Running with technology: Where are we heading?

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ABSTRACT
Running has become popular in recent years, and numerous runners utilize wearable technologies in order to improve their run training. This paper investigates the development and trends in technologies used for run training, and describes how these are changing from solely focusing on the performance (e.g. pace) to having an additional focus on the technique (e.g. foot strike type). Based on this investigation, we present a design space for run-training technologies. By plotting existing technologies onto the design space, we argue that there has been limited attention on how to utilize technique-related information in run-training interfaces. From that finding, this paper presents three questions to be addressed by designers of future run-training interfaces. We believe that addressing these questions will support creation of expedient interfaces that improve runners' technique and training.

Author Keywords
Running technologies, interactive sports-training systems, exertion interfaces, running, sports.

ACM Classification Keywords
H5 m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

INTRODUCTION
According to Running USA ("Running USA"), the number of runners in the US has been increasing every year since 1990, and with advancements in ubiquitous computing and sensor technologies, the development of equipment supporting runners during training has grown as well, illustrated by the increasing number of available GPS sports watches. The main focus of these run-training interfaces has been on pace, distance, route and heart rate covering the performance of a run. Interestingly, recently other aspects related to the technique of the runner have been integrated in the technologies. Running technique or running style refers to the process of running or the kinematic features of a run, e.g. how the runner's feet hit the ground, stride length and frequency, the runner's posture etc. These factors are important as they affect the running economy, e.g. how efficiently a runner runs (the amount of energy used for each step), the risk of injuries and ultimately the performance result of the run (Novacheck, 1998). However, in spite of the emerging abilities to sense running technique aspects, limited attention has been paid to the way runners interact with these technologies and how these interactions should be designed. Nevertheless, an emerging interest in interactions during sport in general is evident from special interest groups (Mueller et al., 2013, 2014) and workshops (Nylander et al., 2014) at HCI conferences.

This paper provides an overview of the development in run-training technologies and proposes a design space for these technologies. By evaluating a plot of existing technologies onto the design space, we argue that limited attention has been paid to technique-focused run-training technologies that assist runners in their movements. Thus, this paper aims to guide future research within the area of human-computer interaction and running by raising three questions related to creating interfaces that assist runners during runs.

EXISTING RUN-TRAINING TECHNOLOGIES

Traditional run-training interfaces
Since 2000 several watches specific for runners have emerged, e.g. Garmin, Polar and Suunto ("Garmin | Forerunner 220/620", "Polar Global", "Suunto"), utilizing various technologies, such as GPS, heart rate monitors and accelerometers. These devices can be used to collect different information about a run, e.g. pace, time, heart rate and distance. The information can be provided to the user, either on the watch display during the run, or as a detailed overview on a computer screen post-run. Smart phone running applications (SPRA), e.g. RunKeeper and Endomondo, have adapted the concepts from running watches by utilizing built-in GPS and accelerometer to track the runner's performances and present the data on the phone screen or on a website after the run. Furthermore, both running watches and SPRAs have started to integrate training schedules in their interfaces, so they can assist the runner during a training session, e.g. by alerting the runner if he/she runs slower or faster than the session-determined pace.

Both running watches and SPRAs have become popular with runners of all skill levels ("7 fitness apps with 16 million or more downloads"). However, these technologies often have a primary focus on running performance, e.g. time and distance, and focus less on running technique. The vast amount of websites giving advice on how to train and reform running style indicate a strong interest by amateur runners, who do not have access to a personal coach, to improve their running

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technique in order to improve their results ("Runner's World", "Running Technique Tips").

