TripleBeat: Enhancing Exercise Performance with Persuasion

Rodrigo de Oliveira
Institute of Computing, University of Campinas
Campinas, Brazil
oliveira@ic.unicamp.br

Nuria Oliver
Microsoft Research & Telefónica Research
Redmond, WA & Barcelona, Spain
nuriao@tid.es

ABSTRACT

We present TripleBeat, a mobile phone based system that assists runners in achieving predefined exercise goals via musical feedback and two persuasive techniques: a glanceable interface for increased personal awareness and a virtual competition. TripleBeat is based on a previous system named MPTrain. First, we describe TripleBeat's hardware and software, emphasizing how it differs from its predecessor MPTrain. Then, we present the results of a runner study with 10 runners. The study compared the runners efficacy and enjoyment in achieving predefined workout goals when running with MPTrain and TripleBeat. The conclusions from the study include: (1) significantly higher efficacy and enjoyment with TripleBeat, and (2) a unanimous preference for TripleBeat over MPTrain. The glanceable interface and the virtual competition are the two main reasons for the improvements in the running experience. We believe that systems like TripleBeat will play an important role in enhancing the exercise experience and in assisting users towards more active lifestyles.

Categories and Subject Descriptors

H.5.2 [**Information Interfaces and Presentation**]: User Interfaces; D.2.2 [**Software Engineering**]: User Interfaces; I.5.4 [**Pattern Recognition**]: Applications; K.8.m [**Personal Computing**]: Miscellaneous

General Terms

Algorithms, Design, Experimentation, Human Factors, Verification.

1. INTRODUCTION

A sedentary lifestyle is a major underlying cause of death, disease, and disability. Unfortunately, levels of inactivity are high in virtually all developed and developing countries. It has been estimated that the proportion of adults who are sedentary or nearly so ranges from 60 to 85% [18].

According to the World Health Organization (WHO) [18], approximately 2 million deaths every year are attributable to physical inactivity. Physical inactivity increases all causes of mortality, doubles the risk of cardiovascular disease, type II diabetes, and obesity [4, 8]. It also increases the risks of colon and breast cancer, high blood pressure, lipid disorders, osteoporosis, depression and anxiety.

Fortunately, technology can play a very important role in promoting and supporting an active lifestyle, *i.e.* a lifestyle that incorporates physical activities, sports and healthy life choices [1, 10]. Both sedentary and active individuals could benefit from personalized and guided workouts, performance monitoring, action-directed instructions and competition as an additional motivating factor.

In this paper we present TripleBeat, a mobile phone based system that encourages users to achieve specific exercise goals. TripleBeat allows users to establish healthy cardiovascular goals from high-level desires (*e.g.* lose fat); it provides real-time musical feedback that guides users during their workout; it creates a virtual competition to further motivate users, and it displays relevant information and recommendations for action in an easy-to-understand glanceable interface.

The paper is structured as follows: First, we review the most relevant previous work in the area of persuasive interfaces for exercise systems. Then, we describe the software and hardware architectures of the TripleBeat system. TripleBeat's competition and glanceable interface are presented in the next two sections, followed by the runner study that we carried out to validate the system. Finally, we present our conclusions and outline our future directions of research.

2. RELATED WORK

Motivation is a key element when developing health monitoring systems, as these systems typically assist users in changing their behavior to maintain or improve their health. While some people engage in regular physical activity without the need of external incentives, we believe that a majority of users would benefit from a motivational tool to support and encourage an active lifestyle.

Fogg's work [9] has described *persuasive technologies* as computer-based tools that persuade people to change their behavior. Some of the strategies presented in his book include self-monitoring, computer-originated recommendations and tailoring.

Additional research on wearable physiological monitoring systems has revealed an array of techniques to motivate users to follow a desired workout routine. In particular, we would highlight four distinct methods for persuading users:

2.1 Personal Awareness

Several commercial products[1] and research prototypes have been developed that improve the jogging experience with information about the user's performance and workout goals. In such systems, current physiological and activity data collected on-the-fly using accelerometers, heart-rate monitors, GPS sensors, *etc.* is captured and presented to the user in a general purpose system [2], or targeted to specific groups, such as children [12] or women [21, 6, 11].

2.2 Social Factors

Social factors are a strong motivating element. Previous research has supported the value of providing real-time information about the performance of other users who are engaged or have been engaged in the same activity. Maitland *et al.* [13] proposed using a mobile phone as a health promotion tool. Their prototype application tracks the daily exercise activities of people carrying phones – using fluctuation in signal strength. They have validated their system with a short-term user study where participants shared activity information amongst groups of friends, and found that awareness encouraged reflection on, and increased motivation for, daily activity. Brien and Mueller concluded in [16] that a jogging experience supporting a conversation between remote partners during the workout was desirable and motivating. Other systems support interaction with a group of friends or peers via instant messaging after a workout session [20]. Vorderer and Hartmann could empirically demonstrate in [22] that competition is the major factor in explaining video game enjoyment. Hence, the big popularity of community-based gaming environments such as XBOX live. Social pressure is so relevant as an external motivational factor that users lose their interest in a competition that is easy to cheat [20].

2.3 Enjoyable Interaction

Other systems exploit the benefits of music on exercise. Reddy *et al.* tackle the problem of consciously selecting songs [19] while recent approaches go further and automatically determine the playlist according to the user's workout goals and physiological responses during the workout [17, 3]. These systems can also adapt the song's tempo to adjust the runner's pace. In [5], Buttussi et al. develop an appealing 3D virtual trainer to monitor the user's position during physical activity in an outdoor fitness trail. Finally, other game related approaches try to bring indoor exercises to a virtual environment [14].

2.4 Unobtrusive/intuitive Notification

A big challenge in wearable exercise and activity monitoring systems is the need to provide the user with relevant information without interrupting or disturbing their workout or current activity. One example of unobstrusive notification is the use of sound spatialization to make it easier to identify the position of the partner while jogging apart [15].

