Designing a Music-controlled Running Application: a Sports Science and Psychological Perspective

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Abstract
Music has long been acknowledged for its effects on participants in sports and exercise. For casual runners music may act as a motivator and distractor of physical strain. It may also serve as a training guide, when sensing technology is used as an enabler for adapting music to a runner's situation in real-time. While many effects of music are known from sports science and psychology, application designers lack a consolidated knowledge base that guides them in designing a running application. This work synthesizes findings from the involved disciplines and provides 7 requirements for an application that increases casual runners' motivation and controls training.

Author Keywords
Sports; running; music; motivation; human-computer interaction.

ACM Classification Keywords
D.2.1. [Requirements/Specifications]: Elicitation methods.

Introduction
Music has long been acknowledged for its psychophysical effects on participants in sports [8]. In

training, music is appreciated for its influence on, for instance, arousal regulation, synchronization, or attainment of flow [13]. Music's motivational qualities [7, 8] are particularly useful and effective in mass sports and/or for beginners.

However, music has to be wisely selected and tailored to an individual's situation to be most effective [6]. Casual sportspeople may lose motivation due to its complexity and dismiss the idea to engage in a sports activity before they have even started with it. Furthermore, the tailoring of appropriate music for a sportsperson is not a one-time-act but requires continuous adaptation to a person's progress and should match the varying conditions while the person engages in a sportive exercise. Technology can be leveraged as an enabler for sensing a sportsperson's condition (e.g., heart rate, pace, speed, etc.) in real-time and for keeping a steady pace.

This field of research is interdisciplinary and needs to integrate the perspectives of computer science, psychology, and sports science. However, findings concerning music in sports have not yet been brought together from these disciplines. The goal of this work is to synthesize findings and translate them into design requirements that allow for well-informed decisions for new applications. We focus on casual running, as there is one particularly interesting phenomenon in the combination of music and running: People instinctively sync their pace with the music's tempo; i.e., they run to the beat [5]. While music has been studied as an accompaniment to the advice of a trainer or an athlete's own knowledge, controlling a training *entirely and solely* by relying on music, has not been addressed before and constitutes a novel contribution of this work.

Related Work

Various applications and research prototypes have been developed to support individuals while walking, jogging, or running by means of music. TempoRun classifies existing music on the user's smartphone into 10 levels depending on speed, with level 1 being a walk and level 10 a sprint. RunningMusicApp offers music with a standard beat of 150 beats per minute (bpm), which can be adjusted to an individual running pace up to plus or minus 20 percent. RockMyRun offers playlists that differ in length and bpm and are composed by international DJs. All 3 applications have in common that users have to select music with convenient bpm on their own to support their walking/running.

In contrast, research prototypes aim at automatizing the music selection process, allowing the user to concentrate on the sports activity. For instance, when using "situated music" [12], the pace of the runner is assessed through a step counter; based on the calculated pace, music that matches this pace is automatically selected. In addition, users may enter a desired target-pace: if a pace above or below that target-pace is detected, music with respectively lower or higher bpm is selected to slow the runner down or speed him/her up [12]. DJogger [2] also calculates a runner's pace and adjusts the playlist accordingly by selecting the following track with appropriate bpm to reach the desired target-pace. MPTrain [10] is a device that works according to the same principle but, besides pace, it also continuously monitors the runner's heart rate. Reactive Music [1] and Robin [9] adopt a rule-based approach; thereby, a piece of music is generated and adapted *while* listening to it; that way entirely individual music is created in real-time.

Overall, existing work investigated various aspects of music-sports-technology combinations and advanced technological solutions tremendously. Still, most of that work considers one specific aspect but does not address the multiple requirements that are put forward from a sports science or psychological perspective.

Research Approach

Research on running has a long history in the sports science domain as well as from a psychological perspective. We draw on these findings and synthesize them into requirements for a music application that is capable of *controlling* the training of a casual runner. Informed by a thorough literature review[1], we additionally used the experience of distinguished experts to obtain a deep understanding of the field. In a first step, for covering the sports science perspective, we interviewed an expert in sports and health sciences with particular expertise in performance diagnostics and training theory. For discussing the psychological aspects, we interviewed an expert in training sciences and sports informatics with particular expertise in competitive sports and effects of music in exercise.