Technique-detecting technologies

The recent advancements in the field of wearable computers have made it possible to measure different parameters of running technique. By using wearable sensors and camera-based motion detection, researchers have shown that it is possible to determine technique parameters such as foot strike type (FST), ground contact time (GCT), cadence, vertical oscillation (VO) and knee flexion-extension angles, (Altman and Davis, 2012; Eskofier et al., 2013; Jakob et al., 2013; Strohrmann et al., 2012, 2011), thereby making it possible to profile running styles, identify opportunities for improvements and recognize fatigue indicators. However, the technique-related parameters measured by the sensors are primarily made available to the runners after the run, often as a kinematic analysis. Thus, as feedback is unavailable during the actual movements, it is hard for runners to adjust their running style accordingly. Despite the fact that some of the technologies are detecting the technique-related parameters in real-time, limited work exists on how to utilize the information to create assistive interfaces, e.g. systems that assist runners during the execution of running movements.

State-of-the-art running watches, e.g. Garmin Forerunner 620, also offer information on the technique, such as GCT, cadence and VO. As a result, the runner is able to inspect these technique-related parameters as numbers on the watch during the run. However, we found by using these watches that it can be difficult to relate, understand and utilize this information to improve running technique. Furthermore, we find that continuously addressing the watch during a run, in order to observe the effects of movement corrections, is inexpedient and ultimately risks inciting an unfavorable running style.

Real-time assistive interfaces

In order to utilize detected technique-related parameters and meet the communicative challenges constituted by the dynamic context of running, we believe that there is a need to investigate alternative feedback methods and mechanisms that differ from conventional screen-based information interfaces.

(Strohrmann et al., 2013) present a wearable sensing system for runners, which uses tactile feedback. The system alerts runners if their arms have inexpedient movements, which can affect the running economy. Thus, the system acts as a ubiquitous running coach, giving feedback on a part of the running technique in real-time.

Eriksson and Bresin uses auditory feedback to alert runners during a run if their vertical displacement is above a predetermined target value (Eriksson and Bresin, 2010). The vertical displacement relates to the work the runner has to do against gravity in each step. Hence, a low vertical displacement should result in an improved running economy, as energy is used to move the runner forward instead of upward.

The Sensoria Fitness Socks (SFS) is a commercial product, which uses pressure-sensing socks, with the ability to measure FST and cadence, and transfer the measurements to a smartphone application ("Sensoria Fitness"). The application then uses auditory feedback to alert runners if they diverge from user-determined run characteristics.

Strohrmann, Eriksson and Bresin and SFS all propose alert systems that alert runners if a movement is inexpedient. However, realizing how to correct an erroneous movement and to what extend it needs correction is difficult based on this discrete feedback (Sigrist et al., 2013). Thus, as technique-related parameters are becoming detectable in real-time, run-training interface designs should utilize this to assist runners in their movements, rather than representing the movements as visual information on a screen post-run.

DESIGN SPACE FOR RUN-TRAINING TECHNOLOGIES

Based on the presented run-training technologies, we now present a design space for run-training technologies. The design space is based on two axes: The focus axis and the feedback axis. Besides presenting a design space, this section also presents a plot of existing technologies in the design space and highlights an area for future investigation.

Focus axis

The focus axis represents a continuum from performance-focused technologies to technique-focused technologies (see Figure 1).

The performance-to-technique continuum

At the performance end of the continuum, focus is on the running performance, e.g. factors such as pace. Heart rate data is a performance related factor as it is not representing the performance result as such, but indicates the runner's physiological state that relates to the performance. Moving into the technique half of the continuum, factors such as GCT, cadence and VO appear. These are direct outcomes of the running technique, and represent effects of physical movements, but not descriptions of the movement itself. At the technique end of the continuum, the focus of the technologies is on the biomechanical execution of the run. This includes factors such as FST and knee flexion-extension angle that describes the kinematic movement of the runner.

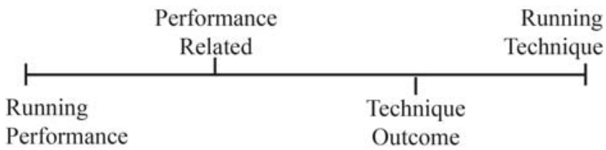

Figure 1. The performance-to-technique continuum illustrating the focus axis.

