Pace Yourself: Leveraging Beats Per Minute in Mobile Interaction to Affect Running Pace

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ABSTRACT
Previous research has examined the effect of Beats Per Minute (BPM) in songs on endurance; however, no study has yet looked at the effect of BPM on pacing and running time. This paper presents one such study, as well as the development of TrackStar, an iPhone application that varies songs by BPM while a user is running to figure out what BPM range alters a users pacing. Using TrackStar, we performed a blind, within-subjects study comparing participants' times and pedometer data for each lap during two mile-and-a-quarter runs at the Stanford Track. During the control trial, participants were given five random songs from the Nike Powersong 2.0 running mix, and in the treatment, one song from each of 5 playlists that ranged in BPM from 100 to 180. In the end, we found that although virtually all participants reported feeling as though they had increased their pace to high BPM songs and slowed down during low BPM songs, there was actually no correlation between pacing and running time with the BPM of songs.

ACM Classification: J.3 [Computer Applications: Health], J.4 [Computer Applications: Psychology], H.4.0 [Information Systems Applications: General], H.5.5 [Information Interfaces and Presentation]: Sound and Music Computing—Systems

General terms: Human Factors, Measurement, Performance, Experimentation

Keywords: Beats Per Minute (BPM), Music, Performance, Running, Contextual Systems

INTRODUCTION
Many runners like to listen to music while running and view their pacing data as an important tool in helping them to run better. As evidenced by the partnership of Nike and Apple Inc. and consequent sales of their Nike + iPod system [1], which keeps track of pedometer data for a runner that they can later look at online, runners are indeed interested in how interactive systems can positively influence their running times and pacing.

Previous work on music's effect on exercise shows that music has broad psychological effects that increase endurance [2]. Music also has a significant effect on physiological responses such as heartrate, blood pressure, perceived exertion, and a smaller effect on norepinephine secretion [3]. Mood and disposition affect endurance and effort tolerance in other exercise studies [4]. However, one study showed that music failed to influence heartrate and perceived exertion [5].

Other studies have also looked at using music's rhythm to increase running performance. A study using "synchronous" music, where a runner determinedly runs in time to the music's pace, showed that music could significantly improve runners' times on 400-meter sprints [6]. However, this study did not look at specific BPM, nor did it try increasing BPM by moderate amounts to see if runners could further improve their times by working up to faster paces. Another study looked at the effect of tempo specifically on exercise and found that tempo could increase intrinsic motivation and enjoyment for exercise [7]. Our work looked to improve these studies and build a contextual system that would look at BPM's effect on pace and time.

Contextual systems have been a focal point for several studies. One interface, LifeTrak, looked into using contextual information for creation of music playlists, but did not analyze its potential for exercise enhancement [8]. Another interface, XPod, is a music player designed to learn users' preferences, then use them along with motion and activity data to predict desirability and appropriateness of a song [9]. A third interface, MPTrain, was able to significantly improve runners' ability to achieve a pre-defined workout goal, made the experience more enjoyable, and increased perception of workout efficacy through music [10]. Finally, PersonalSoundtrack is an interface that plays a song exactly in sync with a runner's pace; however, no studies have been published demonstrating its effects [11]. None of these studies looked at improvements to runners' paces or times, merely self-efficacy and mood measures.

BUILDING AND DESIGNING TRACKSTAR
Based on prior work, observations from researching mobile running applications, and our own needs, we figured out a

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set of features and characteristics that our own custom-designed interface, TrackStar, needed:

- Easy recording of pedometer data and times
- Music playback
- Non-intrusive status updates using voice feedback
- Comfortable and proper placement of music player so as not to intrude on running
- Clear reporting of results for analysis

With these things in mind, we decided to use the iPhone for our development platform. This choice was due to the device's touch capabilities, media playback ability, accelerometer, workout products, relatively large screen, as well as the ease of use and availability of libraries for the device.

