A Musical Guidance System for Ergogenic Benefits in Workouts

Prakhyath Kumar Hegde
Health and Fitness
Samsung R&D Institute, Bangalore
Bangalore, India
prakhyath.h@samsung.com

Shiva Murthy Busetty
Health and Fitness
Samsung R&D Institute, Bangalore
Bangalore, India
shiva.m22@samsung.com

Shoaib Sheriff
Health and Fitness
Samsung R&D Institute, Bangalore
Bangalore, India
shoaib.shrff@samsung.com

Jinmook Lim
Health R&D Group
Samsung Electronics
Suwon, South Korea
jinmook.lim@samsung.com

***Abstract*—Music has become an essential component during indoor and outdoor workouts. Studies show that a budding runner can find a significant increase in motivation simply by listening to music. In this paper, we propose a system to further enhance the ergogenic benefits of music by providing real-time musical guidance derived from variations in user's physiological factors. This system helps user to increase the time spent in desired heart rate zone, thus, benefiting to reach user goal faster.**

Keywords—Music; heart rate; workout zones; music guidance; ergogenic benefits

I. Introduction

A. Motivation and Prior Work

The cultural pursuits of playing and listening to music are wide and almost as ancient as civilization itself. USATF (USA Track & Field), the national governing body for running, banned the use of headphones and portable audio players like iPods at its official races. This was done to ensure safety and to prevent runners from having a competitive edge. Intuitively, for a stimulus such as music to be used on a daily basis by so many people for such a variety of purposes it must have some benefits. In this paper, we have gone one step further by exploring ergogenic benefits of using music, customized as per user's physiological factors in real time.

In the last few years, scientific research has come up with plenty of results regarding the effect of music on sport and exercise behavior. Dr. Costas Karageorghis, deputy head (research) of the former School of Sport and Education, calls music as sport's "legal drug", capable of reducing an athlete's perception of effort by 10% while increasing performance by 20% [1], [2]. In fact, Dr. Costas Karageorghis and Dr. David-Lee Priest's study shows that a budding runner can find a 15% increase in motivation simply by listening to music [3].

There are known to be three major heart rate training zones: weight loss zone, cardio zone and anaerobic zone. Exercising in weight loss zone improves one's general endurance. The body gets better at burning fat resulting in an improved muscular fitness and increased capillary density. Exercising in cardio zone is especially effective at improving the efficiency of blood circulation in the heart and skeletal muscles. Anaerobic exercise improves one's speed endurance. Past research shows that music influences a person's heart rate, thus, having a direct effect on RPE (Rating of perceived exertion) in workouts. The RPE scale is used to measure the intensity of exercise [4], [5].

Earlier experiments suggest that music has no major effect on workout performance when heart rate is in anaerobic zone [6]. So this paper explores mainly weight loss and cardio exercise zones.

B. Main Contribution

This system analyzes heart rate in 3 seconds intervals. If current heart rate is outside the desired workout heart rate zone, the algorithm adjusts musical tempo to bring heart rate within the desired workout zone. Also, the system minimizes the initial time required to reach targeted workout heart rate zone. Once user reaches targeted zone, system tries to keep user there for as much time as possible. Therefore, system acts as a guide throughout the workout period.

II. Methodology

A. Dataset (Participants)

This experiment was conducted with a group of 17 people (11 male & 6 female). All are healthy, aged 23-35 and without any known neurological or hearing disorders. After an informed consent was obtained, participants were asked to use this experimental setup for a period of 2 months. Participants were requested to continue their regular workouts (running or cycling) of around 20 minutes duration with and without real-time music customization on an alternative day basis.

The experimental setup consists of a media playback device, such as a smartphone, a smartwatch wearable and a heart rate monitor strap. Tests were also done with wireless wearable earphones like Samsung Gear Icon X. The smartwatch and the strap are connected to the smartphone for the whole duration of the workout. All participants used a playlist with four predetermined workout music tracks (without vocals) during the workout session.

On the very first launch, user is asked for the age. Next, as shown in Fig. 1(a), the user chooses the workout zone. As the actual workout begins, the play button is clicked to start the music. Henceforth, the wearable device and the strap start tracking steps data and heart rate respectively. This data is shared with the smartphone wherein additional processing is performed.