TripleBeat's approach for persuading users includes: (1) *personal awareness* by allowing users to monitor their heart-rate and pace in real-time, (2) *computer-originated recommendations* by providing real-time feedback on what needs to be done to achieve specific workout goals, (3) *tailoring* by learning from past interactions to provide a personalized experience, (4) *social pressure* by establishing a virtual competition with other runners, (5) *enjoyable interaction* via musical feedback and (6) *unobtrusive notifications* via a glanceable interface.

Given all previous work, the main contributions of the TripleBeat system presented in this paper are: (1) a glanceable interface to provide real-time feedback to the user on workout performance and easy-to-understand recommendations on what should be done to improve performance; (2) a virtual competition with other runners that are either selected by the user or automatically selected by the system to further motivate the user; (3) an automatically proposed optimal workout schedule, based on high-level goals; (4) a score function to quantitatively evaluate the user's performance; and (5) a runner study with 10 runners to validate the system.

3. SYSTEM DESCRIPTION

TripleBeat's software and hardware architectures are based on MPTrain's architecture [17]. MPTrain is a mobile phone based system that takes advantage of the influence of music in exercise performance, enabling users to more easily achieve their exercise goals. MPTrain is designed as a mobile and personal system that users wear while exercising (jogging, walking or running). Before an exercise session, MPTrain's user interface allows the user to enter a desired exercise pattern (in terms of desired heart-rate over time). It then constantly monitors the user's physiology via a heart-rate monitor (heart-rate in beats per minute) and movement via a 3-axis accelerometer (steps per minute). Based on the current heart-rate and pace data, MPTrain selects and plays music with specific features that will encourage the user to speed up, slow down or keep the pace to be on track with his/her exercise goals.

Figure 1 depicts the architecture of the TripleBeat system. The left side of the Figure shows a block diagram of the sensing module with its main components: (1) a set of physiological and environmental sensors (electrocardiogram -ECG- and 3-axis accelerometer), (2) a processing board that receives and digitizes the raw sensor signals and (3) a Bluetooth transmitter to get the processed data and send it wiresly to the Mobile Computing Device (cell phone, PDA, *etc.*). The right side of the Figure depicts a block diagram of the Mobile Computing Module with its relevant components. The Bluetooth Receiver gets the sensed data and makes it available to TripleBeat's software, which then processes the raw physiological and acceleration data to extract the user's heart-rate and speed[2]. After logging this and other relevant information (*e.g.* song being played, percentage of time inside the training zone, *etc.*), the software selects and plays a song from the user's Digital Music Library (DML) that would guide the user towards following his/her desired workout: a song with faster tempo than the current one will be chosen if the user needs to speed up, with slower tempo if the user needs to slow down and with similar tempo if the user needs to keep the current pace.

TripleBeat adds new functionality to the basic MPTrain

[1]iPod (`http://ipod.com`), Polar (`http://polarusa.com`).

[2]We refer the reader to [17] for a detailed description of the heart-rate and pace extraction algorithms.

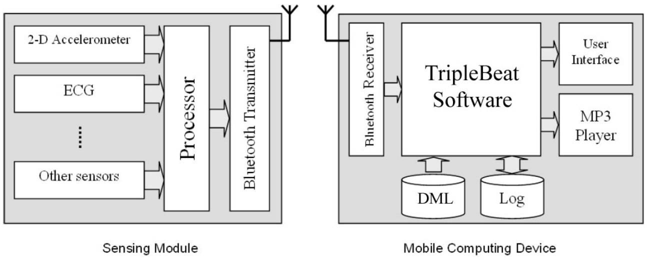

Figure 1: MPTrain/TripleBeat architecture.

system, as it will be described in detail in the next sections. TripleBeat innovations include: (1) a proposed workout schedule based on high-level goals (*e.g.* lose fewer calories but more fat, improve cardiovascular/respiratory health, *etc.*), (2) a glanceable interface that allows users have instant information about their performance and feedback on what they should do to keep their heart-rate inside the proposed *training zone*, (3) a virtual competition with other runners, and (4) a novel score function to quantify the user's performance.

4. PERSUASIVE TECHNIQUES

In this section, we focus on two of TripleBeat's persuasive techniques to motivate runners in achieving their exercise goals: (1) a virtual competition with other runners and (2) real-time personal awareness via a glanceable interface.

Before doing so, we shall provide some background information in cardiovascular training.

4.0.1 Heart-rate Training Zones

Measuring heart-rate during a workout is one of the primary indicators in determining the intensity level at which the heart is working. The heart-rate reserve formula is one of the most effective and widely used methods to calculate the desired training heart-rate. The *heart-rate reserve*, $HR_{reserve}$, is the difference between the user's *maximum heart-rate*, HR_{max}, and his/her *resting heart-rate*, HR_{rest}, where HR_{max} is typically given by $HR_{max} = 220 - Age$. TripleBeat's exercise goals are defined as percentage of the user's *heart-rate reserve*, as given by the Karvonen formula: $HR_{target} = (ZonePercentage \times HR_{reserve}) + HR_{rest}$.

Where and how often the users place themselves in the heart-rate reserve will determine the fitness improvements. With the user's HR_{max} as the reference point, zones in 10% increments help define more precisely the benefits that will be achieved during a workout [7]. Table 1 summarizes the procedures and benefits when exercising in the different training zones.

Based on the user's personal information and high-level goals, TripleBeat will automatically select the ideal training zone for the user.

4.1 Competition as a Motivating Factor

We are particularly interested in exploiting social factors, such as the effect of social pressure and support to assist users in achieving a predefined workout goal. The hypothesis is that users will be more motivated to achieve their goals when they are competing against other users. Therefore, TripleBeat implements a competition between the user and other runners. The opponents can be fictional runners, real

Table 1: Training zones and their respective procedures and benefits

Zone	Procedures and Benefits
Healthy ($50 - 60\% HR_{max}$)	Walk: Decrease body fat, blood pressure and cholesterol.
Temperate ($60 - 70\% HR_{max}$)	Slow jog: Same benefits as healthy zone, but burns more calories.
Aerobic ($70 - 80\% HR_{max}$)	Steady jog: Improves cardiovascular/ respiratory system and increases heart's size/strength.
Anaerobic ($80 - 90\% HR_{max}$)	"Burning" run: Same benefits as aerobic, but burns more calories (less fat).
Maximal/Red Zone ($90 - 100\% HR_{max}$)	Full out run: Used in interval training.

runners that have previously run with the system, or the actual user on past runs. The competition is defined by *how well users achieve their predefined goals*, and not by who runs faster, burns more calories or arrives earlier to a particular landmark. The goal is to encourage users to achieve their exercise goals in a healthy manner. TripleBeat will reward the user when his/her heart-rate stays as close as possible to the proposed target heart-rate.