In addition to building the internals of the application, we also gathered and created content for TrackStar. We found that the Nike PowerSong 2.0 playlist fit our needs as it provided enough content, 20 songs, of varying genre and speed while also being ranked as music that people often ran with [12]. For the other content we used Algoriddim's djay software to modify some of the songs in the Nike PowerSong 2.0 playlist in order to get them to an exact desired beat count. These new versions all had different BPM than their originals, and were one of 100 BPM, 120 BPM, 140 BPM, 160 BPM, and 180 BPM.

EVALUATION

The motivation of our research study was whether a mobile application, like TrackStar, could figure out which BPM ranges are optimal for users to increase and decrease their pacing. Using this data, runners could then develop their own BPM specific playlists for increasing and decreasing their pacing at different times.

Method

Participants: 15 university students (9 male, 6 female) participated in our study, which took place over a week-long time period. We recruited participants by advertising on various Stanford University email lists a workout study in which participation would be compensated in the form of a five dollar Jamba Juice gift card.

Setup: The study used a within-subjects experiment design, and had each of our participants run two mile-and-a-quarter trials while using TrackStar. In the control condition, participants listened to five random songs from the Nike PowerSong 2.0 Mix, while in the treatment condition, participants listened to one random songs from each of five randomly ordered different BPM playlists. In both trials participants ran while wearing an armband with an iPod Touch or iPhone, operating TrackStar, attached. After each lap, participants tapped the screen, which would then change the song, inform them of their pace, and register their pace and time for that lap. At the end of the fifth and final lap TrackStar displayed the results on the screen, which was then recorded for later use. To limit factors like fatigue, each participant was given at least one day of rest between trials.

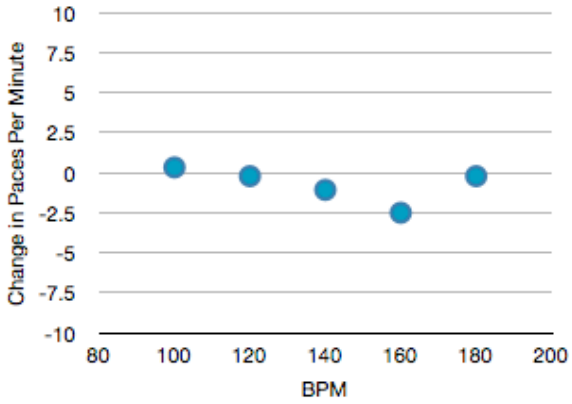

Figure 1: The effect of the treatment condition for the pacing, no matter what the BPM, is nearly negligible. Paces per minute, a value that ranged from 144 to 184, change by approximately 0 across all BPM between the treatment and control conditions. In a paired t-test, $p > .57$.

Procedure: Participants were told that our study was designed to test the effects of music on running, and to run the mile-and-a-quarter at a natural pace. There was no mention of BPM or that some of the songs had been modified. Before every first trial, we flipped a coin to decide if the current participant was going to run the control or treatment first. Participants did not see us flip the coin and change the switch on the screen to indicate to TrackStar if it was to run the control or treatment condition. After attaching the armband and iPod to the user, we explained to them that they were not to start running until the music started to play and that at the end of the each lap to tap the screen. They would know if they tapped the screen correctly if the music stopped playing for about two seconds and they heard a synthesized voice informing them of their current pace and that they were about to be given a new song. After the final lap, we recorded the results, which included the songs they heard, times for each lap, the total number of steps they took in each lap, and the steps per minute for each lap. The users were not allowed to see their results. Afterwards, we conducted a brief, informal interview.

Results

Each lap from the treatment condition was compared only to the corresponding lap from the control condition (i.e. the fourth lap from treatment, whatever its BPM, was compared only to the fourth lap from control), as a way to control for fatigue effects.

After aggregating the data of time on each lap, pace per minute (PPM) on each lap for each participant, and BPM of the treatment condition song for that lap, a simple calculation was made of difference in pacing and time of that control lap versus the treatment lap. The average difference, no matter what the BPM, hovered close to 0 (see Fig. 1). On a paired t-test of the results of the pacing,

no significant difference was found ($p > .57$). Likewise, no significant difference was found for the times to complete each lap (see Fig. 2). Likewise, analyzing just the performance from the treatment lap with the BPM closest to the average PPM of the runner yielded no significant results. Many participants noted that they liked most of the music on TrackStar and found it easy to use.

