Age$), and the exercise phase (warm up, main, or cooldown) to determine the heart rate's optimal intensity range (*OptRange*), the game identifies one of three situations: *MeanHR* in *OptRange*, *MeanHR* above *OptRange*, and *MeanHR* below *OptRange*.

If *MeanHR* is in *OptRange*, users who keep jogging at the current speed are rewarded with gold, potions, or shields. More precisely, if the game proposed a potion or a shield more than five minutes ago and *MeanHR* has been in *OptRange* since then, the game proposes a potion to users who have lost HPs or a shield to users with full HPs but without all three shields. The game determines potion and shield size by the number of times users have met the conditions to get a potion or shield—tiny the first time, medium the second, and huge the third and the following times. Thus, the longer users jog safely in *OptRange*, the more HPs they can recover. If users don't meet the conditions to earn a potion or a shield, the game proposes some gold. The closer *MeanHR* is to the mean of *OptRange* (*OptHR*), the more gold. So, users jogging closer to the optimal intensity can score more points.

A *MeanHR* above *OptRange* isn't healthy, so the game chooses a monster for the ROAV to encourage users to slow down. The higher the *MeanHR*, the larger the monster. So, the HP damage users suffer if they don't slow down is proportional to the risk for their heart. Users who repel a monster with a shield suffer no damage even if they don't slow down enough. However, the shield breaks on use, and to pick up a new one, users must jog in *OptRange* for more than five minutes.

Although a *MeanHR* below *OptRange* isn't harmful, users aren't gaining cardiovascular benefits. So, the system gives users a chance to get tiny gold, whose distance and duration are such that they must increase their speed to reach it before it disappears.

The POI's initial distance from a user is proportional to its value or danger, and the game calculates its duration as distance divided by the speed at which users should run to reach *OptHR* (*OptSpeed*). Because speed and heart rate are in a linear relation, varying by user fitness, we can calculate *OptSpeed* as

$$OptSpeed = MeanSpeed\ (OptHR - RestHR)/(MeanHR - RestHR),$$

where *MeanSpeed* is the mean jogging speed in the last PROC and *RestHR* is the user's resting heart rate. The game uses heart rate information to determine POI type, distance, and duration when a ROAV starts. Then, during the ROAV, the game considers only users' speed to determine whether a POI is reached or avoided. We couldn't consider heart rate for this purpose, because the human body takes seconds or even minutes to adjust the heart rate to current exertion.

The game ends if users' HPs are equal to or lower than 0. Such a score means that they exercised at a potentially harmful heart rate several times without promptly reducing the exercise intensity; thus, the game assumes they're overexerted. Users successfully complete the game when they perform all three exercise phases without losing all their HPs. In this case, they've jogged for the recommended amount of time, which varies with their fitness level.

The first time users play, Monster & Gold asks them how long they usually jog in an exercise session. If they never jog or jog less than 15 minutes, each exercise phase lasts only five minutes. Otherwise, the game

lasts as long as their exercise session, dividing the time among the three phases. Then, each week, the game increases or decreases each phase's duration by considering recommended durations for cardiofitness exercise as well as the users' prior performance. In particular, the main phase's duration varies with the number of times users successfully completed it and the number of times they overexerted in the past week.

The GUI

As Figure 1 shows, Monster & Gold's GUI has three parts. The screen's uppermost part shows a road sign and accompanying text. During PROCs (see Figure 1a), the sign is similar to the "go straight" road sign, and text tell users to keep jogging. During a monster ROAV (see Figure 1b), the sign warns about a monster's presence, and the text informs users of its size. Finally, during gold, potion, and shield ROAVs (see Figure 1c), users see a tourist information sign and text indicating the POI's type and size.

The screen's central part shows an isometric representation of the virtual trail, which resembles a road on a GPS navigation system. During PROCs, the road is empty; during ROAVs, POIs appear. Huge POIs (see Figure 1c) are as wide as the trail, whereas medium and tiny ones (see Figure 1b) are about two-thirds and one-third of the trail width, respectively. This lets users immediately associate a POI's size with its value or danger. Size also indicates the POI's distance and user speed—as users proceed on the virtual trail, they get closer to the POIs, which become larger. (See Figure 1b for a tiny, close POI and Figure 1c for a huge, distant one.)

