Interfaces for Assessing the Rated Perceived Exertion (RPE) during High-Intensity Activities

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Abstract
The ubiquity of heart rate monitors (HRM) has lead to a situation in which amateur athletes often autodidactly engage in online training plans. However, the relationship between the individual heart rate and the exercise intensity is subject to stronger fluctuations and is influenced by other external and internal factors. Using solely a HRM to control the exercise intensity may lead to dangerous misinterpretations, in which other important physiological conditions are ignored and self-awareness is eliminated. In this work, we propose an interface to asses and track the rated perceived exertion (RPE), that periodically motivates the athlete to listen more carefully to his subjective feeling and creates awareness of the body. Even though results may be vague in the beginning, we think that the proposed method is preferable for hobbyists over HRMs if used over longterm.

Author Keywords
Sports Technologies, HRM, RPE

ACM Classification Keywords
H.5.1 [Information Interfaces and Presentation (e.g. HCI)]: Multimedia Information Systems

Introduction
Many amateur athletes have established the practice to keep a training diary of their workouts, either digitally or

Last 4 Weeks	
Avg Rides / Week	2
Avg Distance / Week	148 km
Avg Time / Week	6h 54m
2016 ▾	
Distance	1,639.6 km
Time	74h 38m
Elev Gain	19,586 m
Rides	36
All-Time	
Distance	8,407.7 km
Rides	173
Biggest Ride	222.9 km
Biggest Climb	1,596 m

Figure 1: Example of a training diary summary of a cyclist that was automatically generated with strava.com

Figure 2: Chest strap of a Garmin Forerunner that measures heart rate with two electrodes that acquire an EKG signal.

Figure 3: An optical heart rate sensor of a Microsoft Band 2 with light emitting diodes.

handwritten. Similar to professional athletes, they use it to log data about their workouts, competitions and to define personal goals. If used correctly, it can be a helpful tool to learn from mistakes and adapt personal training strategies over long-term.

As there generally exists no one-size-fits-all approach for training, keeping track of this data is necessary to understand individual differences of how the body responds to certain stimuli. But rather than using the training diary for planning, in many cases, it acts as a source of motivation. For example, keeping records of personal successes, best times and total distances can help to keep on going. The basic elements of a training diary are training duration, frequency, and intensity.

While training duration and frequency is in most sports objectively measurable, the training intensity is often not. Duration is usually tracked by measuring the total elapsed time or traveled distance. On the other hand, training frequency can be assessed by counting the workouts per week. The intensity of a workout can roughly be estimated when combining data like speed or pace and elevation.

20 years ago, heart rate monitors were commonly considered as expensive training tool, almost exclusively used by professional athletes. The first mobile device for measuring the heart rate, the PE 2000, was introduced by Polar Electro in 1983. Since then, heart rate monitoring became mainstream. Today, almost every fitness band, smart phone running app, or GPS watch offers live monitoring and tracking of the heart rate either by using chest straps that measure the EKG signal or optical sensors at the wrist (see Figure 3) that measure the changes of by absorbed light by the blood (see Figure 2).

Many people use their heart rate as an indicator for their training intensity. Although monitoring the heart rate might be helpful as an indicator for the workout intensity during a single workout, it cannot be used to in post-analysis to compare inter-workouts intensities, e.g. of a workout with the one in the week before.

Related Work

In psychology, there have been early efforts to quantify subjective efforts to be able to better understand how people feel taking into account their individual differences [1, 2]. Pure physical work can be measured in watts whereas the the Rated Perceived Exertion (RPE) quantifies the “ resulting work-related strain, defined as the effect of stress on the individual, which depends on each individual’s pre-existing condition“ [3]. It indirectly is a way of measuring the subjective physical activity intensity level by asking the participant how hard the workload is on her or his body (see Figure 4). The individual rating is usually influenced by the perceived changes of body functions, such as an increased heart and breathing rate, and muscle fatigue. The chosen range from 6-20 is to hint towards heart rates of younger adults retrieved, if the rate is multiplied by ten. The numerical RPE scale reaches from 6 - “no exertion” to 20 - “maximal exertion”. In lab studies the participants must choose a number from the scale during the physical activity, which best describes the current intensity level. It has been found that the RPE scale corresponds very well with lactate accumulation during cycling exercise on an ergometer [4].

A fundamental problem in asking for the RPE is which period is taken into account by the participant when the workload varies. Kakarot & Müller investigated how varying workloads could be integrated into a single RPE assessment when intensities were either decreased or increased over time. The authors found the perceived exertion to be significantly higher in series with increasing intensities [3].