There are two key elements in establishing an engaging and fair competition: the evaluation criterion and the selection of the competitors. We describe next these two aspects of the TripleBeat system.

4.1.1 Performance Score Function

TripleBeat proposes a novel *score function* that summarizes how well users achieve their predefined exercise goals. We believe that the design of the score function is critical in effectively motivating users to follow their particular workouts.

Imposing a competition that pushes participants with different exercise goals to their limits is not just inaccurate, but also dangerous. Winning a video game match does not typically involve getting injuries, but in the context of the TripleBeat system, the consequences of an excess may be dangerous. Therefore, TripleBeat includes a score function that is safe, fair and easy to understand.

The score function should quantify how well users follow their desired workout. The proposed score function is proportional to the amount of time a certain runner spent on his/her training zone during the workout. Equation 1 presents a cumulative measure for this score:

$$ZoneAccur(x) = \frac{SecondsInZone}{x} \quad (1)$$

where x is the duration (in seconds) of the workout.

Although this measure gives a good idea about the runner's performance, it lacks information on how close the runner's heart rate was to the target heart rate. In other words, considering two competitors spending the same amount of time inside their target zone, it is impossible to discern which one was doing a better job by just computing this measure. Therefore, we built an additional function, named

Heart Rate Accuracy (HR_{Accur}), given by Equation 2.

$$HR_{Accur}(x) = \frac{|fac(x) - lowest|}{|HR_{target} - lowest|} \quad (2)$$

where

$$fac(HR) = HR_{target} + \quad (3)$$

$$\frac{1.5^{-\frac{|HR_{target}-HR|}{\sqrt{2\times HR_{target}}}} - 1.5^{\frac{|HR_{target}-HR|}{\sqrt{2\times HR_{target}}}}}{2}, \quad (4)$$

$$lowest = min(fac(HR_{rest}), fac(HR_{max})) \quad (5)$$

and where HR_{target} is the target heart rate and HR is the current heart rate.

Note how HR_{Accur} has its highest value on the HR_{target} and falls as an hyperbolic function, reaching zero when $HR = HR_{rest}$. We chose the hyperbolic function to benefit those that stay closer to the HR_{target} and penalize those that deviate from it. The function has similar properties to the secant function $sech(x) = \frac{2}{e^x+e^{-x}}$, but we did some adjustments to make it suitable to our purposes.

The final score is the linear combination of HR_{Accur} and $ZoneAccur$, given by:

$$Score(x) = 0.5 \times HR_{Accur}(x) + 0.5 \times ZoneAccur(x) \quad (6)$$

To visually illustrate the behavior of the score function, Figure 2 depicts a graph of the heart rate, sampled every second, from a hypothetical runner with a constant heart rate acceleration of 1 beat/second. In this example, the heart rate starts at the runner's resting heart rate ($HR_{rest} = 45$ beats per minute or BPM) and ends at his/her maximum heart rate ($HR_{max} = 195$ BPM). Note that the two functions that constitute the score, $ZoneAccur$ and HR_{Accur}, are normalized by the runner's HR_{target} of 143 BPM to ease visualization.

TripleBeat's competition is based on how well users achieve their workout goals as it is quantified by the score function defined above. The system computes this score function every second, which enables real-time evaluation of the user's position with respect to the competitors.

4.1.2 Real-time Competition and Opponents Selection

The second element in the competition is the selection of the opponents. This is a key element in characterizing the competition and will be a determining factor in motivating users via social pressure.

TripleBeat has access to a database of runners that are registered with the system. In its current implementation and for simplicity reasons, the database is locally stored on the phone.

TripleBeat gives the user two options to select their competitors: (1) *manual selection*, where the user manually selects who they want to compete against; and (2) *automatic selection*, where TripleBeat automatically selects the opponents. In the latter case, TripleBeat will select the registered users whose scores are the closest to that of the current user (using a variation of the k-nearest neighbor algorithm). In addition, TripleBeat will always provide a challenge to the user, meaning that it will select at least one competitor with better performance than that of the user. Following, there is a simplified pseudo-code version of the automatic opponent selection algorithm.

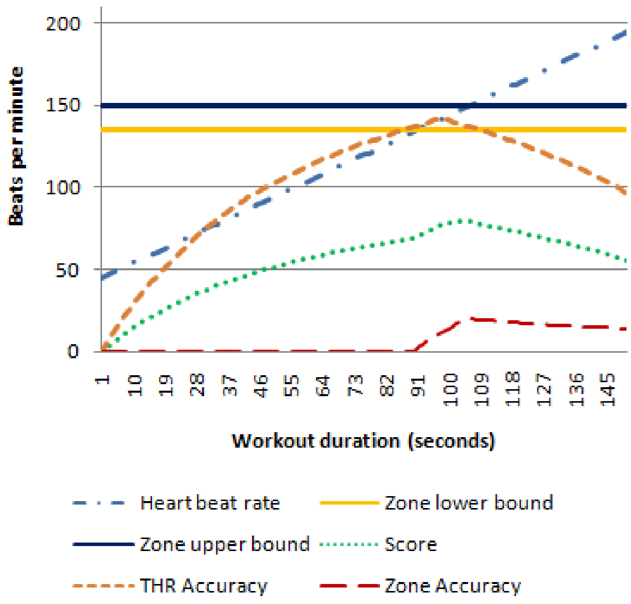

Figure 2: Score function computed for a hypothetical runner with a constant heart rate acceleration of 1 beat/second. Note how the cumulative score increases as the runner's heart rate approaches the target heart rate band and decreases as the heart rate leaves the target heart rate band. The target heart rate band is defined as the +/−5% band around the target heart rate (from 136 to 150 BPM in the example).

```
Opponents* ChooseOpponents(user, *opponents, toChoose) {
  vector S = score differences between user and opponents
  vector S_ABS = absolute values of S
  sort vector S
  sort vector S_ABS

  // find the closest better opponent to the user
  int C = index of smallest positive value from S

  // load (toChoose-1) closest opponents to the user
  for (i = 0; i < toChoose - 1; i++)
    vector OPP[i] = opponent indexed by S_ABS[i]

  // load the remaining opponent
  if OPP has only opponents with lower score than the user's
    OPP.Append(opponent indexed by S[C])
  else
    OPP.Append(opponent indexed by S_ABS[toChoose-1])

  return &OPP;
}
```