The screen's lowest part consists of two rows providing additional text and graphical information. The top row provides users with HP, GP, and shield information. For instance, in Figure 1a, the user has full HPs, 575 GPs, a tiny shield, and a medium shield. The bottom left displays information about the distance from a POI or the end of a PROC; the bottom right displays information about the POI's duration (the time remaining before it disappears). Information about HPs, distance (in monster ROAVs), and duration (in gold, potion, and shield ROAVs) is green when the value is above one-half its maximum, yellow when it's between one-half and one-quarter, and red when it's under one-quarter. This encourages users to pay attention because they're risking losing the game, hitting a monster, or missing an item.

In the middle of the bottom row, an icon indicates that the mobile phone's Enter button opens a game menu. While jogging, the user can press Enter to pause the game and use the up and down arrows to resume playing, start cooldown, or quit immediately.

Audio

Because joggers often focus on the trail and nearby people and objects, they won't continuously look at the phone. So, the game provides some important information through audio.

As in GPS navigation systems, the game's audio relies on a set of prerecorded spoken words combined in real time to produce sentences such as, "After 20 meters, huge gold lasts seven seconds." For each ROAV, the game announces the POI type, size, distance, and duration. Different sounds indicate particular events. For instance, when users don't slow down enough and are caught by a monster, they hear a sinister laugh. PROC announcements are "jog slower," "keep jogging," and "jog faster," according to users' current heart rate, HRMax, and exercise phase.

During our first user evaluation, some users tried to dodge the monsters or jog in the opposite direction. So, we improved the game by explicitly telling users to slow down when they see a monster. Immediately after the game announces a monster ROAV, it tells users to slow down using a calm voice. If users jog one-half the distance to the monster, the game uses a more anxious tone of voice. Finally, when less than one-quarter of the distance remains, the game shouts.

Because users wear the pulse oximeter clipped to their ear, we didn't want to use devices such as wired or Bluetooth earphones, so we used the mobile phone's speaker. However, this solution can raise privacy concerns. Users might not like that people around them can hear the game's context-aware feedback (for example, when the game shouts at them to slow down). So we plan to replace the pulse oximeter with Bluetooth-based heart-rate belts and deliver audio via earphones, which would also let the game support users by playing their favorite music.[10]

User Evaluations

We performed two evaluations of Monster & Gold with two different groups of users. Before each evaluation, we performed a pilot test with two additional users, which let us refine the game and evaluation design.

Each group consisted of eight males and six females. In the first group, user age ranged from 24 to 49, averaging at 27.71. In the second group, age ranged from 19 to 26, averaging at 22.29. In both groups, users' physical activity frequency varied from one to three times per month to four to five times per week. Only two users from each group played video games almost every day, whereas the others played a few hours per week or less.

The evaluations took place on a paved, flat terrace. Users wore an Alive Technologies pulse oximeter with its main unit in a pocket (see Figure 2a). A hand-worn case held a Windows Mobile phone with an internal Sirf Star III GPS device.

The First Evaluation

Before starting the game, we invited the users to read its four simple introductory screens carefully and to ask the experimenters for clarification if needed. We didn't provide information about game rules because we wanted to see whether the rules, GUI, and audio were enough to train users in exercising effectively by reacting to game events correctly. After the users read the instructions, the game asked them for their age and then started. While users jogged, the game constantly logged their parameters and game events to allow for a quantitative postsession analysis. Afterward, we administered questionnaires to the users, in which they rated statements (such as "The game was easy to understand") by specifying their level of agreement on a Likert scale (1 meaning "strongly disagree" and 5 meaning "strongly agree"), with the option to provide additional feedback.

We asked users to rate the game's understandability, the audio's and graphics' usefulness, the usefulness to understand when to increase and decrease speed, and the game's effect on motivation. We also asked them whether they would jog more often and more willingly if they could always use the game.