During the training phase, a visual indicator in wearable app helped to calibrate the variables in (4). Fig. 1(b), 1(c) & 1(d) show the wearable screen during various possibilities during workout. In Fig. 1(b), a blue background indicates that current heart rate is below the desired zone. As a result, an increased tempo of "1.4x" is provided. In 1(c), the current heart rate is within the desired zone. A green background coupled with normal tempo is used. When current heart rate is above the desired zone, a red background is used, as shown in Fig. 1(d). The system attempts to slow down the user by providing a tempo of "0.92x". The values derived in this phase are used in (4).

Fig. 1. Screenshots of the view presented to the user on the circular smartwatch at different stages of the workout.

B. *Overview of the approach*

Fig. 2 shows complete flow of the proposed system. User first selects the desired workout heart rate zone. Then, the system begins recording heart rate and steps. For the initial configuration, music beats are synchronized with user steps. After synchronization, current heart rate is compared with selected heart rate zone.

If current heart rate is below the desired workout heart rate zone, music BPM (Beats per Minute) is increased to motivate the user to run/cycle faster. This results in an increased heart rate, which takes the user towards preselected zone faster. Once the user's heart rate lies within the selected workout zone, the music tempo is maintained, so as to keep him there for the longest possible time.

If and when, the user goes above the desired workout heart rate zone, music BPM is decreased to make the user run/ride slower. The user is thus, pushed back towards the workout heart rate zone.

This process of altering music tempo is done as long as heart rate is not in the target zone and until workout cooldown period is reached. Usually cooldown period lasts for the last 2-5 mins of the workout.

C. *Equations*

Initial configuration comprises of the user's age and desired workout target zone. These data are used to calculate upper limit and lower limit of heart rate for the target zone using the age-predicted HR_{max} (i.e., 220 - age) equation formulae.

$$\text{Max Heart Rate (MHR)} = 220 - \text{age} \quad (1)$$

$$\text{Zone Lower Limit (ZLL)} = \alpha * \text{MHR} \quad (2)$$

$$\text{Zone Upper Limit (ZUL)} = \beta * \text{MHR} \quad (3)$$

Where,

α = 0.6 for weight loss zone, 0.7 for cardio zone

β = 0.7 for weight loss zone, 0.8 for cardio zone

Here α and β are constants and vary based on selected workout zone. As weight loss zone lies in 60-70% of MHR, α is 0.6 and β is 0.7. Similarly, since, cardio zone lies in 70-80% of MHR, α is 0.7 and β is 0.8 [7]. After finding ZLL and ZUL for selected zone, we guide user in such a way that his heart rate stays between ZLL and ZUL for maximum duration. To achieve this, Tempo Change Factor (TCF) is added to the music as long as user's heart rate is not in the selected zone. System defines music tempo boundaries as 90% and 150% of original to retain essential music properties. Below formula is used to calculate TCF:

$$\text{TCF} = \varepsilon * (\text{HR} - \gamma) / \delta \quad (4)$$

Where,

HR = current heart rate

ε = +0.01 if HR < ZLL, -0.01 if HR > ZUL

γ = 0 if HR < ZLL, ZUL if HR > ZUL

δ = ZLL if HR < ZLL, ZUL if HR > ZUL

As evident from (4), ε is used to decide whether to add or subtract TCF from music tempo. ε is +0.01 when user's heart rate is below ZLL. Hence, music tempo increases steadily until target zone is reached. Similarly ε is -0.01 when user's heart rate is above ZUL. In this case, Music tempo decreases.

D. *Noise Elimination and Correction*

The window of data observation is designed to exclude the first 15 seconds after warmup to allow the user time to transition in to the workout. A suitable amount of time is similarly excluded before cooldown period.

Additionally, the user may decide to take a break during the workout for a variety of reasons. If no separate action is taken, the guidance system can interpret this as a slowing user and may attempt to drive him on. The steps sensor, however, aids in recognizing this situation. For the resting period, the music can be paused and additional processing halted.

Furthermore, a total of 10 different gear devices comprising four different models and three different heart rate monitor straps were used in the experiment to eliminate any model specific errors in measurement.