4.2 Persuasion with a Glanceable Interface

TripleBeat is designed to provide real-time feedback to the user, both auditory via the automatically selected music and visual by means of its graphical interface. The use of a mobile device presents the additional challenge of having a very small display that is typically viewed while in motion. There is no universal solution to the problem of presenting the user with easy-to-understand, real-time physiological and pace information on a small display. In TripleBeat, we have developed a glanceable interface that would enable quick intake of visual information with low cognitive effort. The two motivating factors are: (1) the need to present the physiological and pace data, together with the system's recommendation of action, in an intelligible manner, and (2) the constraint of a small display that is going to be looked at while running outdoors.

Figure 3 displays two screenshots of TripleBeat's glanceable interface as seen during a workout session. The interface aims to give accurate real-time information (every second) about the runners heart rate and pace, and a recommendation on what should be done to maximize the running score. The interface needs to clearly inform the user about the need to increase, decrease or maintain the current pace to remain in the proposed training zone. Additionally, the interface presents information about the competition, including the user's current position and the difference in score to the next and previous opponents. Finally, the bottom part of the interface displays, from left to right and top to bottom, the total number of calories burned, the total time of workout and the name of the song being played.

Figure 3: TripleBeat's glanceable interface. The screen on the left uses red color semantics to inform the user that his/her current heart rate is out of the suggested training zone. The plus sign indicates the need to speed up the heart rate by 6 BPM. The screen on the right illustrates the case where the user's heart rate is inside the target zone –hence the green background color–. In this case, TripleBeat displays the actual heart rate, as there is no need to increase or decrease the heart rate. The user's position in the competition is shown on the right side of the interface. Right below, there are the names and distance in score to the opponents. The lower part of the interface displays, from left to right, the total number of calories burned and the total time of workout. Finally, the name of the song currently being played is shown at the very bottom together with a progress bar underneath.

5. EXPERIMENTAL RESULTS

To validate the TripleBeat prototype, we conducted a user study with 10 runners. The goals of the study were to both evaluate the persuasive techniques proposed in this paper, and the TripleBeat system as a final product. Next, we shall summarize materials and methods applied and discuss the results and conclusions of the runner study.

5.1 Material

5.1.1 Hardware and Software

All participants used the same hardware and software. The hardware consisted of an AliveTec ECG and acceleration monitor attached to either a leather chestband that contained the 2-lead ECG sensors, or to 2 adhesive ECG electrodes by Ambu which are designed for ambulatory recording. The sensors were wirelessly connected via Bluetooth to an Audiovox SMT5600 or a Cingular 2125 mobile phone[3]running the MPTrain / TripleBeat software. The DML stored in the phone had about 70 songs of different genres and tempos (see [17] for more details on the DML).

5.1.2 Participants

From an initial pool of 20 participants who registered for the study, 10 (8 men and 2 women) were able to finish all the required running sessions and fill out the correspondent questionnaires. They were recruited by email advertisement to several running groups within a big corporation. Their ages ranged from 25 to 41, with an average of 33 years. Except for one participant, all others were regular runners of various levels of expertise and fitness. All of them were in good health.

Before their first run, participants filled out an online pre-run questionnaire about their demographic information, running habits and general health. We shall present next a summary of their answers to the pre-run questionnaire.

The 9 regular runners used to run 4 times per week, for an average of 56 minutes each time. Three of them ran with other partners, mostly because it increased their motivation to finish the workout. The remaining six who did not run with other people pointed out two main reasons: difficulty in matching their schedules (2 participants) and coordinating the same workout (4 participants).

It is interesting to note that only 1 participant used to carry his cell phone while running. Some of the reasons mentioned for not taking the mobile phone include not having a place where to put it, worrying about it getting damaged, not being able to talk and run, avoiding being disturbed and not being able to play music with it. On the other hand, 5 participants listened to music while running with a portable media player. The main reasons for listening to music were to pass time faster (3 participants) and to better focus on the workout (2 participants). Most runners who did not listen to music while exercising pointed out that they preferred a quiet run with less distractions.

With respect to heart rate monitoring, 6 runners used a heart rate monitor at least once while running, but only 2 wore one regularly. The main reasons to monitor heart rate were the benefits of being aware of the training zone and the ability to pace the effort during the run. The reasons given for not wearing it include the perception of not adding much value to the run and the inconvenience of having to wear a chestband to be able to monitor heart rate. Finally, 4 runners were familiar with the MPTrain system as they had participated in a previous MPTrain runner study that had taken place in the Spring of 2006.

[3]Due to an accident where the phone broke, we had to switch phones from the Audiovox to the Cingular. As the latter has higher screen resolution, the software was adapted accordingly.

5.2 Methodology

5.2.1 Assays, Treatments and Procedures

We have already validated the impact of musical feedback to assist runners in their workout in [17]. Therefore, this study was dedicated to compare TripleBeat with MPTrain. In particular, we wanted to: (1) compare TripleBeat's efficacy in assisting runners to achieve a predefined workout when compared to MPTrain; (2) evaluate TripleBeat's enjoyment of use when compared to MPTrain's and (3) validate TripleBeat's persuasive techniques. Thus, two measures were quantitatively evaluated in the study:

1. *Efficacy:* This measure evaluates the success in keeping the runner's heart rate inside the proposed training zone. We evaluated the efficacy of the system in two ways: (1) *objectively:* the runners' performance was automatically computed as the percentage of time spent running inside the target zone[4]; and (2) *subjectively:* via the self-reported efficacy on a post-run questionnaire after each of the running sessions;

2. *Enjoyment:* This measure was obtained from a subjective evaluation via a post-run questionnaire after each of the running sessions.