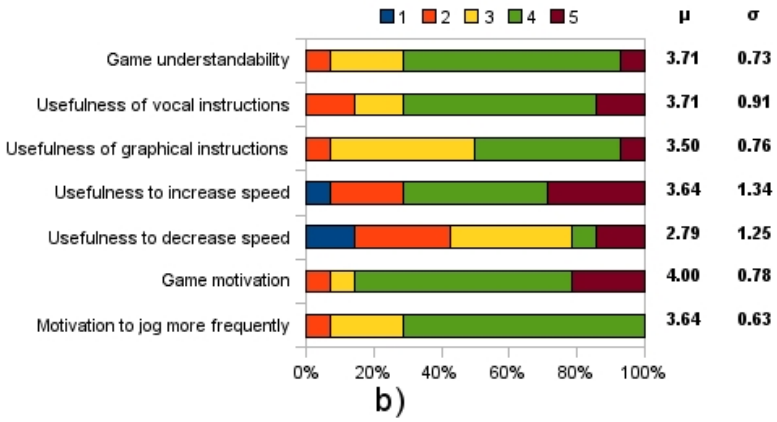
An evaluation session lasted approximately 35 minutes. Users took approximately 10 minutes to fill in profiling information, put on the devices, and read the introductory screens. They took up to 15 minutes to play the game (15 minutes if they managed to complete three phases of five minutes each, less than 15 minutes if they lost all their HPs). They took approximately 10 minutes to provide ratings and suggestions.

Figure 2b shows users' ratings in the first evaluation, as well as their mean (μ) and standard deviation (σ). The average rating for game understandability was 3.71 (σ = 0.73), the average usefulness of audio was 3.71 (σ = 0.91), and the average usefulness of graphics was 3.50 (σ = 0.76). Users understood when they should increase their speed (μ = 3.64, σ = 1.34) but not when they should slow down (μ = 2.79, σ = 1.25). Game logs confirmed these ratings—141 times out of 175, users sped up to get items, whereas they slowed down enough to avoid monsters only 24 out of 85 times.

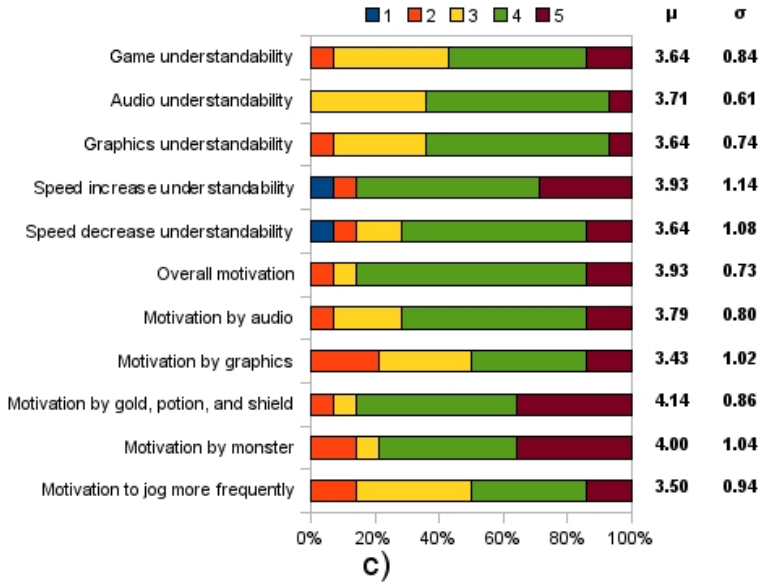
By observing users, analyzing logs, and considering users' suggestions, we concluded that several factors contributed to this situation. A few users didn't understand that monsters inflict damage, so they ran up to them as if they had to fight them. Some tried to avoid monsters by dodging them or running in the opposite direction, and thus didn't slow down enough or at all. Some users didn't consider monster duration. Others slowed down but not enough to avoid the monster because they were overexerted, so the monster lasted a long time.