The collected requirements from the literature review and the expert discussions were consolidated and translated into requirements specifications that consider the sports science and psychology perspective. We started our work by drawing on expertise in these fields, as users are typically not in a position to express their psychological requirements and lack a thorough knowledge about sports performance or health aspects. For example, a user might find it a good experience to run with a low heart rate; however, from a sports science perspective this may not be the most effective and efficient method to enhance performance. Still, in the next steps of our research, we will focus on user requirements, which is, however, beyond the scope of the present paper. In the concept-engineering phase, we drew on computer science literature that discusses potential technological solutions and mapped the specified requirements with identified technological solution opportunities. In a follow-up step, we drew again on the experts, having them reflect on the proposed concepts.

[1] Due to space limitations, it cannot be presented here.

Design Requirements

Casual runners rely on *extrinsic motivation* and *distraction from physical strain* [e.g., 11, 15], which can both be provided through music. From literature review and expert discussions, we could identify 7 requirements (R1-R7). R1-R3 refer to using music to indicate to the runner the actions he or she should take, R4-R6 refer to requirements for a successful training regime, and R7 targets the characteristics that music has to have to function as a motivator for the runner. For each of the requirements, we (i) explain the requirement from a sports science and/or psychological perspective, (ii) explicate how music may be a means to address the respective requirement, and (iii) discuss possible technological solutions to meet the respective requirement. In discussing the technological solution opportunities, we assume that the user is equipped with an easy-to-carry mobile device (e.g., a smartphone) with a running training application, potentially with hardware extensions (e.g., a heart rate belt), and head- or earphones for listening to the music. Note that current mobile devices may not (yet) have the required computation power for every proposed solution. Further, we emphasize that this

work focuses on *controlling training*, which may not be appreciated by all casual runners, as some may not engage in running for improving performance.

R1: Intensity Control through Pace Regulation
A classification of music based on its bpm into 3 categories is recommended to regulate the relative but not the absolute pace [14]. Therefore intensity can be controlled by having a runner adapting his/her step frequency (pace) synchronously to the bpm of a piece of music; adaptation of pace to bpm is intrinsic to people and happens automatically [5]. Differing sound volumes support the desired intensity/relative pace. Against this background, we can basically set 3 categories of music concerning their intensity effects: Category 1: bpm between 120 and 130, and low sound volume. This category is mainly used for warm-up and cool-down; Category 2: bpm between 135 and 145, and medium sound volume. This category supports extensive moderate running; Category 3: bpm between 145 and 155, and high sound volume. This category pushes for intensive running. Thereby, a constant beat within a piece of music is necessary (i) to keep the runner's step frequency and consequently his/her running pace constant; and (ii) to easily assign music to one of the 3 categories.

Basically, we identify 3 solutions to provide music in the required tempi: (i) Out of a music database, a piece of music is selected that matches the pace that falls in the respective category [10, 12]. (ii) A piece of music is slowed down or speeded up, such that the required bpm score is reached [2]. (iii) Music is generated on the fly with the required bpm score [1]. Sound volume may be easily adapted to match the requirements of the respective category.

R2: Heart Rate Monitoring
For a training that matches an individual's condition and requirements, it is advisable to continuously monitor the user's heart rate. For calculating the optimal training zones (concerning heart rate), 2 measures have to be ascertained first: (i) the resting heart rate (RHR), which is measured when sitting; and (ii) the maximum heart rate (MHR), which is measured through an running all-out-test: 10 min warm-up followed by a 2.000 m ascending run. Based on RHR and MHR the optimal training zones (according to Karvonen [3]) can be calculated:
`Training heart rate = (MHR-RHR) * factor + RHR`
with the following `factors`: 0.5 for warm-up and cool-down (corresponds to music of category 1); 0.6 for extensive running (corresponds to music of category 2); 0.8 for intensive running (corresponds to music of category 3). Training zones have to be increased by 5 bpm every 20 min for consideration of the cardiovascular drift. The linkage of heart rate monitoring hardware with the music application may be realized via a Bluetooth solution. RHR and MHR may be entered manually into the application, which is then used for further calculations. Alternatively the application registers the results of RHR and MHR via a heart rate monitoring band. After every 20 min of sports activity, the training zones should be raised by 5 bpm by playing music with the respective bpm.