Feedback axis

The feedback axis represents a continuum from representative to assistive feedback (see Figure 2), illustrating how feedback can vary from representing the run to assisting runners in their movements.

The representative-to-assistive continuum

At the representative end of the continuum sits technologies that solely present the runner with representative feedback about a run, often in the form of numbers, e.g. distance represented in kilometers or FST represented in percentages. Contextual representative feedback is slightly more assistive, and refers to combining different data to provide the runner with a better understanding of coherences between the measurements, e.g. by correlating a route map with different paces or correlating elevations with cadences. Moving into the assistive half of the continuum, feedback is provided to the runner in real-time to assist movements as they are executed. Examples include systems that provide alerting feedback and thereby assists the runner to detect that a certain factor deviates from the expected, e.g. a running watch warning about a drop in pace or a haptic alarm detecting inexpedient arm movement (Strohrmann et al., 2013). At the assistive end of the continuum lie the assistive technologies that not only alert the runner when a behavior is inexpedient, but also indicate the magnitude of the inexpediency and assist the runner in correcting their behavior. These systems exist as virtual coaches within performance-focused run-training interfaces, e.g. ("Help2Run") that keeps track of a runner's training schedule and training sessions, adapts the schedule in relation to weekly results and continually assists the runner during training sessions.

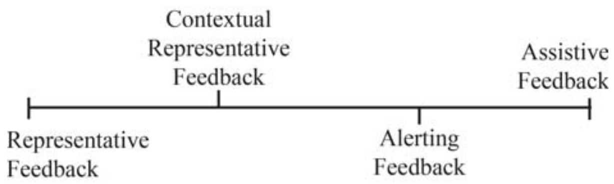

Figure 2. The representative-to-assistive continuum, illustrating the feedback axis

Existing technologies in the design space
Figure 3 shows existing run-training technologies plotted onto the proposed design space. The figure shows that kinematic analysis tools, which investigate running technique features, and SPRAs and running watches, which gather information on running results, reasonably cover representative feedback systems. Some SPRAs and watches also provide performance-focused feedback in an assistive way in real-time. However, providing assistive feedback to the runner about running technique features is not well explored. This area primarily contains the aforementioned alert systems. Thus, we argue that there is a need to investigate how we can provide complex technique-related feedback to the runner in an assistive and expedient way. This will enable creation of run-training interfaces, which potentially improves the running technique, reduces the risk of injury and improves performances of runners.

DISCUSSION
In this discussion, we highlight three questions on modality, data representation and temporality that we believe need to be addressed by interaction designers, in order to develop expedient run-training technologies that can assist runners in improving their running technique.

Modality: How to interact?
As described previously, it can be cumbersome to use the screen on a running watch as interaction platform for guiding running movements. Thus, auditory interfaces have been adopted by run-training technologies. However, depending on the information that is to be communicated, the choice of modality should always be examined carefully in correlation to the actual message. For example, if the message is the pace during the last lap, an audio message seems sensible, whereas for informing the runner whether his/her knee moved too high, a haptic signal might be more appropriate. Furthermore, Sigrist et al. argues for the use of multimodal feedback in motor-learning as it potentially supports learning several aspects of a complex movement simultaneously (Sigrist et al., 2013).

Data representation: What information?
When aiming to assist runners in improving their running technique, additional challenges arise in terms of what information is communicated. For example, most runners do not have sufficient motor skills to change their foot strike type from rear to front, merely by getting information about where they land, as provided by SFS.