The game's motivational effect received a positive average rating (μ = 4.00, σ = 0.78); most users reported that they would jog more often and more willingly if they could always use the game (μ = 3.64, σ = 0.63).

a)



b)



c)

Figure 2. Monster & Gold user evaluation: (a) a user wearing the devices, (b) the first evaluation results, and (c) the second evaluation results. The first evaluation's ratings show that users generally agreed with all statements except usefulness to decrease speed. The second evaluation's ratings show that we effectively improved this aspect and also con‡rm positive results about the game's understandability and motivational effect.

The Second Evaluation

To overcome the issues that prevented some users from understanding when to slow down, we changed monster distance and duration to let users gradually slow down, increased the size of duration and distance information on the screen, and added more audio feedback.

After implementing these improvements, we carried out a more extensive evaluation. To separate understandability issues from the game's motivational effect, the evaluation had two parts. In the first, as in the first evaluation, we didn't provide any explanation about game rules. The users played the game for five minutes, then rated its understandability, audio, and graphics. We also asked them whether they understood when they had to jog faster or slower. In the second part, we explained game rules to the users and asked them to play again, then rate the motivation that the game provided, the audio, and the graphics.

We also asked the users to rate how much the gold, potions, and shields motivated them to jog faster and how much the monsters motivated them to slow down. Finally, we asked them whether they would jog more often and more willingly if they could always use the game and gave them the option of providing additional feedback.

An evaluation session lasted approximately 50 minutes. Users spent approximately 10 minutes to fill in profiling information, put on the devices, and read the introductory screens. They took 5 minutes to play the game for the first time. They took approximately 10 minutes to provide ratings about understandability and to listen to explanations about the game rules. They then took up to 15 minutes to play the game for the second time and approximately 10 minutes to rate statements concerning motivation and provide suggestions.

Figure 2c shows the results. The average rating for game understandability was 3.64 (σ = 0.84), the average for audio understandability was 3.71 (σ = 0.61), and the average for graphics understandability was 3.64 (σ = 0.74). Users reported that the game helped them understand when they should jog faster (μ = 3.93, σ = 1.14) as well as slower (μ = 3.64, σ = 1.08). Game logs about evaluation's first part, in which users weren't aware of game rules, confirmed these positive results: users sped up to obtain 53 out of 75 items and slowed down enough to avoid 15 out of 23 monsters.

So, the game effectively trained users in correcting their jogging speed and reaching the optimal intensity 69.4 percent of the time. Most users in the remaining 30.6 percent sped up or slowed down, but not enough to get an item or avoid a monster. Only one user (who rated 1 for understandability of speed increase and decrease) didn't understand that the game was telling him to speed up and slow down, and seemed to ignore most items and monsters.

The rating for motivation was 3.93 (σ = 0.73). In particular, gold, potions, and shields motivated users to speed up (μ = 4.14, σ = 0.86), and monsters motivated users to slow down (μ = 4.00, σ = 1.04). Motivation ratings for audio and graphics were 3.79 (σ = 0.80) and 3.43 (σ = 1.02), respectively. Half the users also reported they would jog more often and more willingly if they could always use the game (μ = 3.50, σ = 0.94).

Regarding neutral or negative ratings, some users commented that they thought the game could be repetitive if played several times. Indeed, some users suggested that we implement different difficulty levels by possibly varying the POI design among levels and by proposing different task durations and distances. Users also suggested that we use additional or alternative feedback sounds that they considered more effective (for instance, a bouncing noise when a shield repels a monster) and we provide additional information on the screen, such as elapsed time since they began jogging.

Our evaluations indicate that the improved version motivates and trains users in jogging for cardiovascular exercise. We're focusing on improving the game by enhancing user-adaptive features. For example, we'll consider more details about users, such as weight and training goals. We'll also consider user performance details such as calories burned per session and long-term variations in the ratio of jogging speed to heart rate. Such an approach should provide each user with a tailored, fun training plan.

Such training plans, combined with long-term adaptations of game difficulty, should help provide motivation over time. We'll also try to promote positive social dynamics by letting users share game scores on the Web. Testing these enhancements' long-term effects will require longitudinal evaluations.

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