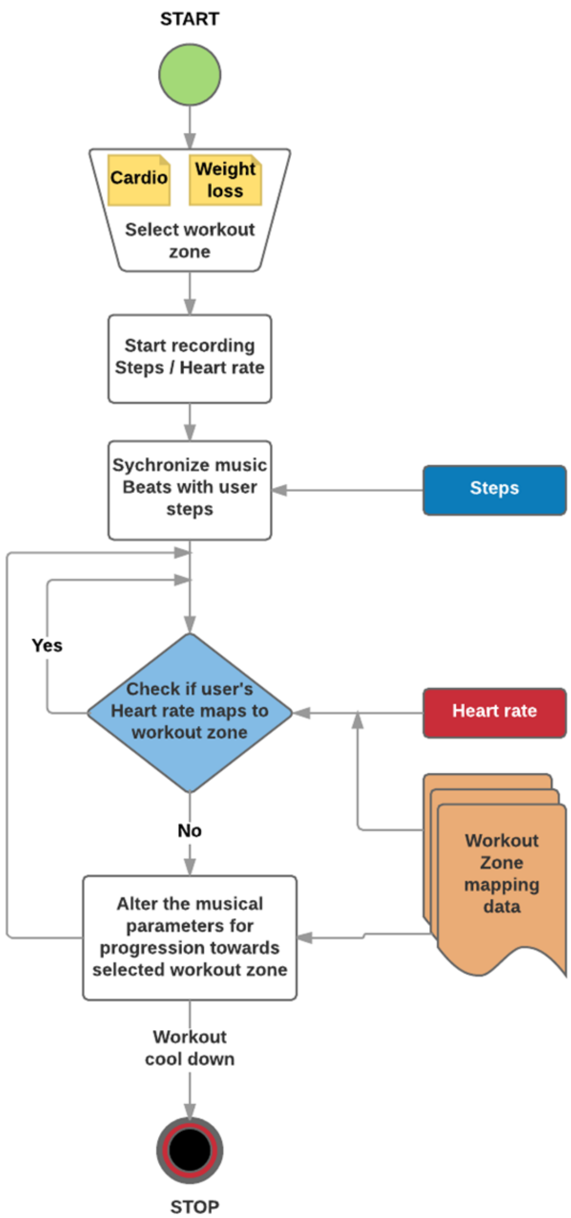
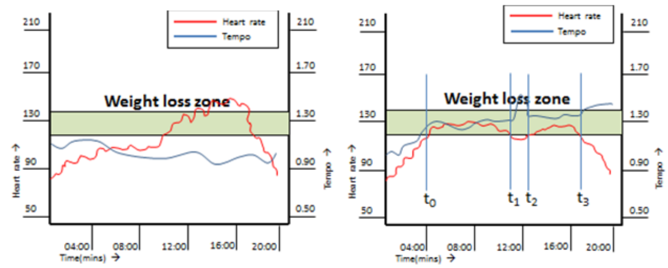


Fig. 2. Flow of the music guidance system.

III. Results and Discussion

To test out the experiment over a period of 2 months, 17 participants were identified. None of the participants were aware of their live physiological vitals during workout. No other external guides were in presence either.

Fig. 3 and 4, show the graphs of heart rate and music tempo plotted in Y- axis vs Time in minutes plotted in X-axis. User's heart rate and music tempo are depicted in red and blue lines respectively. Fig. 3(a) shows weight loss workout done by participant 1 without musical guidance. As there was no music guidance to influence his heart rate, user was considerably below the target zone.



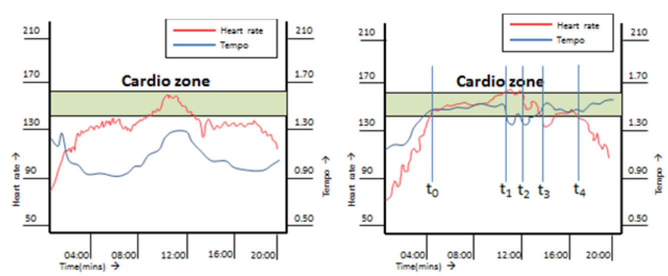
a) b)

Fig. 3. Weight loss zone workout for participant 1.

In Fig. 3(b), however, the effects of the musical guide can be clearly seen. Till t0, as heart rate is below the selected zone, music tempo is constantly increased to motivate the user to workout harder. Then, music tempo doesn't change from t0 to t1 as user's heart rate is in desired workout zone. When user's heart rate goes below the target zone at t1, music tempo is increased to push the user towards desired zone. Similar effect can be seen from t2 to t3. Post t3, user's heart rate lies below required window, so music tempo is increased.

Fig. 4 depicts the workout with a cardio zone target. As can be seen in Fig. 4(a), the user fails repeatedly to stay in the cardio zone for the maximum duration of the workout.