R3: Training Method
Each training session starts with a 5 min warm-up and ends with a 5 min cool-down. The main session can take 2 different kinds of training methods:
(a) continuous method: e.g., warm-up, 20 min continuous running, cool-down; or (b) interval method: e.g., warm-up, 3×4 min intervals with 4 min interval

pause, cool-down. Training science confirms positive effects for both methods. The continuous method (a) means moderate strain, while the interval method (b) is rather intensive. When a running session is activated in the application, the user should be able to choose between the methods. According to the selected method, the music 'program' starts. For (a), music of category 1 plays for 5 min, followed by music of category 2. After the respectively calculated duration of the training (e.g., 20 min), cool-down music of category 1 is played. For (b), warm-up music of category 1 plays for 5 min. Then the application switches to 4 min music of category 3. Then the music stops for a 4 min interval pause; alternatively, very slow music or music without beat (e.g., spherical music) may be played. This is repeated until the required training duration (minus 5 min) is reached. Thereafter, cool-down music of category 1 is played.

R4: Performance Diagnostics
A 2,400 m running test is necessary before a user starts training and should be repeated every six weeks for a performance review. The (expected) improvement of the performance will have an additional positive effect on a runner's motivation. When the application is first started, the user should be guided through such a test. The application automatically reminds the user of repeating the test every six weeks. The application documents performance progress by recording the times for the tests. A positioning solution, such as GPS (Global Positioning System), can be integrated into the application for measuring the 2,400 m.

R5: Training Volume
Training volume for the first 2 weeks is 3×30 min/week and is then increased by 10 percent every second week until a training volume 3x1 hour/week is reached. This upper limit is chosen at this point of research, as we assume that the average casual runner does not have more time at disposal for investing in sport activities. Calendar functionality allows a user to plan training sessions. Synchronization with the prevailing calendar applications (e.g., using the Calendaring Extensions to WebDAV (CalDAV) standard) facilitates the user's planning activities and allow for reminders.

R6: Duration of Training Sessions
The duration of the initial training sessions is 30 min and is then increased by 10 percent every second week. It is important to start with a short duration to avoid overstraining the untrained runner. The length of the playlist controls the duration of the training.

R7: Motivating Aspects of Music
Music is motivating if it matches the runner's taste, the lyrics are pleasant for the runner, it evokes positive associations, and it is selected by the runner him or herself [6]. In order to match a runner's music taste, it is advisable to use existing music on a runner's mobile device. The drawback of this solution is that lyrics of the songs in the personal music libraries have to be analyzed at first use of the application and after every library update. As digital music contains meta-data in the files, though, retrieving the respective lyrics is not difficult (e.g., by using the Musixmatch API). Certainly, connectivity to the Internet has to be available on the device. Two solutions are thinkable: Either the music content is provided with the application and is stored on the device, or an approved music database is provided remotely, for which connectivity to the Internet has to be granted. For the analysis of the lyrics, text mining and text analysis are applicable [4].

For an evaluation whether a piece of music evokes positive associations, not only lyrics but also harmonies have to be considered, for which the Brunel Music Rating Inventory-2 [7] provides a viable solution.

Future Work

The requirements need to be based on comprehensive and reliable insights, which still have to be validated. Future work will further include an evaluation of several technological solution alternatives. Furthermore, it is essential to integrate users in the evaluation and further developments, particularly with respect to acceptance, motivation, and overall user experience. Still, continuous integration of expertise from sports science and psychology is significant with respect to the evaluation of user performance, correctness of the music-technology solutions in the various specific situations while training, and health-related issues.

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