Hence, the study consisted of two assays:

1. *MPTrain vs TripleBeat*: The first assay evaluated the differences in efficacy and enjoyment between the runner's interaction with MPTrain and TripleBeat.

2. *Competition vs No Competition*: The second assay evaluated the competition feature in the TripleBeat system. Thus, we compared the two measures of efficacy and enjoyment in TripleBeat with and without competition.

In order to carry out these assays, we asked participants to take part in 3 to 4 outdoor running sessions. Each session had 3 phases: warm up for 3 minutes, workout for 40 minutes and cool down for 3 minutes. Physiological and pace data were recorded and analyzed only during the workout phase. Each session corresponded to one of the following running conditions:

1. *MPTrain Baseline:* TripleBeat needs to analyze first a database of potential competitors before it can select the opponents for a given user and perform the real-time competition. Therefore, all participants had to do their first run with the MPTrain interface in order to collect their baseline data. However, this procedure could spoil a fair comparison between the MPTrain and TripleBeat systems with respect to the first assay: every runner would have had their first experience with the MPTrain system, thus biasing the results. This potential bias was fixed with an additional MPTrain run, and an appropriate methodology for selecting the data to analyse, as explained below.

2. *TripleBeat (No Competition):* 50% of the participants did their second run using TripleBeat's interface (Figure 3) without the competition information. The next step for this group of runners was a third run using TripleBeat in competition mode.

3. *TripleBeat (Competition):* Likewise, the other 50% of the participants did their second run using TripleBeat's interface in competition mode and the third run without the competition. When running in competition mode, participants were given the choice of either manually selecting their opponents or letting the system automatically select them based on their best previous run.

4. *MPTrain Last Run:* This session was created to address the bias issue raised by the *MPTrain Baseline* session. In order to generate the data needed for the opponents choice algorithm and still allow comparisons between MPTrain and TripleBeat, we asked 50% of the participants to do a last run with MPTrain. Therefore, we split the participant population in two halves: For first half, we used data from their *first* interaction with the systems. In the case of the second half, we used data from their *last* interaction with the systems. Therefore, this analysis procedure allowed a fair comparison on the first assay while still supporting the second assay.

Using these four sessions, we created four running groups, as depicted in Table 2. The first assay compared MPTrain and TripleBeat's interfaces by considering only data from the *first* interaction with the systems on groups 1 and 2[5], and the *last* interaction for groups 3 and 4[6]. In the case of the second assay, all values collected with TripleBeat could be used as 50% of the runners started in competition mode (groups 2 and 3) and the remaining 50% started without it (groups 1 and 4).

Before each running session, each participant was given instructions and a demonstration on how to use the system. The goal of the runners during the study was emphasized during this setup period: They were asked to keep their heart rate as close as possible to the target heart rate that corresponded to their workout goal.

The duration of the workout and the number of opponents were fixed during the experiment to 40 minutes and 2 opponents respectively. Runners could, however, select the *intensity* of the workout that they wanted to do, ranging from an active walk or intensity level 1 (55% of $HR_{reserve}$) to cardio/strength gain or intensity level 4 (85% of $HR_{reserve}$). The participants in the study covered all levels of intensity: Intensities 1 through 3 were chosen by 20% of the runners each, and intensity 4 was selected by the remaining 40%. Once runners chose an intensity level, they were required to run at that intensity level in all their running sessions.

Figure 4 shows an example of the setup screens shown to one participant. Note that the right-most screen in the Figure was only shown during the competition session.

As soon as the participants became confident on how to use the system (typically in about 10 minutes), they were

[4] Note that this is the second component of the score function given by Equation 6. We used the score function to select the opponents and perform the competition, but the efficacy in the study was measured by the more common measure of $ZoneAccur$.

[5] Note that the 3^{rd} run in these groups was ignored to avoid bias, as previously explained.

[6] Likewise, the 1^{st} and 2^{nd} runs in these groups were ignored.

Table 2: Experiment sample divided into four groups to allow comparisons between MPTrain and TripleBeat on the first assay and TripleBeat with competition and TripleBeat without competition on the second assay.

Group	Subjects	Running Sequence
Group 1	1 and 2	1) MPTrain
		2) TripleBeat (no competition)
		3) TripleBeat (competition)
Group 2	3, 4 and 5	1) MPTrain
		2) TripleBeat (competition)
		3) TripleBeat (no competition)
Group 3	6 and 7	1) MPTrain (just for baseline)
		2) TripleBeat (competition)
		3) TripleBeat (no competition)
		4) MPTrain
Group 4	8, 9 and 10	1) MPTrain (just for baseline)
		2) TripleBeat (no competition)
		3) TripleBeat (competition)
		4) MPTrain

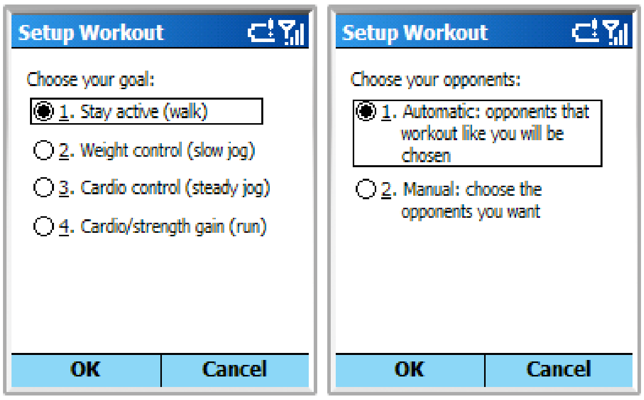

Figure 4: Setup workout interface. On this example, the user selects to keep active by just walking and on the second screen lets the system choose the most adequate opponents to his/her profile.

sent off for a 46 minute exercise session. All runners were asked to run on a flat route and to follow exactly the same route on each of their runs.