The presence of a musical guide, as shown in Fig. 4(b), motivates the user to push harder. Till t0, Music tempo is increased in constant rate as heart rate is below the desired workout zone. There is no change in music tempo from t0 to t1 as user's heart rate is in selected zone. Then, music tempo is decreased from t1 to t2 as user's heart rate goes beyond cardio zone so as to push user towards cardio zone. Similar effect can be seen from t3 to t4. As a result, a much more effective workout is achieved, with the user spending around 63% of his time within the target heart rate zone.



a) b)

Fig. 4. Cardio zone workout for participant 2.

All recorded workouts are around 20 minutes. Table 1 shows the average percentage of workout duration across all users with heart rate maintained in selected zone. Average improvement in retention of 22% and 9% were observed in weight loss and cardio zones, respectively.

Table 2 shows the average time duration across all users to reach desired workout zone. Although zone reaching time varies on an individual basis, reasonable improvements were observed after 2 months.

By spending most of the workout duration in desired zone, user will be able to achieve his selected goal faster than usual.

TABLE I. AVERAGE PERCENTAGE AND STANDARD DEVIATION OF WORKOUT DURATION (SECONDS) WITH HEART RATE MAINTAINED IN SELECTED ZONE

Workout duration ≈ 1200 seconds		**Music (Average, σ)**	**Music + Guidance (Average, σ)**
Weight loss zone	Running	33, 40	54, 42
	Cycling	45, 47	68, 53
Cardio zone	Running	44, 50	54, 47
	Cycling	23, 38	32, 39

TABLE II. AVERAGE AND STANDARD DEVIATION OF WORKOUT TIME (SECONDS) TO REACH PRESELECTED ZONE

Workout duration ≈ 1200 seconds		**Music (Average, σ)**	**Music + Guidance (Average, σ)**
Weight loss zone	Running	120, 9	101, 8
	Cycling	231, 12	194, 8
Cardio zone	Running	370, 23	320, 17
	Cycling	533, 30	471, 22

IV. CONCLUSION

Proposed method is a musical guidance system that aims to maximize the workout duration in the target workout zone. An experiment with 17 participants was conducted and an increase in workout zone retention by 22% for weight loss and 9% for cardio zone was observed. An average reduction of 28 seconds for weight loss and 56 seconds for cardio zone was found in time to reach preselected zone.

Further efforts can be put in to explore the direct benefits of music guidance in meeting the user's targets like weight loss or endurance gain over a period of time.

Future work can encompass the area of content optimization and workout personalization. Music content is provided as a service over the internet. A mechanism that uses music genre to further guide the workout sessions would be greatly beneficial. For instance, fast, loud and bass-driven music helps best for the intense portions of a workout. Slower gentler music is more suited, however, for the warmup/cooldown sessions. Additional amounts of personalization can be provided to incorporate the musical preference of the user.

Learning systems can also be incorporated to further enhance the efficiency of the system. For instance, one user may increase the pace as a reaction to a faster music tempo in a short duration. A different user, however, may need more time to increase the pace by the same amount.

REFERENCES

[1] C. I. Karageorghis and D. L. Priest, "Music in the exercise domain: a review and synthesis (Part I)", International Review of Sport and Exercise Psychology, Mar 2012; 5(1): 44–66.

[2] C. I. Karageorghis and D. L. Priest, "Music in the exercise domain: a review and synthesis (Part II)", International Review of Sport and Exercise Psychology, Mar 2012; 5(1): 67–84.

[3] C. I. Karageorghis, et al, "Psychophysical and ergogenic effects of synchronous music during treadmill walking", Journal of Sport & Exercise Psychology. 2009; 31:18–36.

[4] V. M. Nethery, "Competition between internal and external sources of information during exercise: influence on RPE and the impact of the exercise load", J Sports Med Phys Fitness, 2002; 42: 172-178.

[5] S. Yamashita, K. Iwai, T. Akimoto, J. Sugawara, and I. Kono, "Effects of music during exercise on RPE, heart rate and the autonomic nervous system", J Sports Med Phys Fitness. 2006; 46: 425-30.

[6] T. Atan, "Effect of music on anaerobic exercise performance", Biology of Sport, Mar 2013; 30(1): 35–39.

[7] S. EDWARDS, "The Heart Rate Monitor Book. Sacramento", Fleet Feet Press, 1993; pp. 113–129.