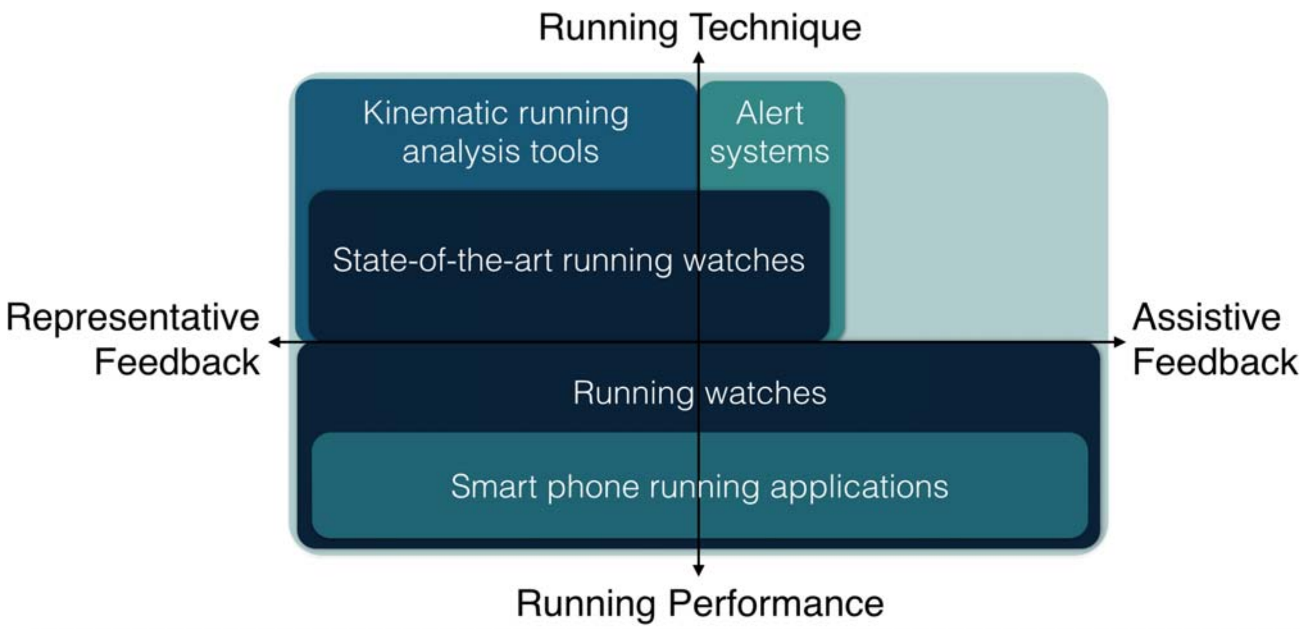

Figure 3. A design space of run-training technologies plotted with existing technologies

Instead, designers of assistive run-training interfaces should learn techniques from run coaches, who encourage runners to “take smaller steps” or “look down the valley”, in order to change their running style. Another approach is to investigate the use of sonification, where variables are mapped to sound parameters. By using sonification, the runner is not only alerted when something is wrong, but is additionally informed on how it is wrong (Godbout and Boyd, 2010). However, we believe there is a need to explore these different interaction techniques and investigate their effects on runners. Furthermore, designers of assistive run-training interfaces should be careful not to introduce unexpected, inexpedient behavior inferred by the information provided to the runner (Jensen et al., 2014).

Temporality: When to assist?

Besides determining an assistive data representation and a suitable modality, the temporal aspect of feedback should be considered as well. Constantly providing the runner with information presumably reduces the user experience of a training interface. Periodical information, e.g. at every lap, is suitable for some parameters, however, in other instances the runner might want immediate feedback on movement changes. Alerting feedback systems assist the runner to avoid inexpedient movements, however, it might be demotivating for runners to get only negative feedback. Self-controlled feedback has shown positive results in post-performance, feedback systems (Sigrist et al., 2013), however, it is not trivial to transfer those concepts into the complex and dynamic environment present during runs.

CONCLUSION

In this paper, we outlined the recent development in run-training technologies and proposed a design space, illustrating the focus of existing systems. Based on a plot of existing technologies onto the design space, we argued that there exists a need to investigate how to create assistive, technique-focused, run-training interfaces. We also presented three questions to be addressed by designers of future run-training interfaces. We believe that addressing these questions will support creation of interfaces that can improve runners’ technique and training in general.

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