5.2.2 *Statistical Analysis*

Two assays (efficacy and enjoyment) were performed with two treatments each. They were submitted to a randomized experimental design with 10 subjects. The treatments for the first assay were MPTrain and TripleBeat. The treatments for the second assay were TripleBeat with and without competition.

The statistical analysis was carried out using the Statistical Analysis System (SAS)[7] including an analysis of variance (ANOVA). Since the runners performance was evaluated by the percentage of time spent running inside the proposed training zone, the variate was transformed using *arcsin* of the square root of the percentages, a standard statistical procedure applied whenever the residues do not follow a normal distribution.

[7] http://v8doc.sas.com/sashtml/stat

5.3 Results and Discussion

We shall present next the results in evaluating the *efficacy* and *enjoyment* of the MPTrain and TripleBeat systems.

Table 3 contains the percentage of time spent by each participant inside their training zone during each workout session and Table 4 contains the corresponding information for each of the analysis groups.

5.3.1 *First Assay: MPTrain vs TripleBeat*

First, we shall focus on comparing MPTrain with TripleBeat. The average percentage of time inside the training zone was 57.1% with MPTrain and 82.8% with TripleBeat ($P < 0.05; N = 10$). Thus, the TripleBeat system was *significantly more effective* than MPTrain in keeping runners inside their desired training zone. Additionally, Table 4 shows that 100% of the subjects spent more time inside the proposed training zone when running with TripleBeat than with MPTrain.

Table 3: Percentage of the workout time spent inside their training zones during each session.

Subjects	MPTrain (first run)	MPTrain (last run)	TripleBeat (no compet.)	TripleBeat (compet.)
1	33.2%	—	49.3%	**99.9%**
2	6.2%	—	**68.3%**	29.6%
3	86.2%	—	**100%**	**100%**
4	5.4%	—	19.3%	**50.2%**
5	85.1%	—	**100%**	**100%**
6	75.4%	25.5%	61.1%	**86.9%**
7	93.2%	94.2%	**99.6%**	89.5%
8	80.5%	71.0%	83.2%	**99.7%**
9	18.5%	73.7%	94.2%	**100%**
10	69.8%	90.7%	96.4%	**99.7%**

Table 4: Comparison between the percentage of time spent inside the training zones with the MPTrain and TripleBeat interfaces.

Group	Subjects	MPTrain	TripleBeat
Group 1	Subject 1	33.2%	**49.3%**
	Subject 2	6.2%	**68.3%**
Group 2	Subject 3	86.2%	**100%**
	Subject 4	5.4%	**50.2%**
	Subject 5	85.1%	**100%**
Group 3	Subject 6	25.5%	**61.1%**
	Subject 7	94.2%	**99.6%**
Group 4	Subject 8	71.0%	**99.7%**
	Subject 9	73.7%	**100%**
	Subject 10	90.7%	**99.7%**
Average*		57.1%	**82.8%**

* *MPTrain* $<$ *TripleBeat* ($P < 0.05; N = 10$)

With respect to the subjective evaluation of efficacy, participants were asked if their experience with each of the systems was more effective, about the same or less effective than all the runs they had in the past. MPTrain was considered more effective by 4 subjects while TripleBeat in competition mode doubled this preference (8 participants). This significant difference in the perception of efficacy corroborates the performance evaluation results.

Therefore, we shall conclude that *TripleBeat was more effective than MPTrain in assisting runners to achieve their exercise goal*.

Figure 5 summarizes the main reasons as pointed out by the participants for the perceived efficacy. The left of the Figure contains the information for the MPTrain system, where musical feedback and heart rate graph monitor were the most important reasons for efficacy. On the other hand, the primary reason for TripleBeat's efficacy was its **glanceable interface** (8 subjects).

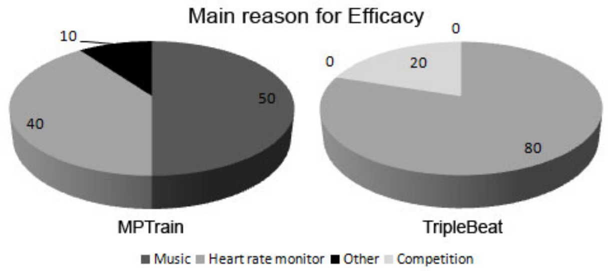

Figure 5: Main reasons for efficacy on MPTrain and TripleBeat in percentage of subjects.

Finally, with respect to perceived enjoyment, participants were asked to rate their experience as being more enjoyable, about the same or less enjoyable than all the runs they had in the past. MPTrain was considered more enjoyable by 5 runners and TripleBeat by 6. This difference does not reveal a significant difference. However, when subjects were asked to select their system of preference, **all** of them chose TripleBeat over MPTrain (see Figure 9).

Figure 6 summarizes the main reasons for the perceived enjoyment of the runners. With MPTrain, music was the most important factor for enjoyment (5 subjects). With TripleBeat, the competition was the main reason for enjoyment (5 subjects).

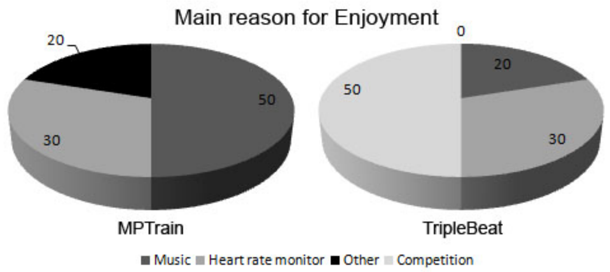

Figure 6: Main reasons for enjoyment on MPTrain and TripleBeat in percentage of subjects.

5.3.2 *Second Assay: Competition vs No Competition with TripleBeat*

The second assay was the impact of a competition in motivating runners to achieve their workout goals. Therefore, we analyzed the *efficacy* and *enjoyment* of the TripleBeat system, without and with competition.