Interestingly, virtually all participants reported *feeling* like they were adjusting their pacing and times to fit the music in the post-run interview, but the data shows that this was not the case. One participant who has just finished the treatment condition said, "'Eye of the Tiger' [100 BPM] felt weird to run to because of the syncopated start sequence; I think my pace changed," when in fact he ran his second-fastest PPM, 178, of the five that lap, and his paces per minute only ranged from 172 to 180. (Notice as well how difficult it would be to keep "pace" with 178 PPM to a 100 BPM song.) Another participant said, "One song seemed slower than my running. It probably slowed me down because I tried to keep pace with the music," when his PPM ranged from 158 to 162, and the lap with that song was 159 PPM. Thus, participants felt that they were adjusting their pace to keep in time with the music when in fact they were not.

DISCUSSION

In contrast to the multitude of studies that were able to show an effect or at least a trend, TrackStar failed to yield any results. Reasons could be any or all of the following:

- *Lack of explicit manipulation:* Participants were told before the experiment that we were simply doing a running study that involved music, and before running, were only instructed to "run as normal," in an effort to make results as generalizable as possible. Without the explicit instruction to make the running pace synchronous with the music, perhaps people did not try to.
- *Pace Per Minute does not accurately predict time:* Our slowest total time for the 5 laps on the control trial was 12:06; that participant ran an average PPM of 171. Our fastest participant finished 5 laps in 7:40, and had an average PPM of 155. R-squared value for time and pacing is .10 – so in fact *slowing* the pace may be beneficial if that is the case, not speeding it up.
- *Preferences for songs are different:* It seems that what "pumped up" participants was really just whatever music they liked and were familiar with, not easily-summed-up inherent qualities of the song like BPM. Thus, BPM alone cannot be used to pump people up or slow them down.
- *The difficulty of matching one's pace to BPM:* People are generally pretty bad at pacing themselves – one person who described herself as "very responsive to music physically" hardly adjusted her PPM throughout the treatment trial at all. Even when people feel like they are running to the music, they may not be. Thus, BPM may not be the characteristic to adjust and control for.
- *Time data was never given:* At the end of each lap, TrackStar only told the participant what his or her PPM was, which some runners reported as useless information. If instead an interface told the runner his or her time for the lap, a more significant effect of improving time might be observed, though we did not want to confound looking at just the effect of BPM.

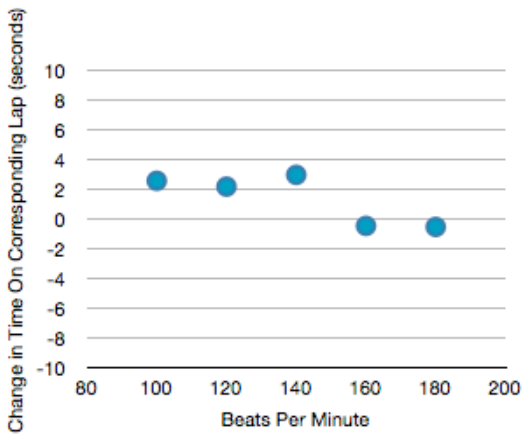

Figure 2: The effect of the treatment conditions on time is also nearly negligible, with a maximum effect of just over 2 seconds on time.

CONCLUSION AND FUTURE WORK

In this study, we tried to influence the pacing and time of runners through the BPM of the songs they were listening to. By designing and implementing an application, TrackStar, that could record all the relevant data while maintaining ease of use, we ran a controlled within-subjects design to test if the manipulation could work. However, we found that although participants reported feeling different, no difference at all was observed in either pacing or time data between the control and treatment trials. BPM alone does not appear to have an effect on pace, even if it does on mood. Further work needs to be done to test what would happen with a more explicit manipulation, where runners would be told to run to the music.

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