Rating	Perceived Exertion
6	No exertion
7	Very, very light
8	
9	Very light
10	
11	Fairly Light
12	
13	Somewhat hard
14	
15	Hard
16	
17	Very hard
18	
19	Very, very hard
20	Maximal exertion

Figure 4: The 15-grade scale for ratings of perceived exertion, the RPE scale by Borg.

It is further relevant for the design of an interface for assessing RPE if intervals at different intensities gain the same attention by the athlete. Either all intensities can be equally weighted or the ratings were determined entirely by the last intensity [3]. This directly if the RPE interface triggers at specific interval or, e.g., after peak intensities such as climbs.

Interface Concepts

In the following, we propose two interfaces for assessing the RPE during workouts. Each interface is meant to meet the specific requirements of the sport aiming for accessibility at high intensities.

Cycling

In cycling, our design is inspired by the physical buttons used for electronic gear shifting systems, such as Shimano Dura Ace Di2 (see Figure 5). These have a natural affordance though clearly communicating the cyclist an up and down analogy. Feedback about the selected RPE is provided on display mounted at the center of the handlebar. To initiate an RPE measurement, the athlete presses either the down or up arrow and the minimum RPE gets displayed. To increase the RPE number, it is possible to hold down a button for a fast automatic increment or decrement. Thereby, the user can make a rough selection of the target RPE range, followed by a fine grained single-button-press choice. The design decision for physical buttons, which provide tactile feedback, is motivated by the necessity to tightly hold the handlebar at high intensities. Going uphill, cyclists tend to apply reaction forces at the handlebars when they remained seated on the saddle [5]. Therefore, they cannot take a complete hand away from the handlebar to interact, e.g., with a touchscreen mounted at the handlebar. Thesee

Figure 5: An RPE interface mockup for cyclists

buttons can be operated with a single thumb, while keeping the rest of the hand closed.

Moreover, the selection process can be initiated by the cyclists with requiring only a minimal visual reassurance of the selected number on the display. Finally, after a timeout of three seconds, the selected RPE will be sent away via Bluetooth LE. Feedback is provided on the display and after a successful transmission, the display gets cleared. The RPE that is assessed that way, is marked with the timestamp of the first button press of the session as this is the point when the athlete likes to enter the information she or he has in mind.

Running

For the concept of the running prototype, we decided to use smart-glasses with an integrated heads-up displays,

Figure 7: RPE Interface for running using the Recon Jet smart glasses. The swipe forward increases the RPE level, while a swipe with finger backwards decreases it.

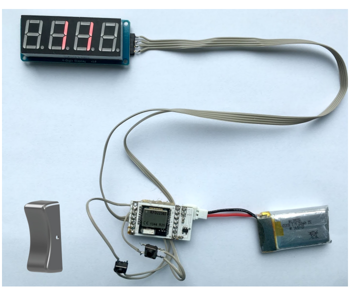

Figure 6: Cycling prototype built with an RFduino, a 7 segment display and two PCB buttons and 3D model of a rocker switch.

specifically made for sports, e.g. Recon Jet[1].

The heads-up display is equivalent to a 30 inch screen viewed from 7 feet (2 m) away. The RPE number can be increased by a swipe gesture forward and decreased with a swipe backwards (see Figure 7). The gestures are recognized by an optical touchpad sensor which still works when wearing gloves and in bad weather conditions. The combination of swipe gestures and heads-up display may also has an advantage at high intensities. For example, motion blur leads to bad readability of small fonts and wristbands or running watches. We believe the heads-up display provides better visual feedback as it is directly attached to the head. Additionally, we think that the swipe gesture is preferable over button presses or touch interaction, since it requires less precision. The RPE view should be integrated within the menu of the Recon Jet to be able to access basic information, e.g. total distance, time, and current peace. Additionally, when sharing RPE as part of a track, followers can easily identify sections of high and low effort and adapt their plans based on this information to plan their workouts.

Conclusions

In this work, we proposed two interface concepts for assessing the Rated Perceived Exertion (RPE) during high-intensity activities. Currently, we work on prototypes to conduct user studies to evaluate the concepts. Figure 6 shows the current prototype for cycling. We are confident that assessing RPE not only in lab studies but also during workouts improves the comparability of the personal training workload. Also we think that RPE measurements can provide a reliable way for self-assessment that is preferable over heart-rate monitors and therefore should be included in training diaries.

[1] http://www.reconinstruments.com/products/jet/

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