Table 3 contains the average percentage of time spent inside the training zone for this assay: 77.1% for TripleBeat without competition and 85.5% for TripleBeat with competition. This difference is not significant ($P > 0.05; N = 10$), which might suggest that TripleBeat's efficacy is not due to the competition. Figure 5 reinforces this conclusion: only 2 participants considered competition as being the main efficacy factor in TripleBeat. The glanceable interface to the heart rate monitor was considered the most relevant reason for TripleBeat's efficacy, both in competition and no competition mode (see Figure 7)

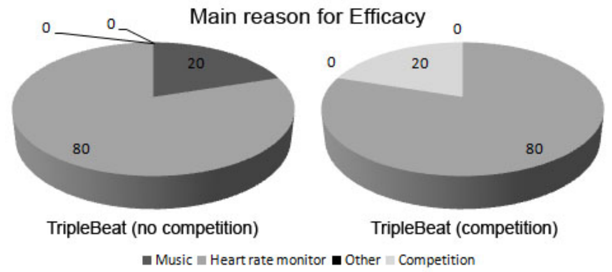

Figure 7: Main reasons for efficacy in TripleBeat (without and with competition) in percentage of subjects.

However, the subjective evaluation of enjoyment revealed a preference for the competition. Figure 8 shows that TripleBeat without competition was considered enjoyable mostly due to the music (preferred by 6 subjects). In TripleBeat with competition, 5 participants attributed their enjoyment to the competition.

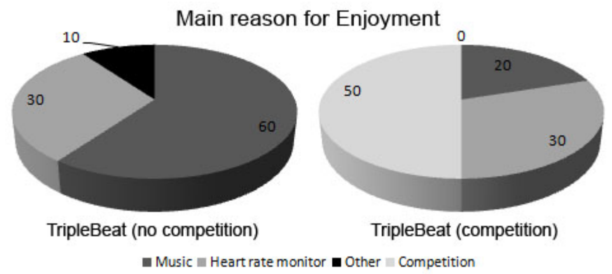

Figure 8: Main reasons for enjoyment on TripleBeat (without and with competition) in percentage of subjects.

As shown in Figure 9, TripleBeat was unanimously preferred over MPTrain by all participants. TripleBeat with competition was considered more desirable than without the competition by 7 runners, which confirms the importance of social pressure as a factor for enjoyment.

Finally, Figure 10 summarizes the main results obtained with the subjective evaluation.

6. CONCLUSIONS AND FUTURE WORK

TripleBeat is a mobile phone based system that includes persuasive techniques for exercise enhancement. We have carried out a runner study to evaluate two of these techniques: a glanceable interface for increased personal aware-

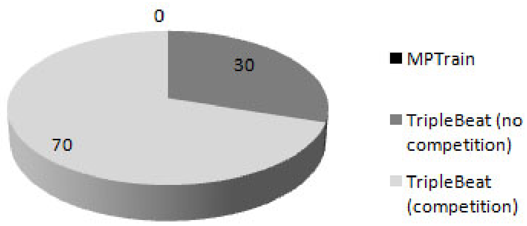

Figure 9: Subject's preferred system in percentage of subjects.

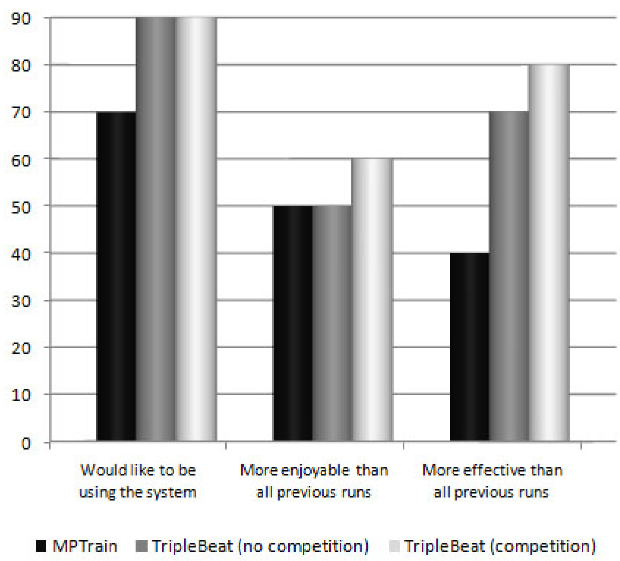

Figure 10: Summary of the subjective evaluation. Runners perception of MPTrain and TripleBeat in percentage of runners.

ness and for providing real-time recommendations, and a virtual competition with other runners.

From the study, it could be concluded that TripleBeat is *significantly more effective* in helping runners achieve their workout goals. TripleBeat's higher effectiveness was measured both objective and subjectively. TripleBeat was found to be more effective than MPTrain, mostly due to its glanceable interface rather than to the virtual competition. However, the competition was considered to be the most important reason for enjoyment. Most subjects preferred TripleBeat with competition over TripleBeat without competition. Moreover, *all* participants preferred TripleBeat over MPTrain.

In sum, our experimental results support the hypothesis that TripleBeat's persuasive techniques have a positive impact on exercise monitoring systems. We have found the user interface to be the most important element in increasing the efficacy of these systems, while social factors via a competition contribute to a more enjoyable experience. We believe that systems like TripleBeat will have an important role to play in supporting a more active lifestyle.

Next, we shall highlight a few lines of future research that we are planning to pursue:

1. *Real-time telemetry:* Specialized audio feedback via a personal trainer located anywhere to assist the users on the fly might be an important enhancement to increase TripleBeat's efficacy.

2. *Performance Social Network:* TripleBeat's data may be integrated in a social network where users could share their exercise performances and make them available to friends and family. Users could download their friends' data and use TripleBeat to compete against them or just check their friends progress.

3. *Improved score function for multiple target zones:* For the purposes of the study, TripleBeat's proposed workout consisted of a single 46 minute long training zone. Most of the participants (80%) in the study found that TripleBeat chose the right opponents to compete with them. However, the accuracy of the proposed score function could be compromised in the case of interval training or multiple target zones. This is due to the fact that every time there is a change of target heart rate –*i.e.* each interval during interval training, there is a delay until the human heart can adopt it. Therefore, additional research may need to be carried out to include this factor in the proposed score function.

4. *Motivational training:* TripleBeat should be able to learn from the user's past performances to propose more personalized training schedules. For example, the target heart rate could be computed considering not only the high-level goal of the workout, but also the user's performance history. Thus, the system would present each runner with a training proposal that would be challenging, but not impossible to achieve.

5. *Additional contextual information:* Additional contextual information would improve the system's decisions to select music, opponents and adequate trainings. Among them, we are planning to include: (1) GPS data to propose routes, connect with other geographically close runners, *etc.*, (2) body and external temperature to detect dehydration, (3) barometric pressure to measure incline, and (4) diet, overall mood and stress levels.

7. ACKNOWLEDGMENTS

We would like to thank all the runners that participated in our runner study for their time, effort and feedback.

8. REFERENCES

[1] A. Andrew, Y. Anokwa, K. Kosher, J. Lester, and G. Borriello. Context to make you more aware. In *Proceed. Int. Workshop on Smart Appliances and Wearable Computing (ICDCS'07)*, 2007.

[2] R. Asselin, G. Ortiz, J. Pui, A. Smailagic, and C. Kissling. Implementation and evaluation of the personal wellness coach. *icdcsw*, 05:529–535, 2005.

[3] J. T. Biehl, P. D. Adamczyk, and B. P. Bailey. Djogger: a mobile dynamic music device. In *CHI '06: CHI '06 extended abstracts on Human factors in computing systems*, pages 556–561, Montréal, Québec, Canada, 2006. ACM Press.

[4] F. Booth, M. Chakravarthy, S. Gordon, and E. Spangenburg. Waging war on physical inactivity: using modern molecular ammunition against an

ancient enemy. *Journal of Applied Physiology*, 93:pp. 3–30, 2002.

[5] F. Buttussi, L. Chittaro, and D. Nadalutti. Bringing mobile guides and fitness activities together: a solution based on an embodied virtual trainer. In *MobileHCI '06: Proceedings of the 8th conference on Human-computer interaction with mobile devices and services*, pages 29–36, Helsinki, Finland, 2006. ACM Press.

[6] S. Consolvo, K. Everitt, I. Smith, and J. A. Landay. Design requirements for technologies that encourage physical activity. In *CHI '06: Proceedings of the SIGCHI conference on Human Factors in computing systems*, pages 457–466, Montréal, Québec, Canada, 2006. ACM Press.

[7] S. Edwards. *The heart rate monitor guidebook to heart zone training*. Sacramento, California: Heart Zones, 2002.

[8] K. Flegal, M. Carrol, R. Kuczmarski, and C. Johnson. Overweight and obesity in the united states: prevalence and trends, 1960-1994. *Int. Journal of Obesity*, 22:pp. 39–47, 1998.

[9] B. Fogg. *Persuasive Technology: Using Computers to Change What We Think and Do*. Morgan Kaufmann Publishers, 2003.

[10] C. for Disease Control, P. U. D. of Health, and H. Svcs. Preventing obesity and chronic diseases through good nutrition and physical activity. *Preventing Chronic Diseases: Investing Wisely in Health*, 2003.

[11] R. Gockley, M. Marotta, C. Rogoff, and A. Tang. Aviva: a health and fitness monitor for young women. In *CHI '06: CHI '06 extended abstracts on Human factors in computing systems*, pages 1819–1824, Montréal, Québec, Canada, 2006. ACM Press.

[12] J. Hartnett, P. Lin, L. Ortiz, and L. Tabas. A responsive and persuasive audio device to stimulate exercise and fitness in children. In *CHI '06: CHI '06 extended abstracts on Human factors in computing systems*, pages 1837–1842, Montréal, Québec, Canada, 2006. ACM Press.

[13] J. Maitland, S. Sherwood, L. Barkhuus, I. Anderson, M. Hall, B. Brown, M. Chalmers, and H. Muller. Increasing the awareness of daily activity levels with pervasive computing. In *Proceedings of the first international conference on Pervasive Computing Technologies for Healthcare*, pages 1–9, Innsbruck, Austria, November 2006. IEEE.

[14] S. Mokka, A. Väätänen, J. Heinilä, and P. Välkkynen. Fitness computer game with a bodily user interface. In *ICEC '03: Proceedings of the second international conference on Entertainment computing*, pages 1–3, Pittsburgh, PA, USA, 2003. Carnegie Mellon University.

[15] F. F. Mueller, S. O'Brien, and A. Thorogood. Jogging over a distance: supporting a "jogging together" experience although being apart. In *CHI '07: CHI '07 extended abstracts on Human factors in computing systems*, pages 2579–2584, San Jose, CA, USA, 2007. ACM Press.

[16] S. O'Brien and F. F. Mueller. Jogging the distance. In *CHI '07: Proceedings of the SIGCHI conference on Human factors in computing systems*, pages 523–526, San Jose, California, USA, 2007. ACM Press.

[17] N. Oliver and F. Flores-Mangas. Mptrain: a mobile, music and physiology-based personal trainer. In *MobileHCI '06: Proceedings of the 8th conference on Human-computer interaction with mobile devices and services*, pages 21–28, Helsinki, Finland, 2006. ACM Press.

[18] W. H. Organization. Move for health program.

[19] S. Reddy and J. Mascia. Lifetrak: music in tune with your life. In *HCM '06: Proceedings of the 1st ACM international workshop on Human-centered multimedia*, pages 25–34, Santa Barbara, California, USA, 2006. ACM Press.

[20] M. Sohn and J. Lee. Up health: ubiquitously persuasive health promotion with an instant messaging system. In *CHI '07: CHI '07 extended abstracts on Human factors in computing systems*, pages 2663–2668, San Jose, CA, USA, 2007. ACM Press.

[21] T. Toscos, A. Faber, S. An, and M. P. Gandhi. Chick clique: persuasive technology to motivate teenage girls to exercise. In *CHI '06: CHI '06 extended abstracts on Human factors in computing systems*, pages 1873–1878, Montréal, Québec, Canada, 2006. ACM Press.

[22] P. Vorderer, T. Hartmann, and C. Klimmt. Explaining the enjoyment of playing video games: the role of competition. In *ICEC '03: Proceedings of the second international conference on Entertainment computing*, pages 1–9, Pittsburgh, Pennsylvania, 2003. Carnegie Mellon University.