Designing for Movement – the Case of Sports

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ABSTRACT
We have identified six themes we identified as interesting for future work in movement based interaction design for sports: the central position of the subjective feeling, the core of sports is enough, feeling did not prevent injury, non-interpretive representations, the shortcomings of logging biodata, and temporality of feedback. The themes are grounded in technical explorations for golf and running and a set of interviews with athletes. Here, we outline findings from our work to illustrate these themes.

Categories and Subject Descriptors
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

General Terms
Design.

Keywords
Movement, sports, interaction, design, sensors, feeling, accelerometer data, interviews.

1. INTRODUCTION
Body control, awareness of how the body is moved, and precision in the body movement is central to successful performance I nsports. One of many things athletes need to learn, is to be aware of exactly how they are moving and how that affects the technique of their specific sports. Thus, a key skill for athletes to develop is the perception and awareness of how they are moving and how that links to their performance. A major challenge for anyone aiming to contribute to the improvement of athletes' abilities is to support them in developing a correct 'feeling' of a technique, and for the athletes to perform and appropriate it, thus developing their own sense for the desired movement. The traditional way of improving such skills is through instruction combined with a large amount of varied exercise with and without specific devices. Dedicated training devices and methods are used, e.g. golf clubs with whippy shafts or cross country skiing without ski poles, as well as general purpose tools such as mirrors, video capture, and to a certain extent traditional performance measures such as time, speed etc. can support in the development of such perception and skills. In most sports, special purpose tools such as high speed video technology and motion capture are used to analyze the specific movement patterns of an athlete. Recently, we have started to see dedicated light-weight interactive technologies that can be used during the real time performance of a sporting activity. This has led the CHI community to address interactive technology in sports as an emerging area. Following the overall trend of research in bodily interaction [27], exercise, motivation, and well-being [1, 6, 34], we now start to see work that deal with actual sports and their performance e.g. [30, 32] and the 2013 SIG *HCI with Sports* [20].

We are interested in the actual performance of the sport, and how mastering the technique of specific sports can be supported through the use of mobile technology. We have initiated this work through technical design explorations as well as through ethnographically oriented interviews on current use of consumer products for sports.

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2. THEORY
Much current interest in corporeality and kinaesthetics in interaction design has emerged from theories of the role of bodily practices in meaning making and human thinking. In particular, the philosophies of Merleau-Ponty [17], Sheets-Johnstone [28], and Shusterman [29] have been explored in order to understand how they can practically inform design of bodily engaging technologies. In our work we have taken specific theoretical starting point in Merleau-Ponty's [17] phenomenological perspectives on action and perception. Merleau-Ponty attempted to explain human perception in a non-representationalist fashion with a focus on our corporeal existence and how the specific characteristics of our bodies shape our perception, sense-making, and action. In explaining human perception Merleau-Ponty did not make a separation between body and cognitive processes letting one come before the other. Rather, he aimed towards showing how these are an integrated couple in a dynamically perceiving *experiential body*. Maxime Sheets-Johnstone's phenomenology of movement is an even more radical attempt to put body and movement at centre stage of human cognition. She extends the ideas of Merleau-Ponty by arguing not only for the corporeal grounding of perception, but placing specific emphasis on how movement of the body should be taken as the essential characteristic from which thinking and perception are built. Rather than viewing body movement as being controlled by mental processes, she proposes movement as the basis for cognitive processes, through the notion of *thinking in movement*. According to this, sensing the world and acting in it do not belong to two separate domains, but are part of the same experiential world. Thereby, she denies the idea of separating thinking from its expression, and the claim that a thought in the head exists prior to its expression, and instead argues for the idea that thinking and acting are integrated dynamic process created in a mindful body. We believe that these perspectives challenge how we should

investigate and theoretically approach experiential aspects of design and use of interactive artefacts by shifting focus towards experience as a phenomenon grounded in bodily experiential qualities, and away from cognitively oriented perspectives. In design-oriented research we see an increasing number of attempts that start out from the perspectives. Examples of recent work addressing these challenges are [27, 35] that explore the implications of pragmatist and phenomenological theories to develop design approaches for bodily engaging technologies. Further examples include those that map out experience-based interaction qualities such as suppleness [12] and pliability [15] , as well as design frameworks for understanding the physiological dimensions of the body in interaction [8] bodily aspects of human action and perception, and ways of making these relevant and usable in design [10, 33]. Our work attempts to further contribute to these attempts through practically oriented design work in the area of HCI and sports. By specifically considering these theoretical perspectives in our design work, we hope to further reveal how the role of the body in experience and how it can be made relevant in interaction design research in general, and sports specifically.

3. RELATED WORK

Along with health-care and wellness, sports and recreational activities constitutes one of the most rapidly growing areas of personal and consumer-oriented cloud computing-based technologies with a turnover of $200 billion only in the US. This is visible through early introductions of mobile sensor-based end-user products such as the Nike+, sensor equipped sports watches, apps like Runkeeper, and how these connect to social and broadcasting media. The area is still in an early phase of development based on first generation technologies and infrastructure, but is constantly refined and improved due to rapid market expectations and new technical opportunities. Emerging products, such as smart watches, glasses and sensing textiles will also pose new requirements on interaction design as well as providing novel design opportunities.

A survey of existing work in interaction design reveals that authentic sports is a mostly unexplored domain within interaction design and provides a set of challenges and opportunities that will push the field forward.

We classify the body of existing work in the broad categories of technical exploration, bodily interaction, new forms of play, and socio-motivational systems.

Technical exploration work is mainly devoted to exploring the technical potential of sensors in the context of, e.g., wearable computing. Work in this category, e.g. [3, 5, 18, 36], is related to sports in the sense of enabling technologies, but it is generally marked by the absence of fieldwork and experiments in the wild.

Bodily interaction refers to work where the aim is to create innovative interaction techniques. Illustrative examples include using heart rate or breathing patterns to play games [23, 31, 37] and music [26] as well as new gesture interaction [4]. This category of work, which is fairly well represented in the recent literature, sometimes uses sports as a related application domain among many.

New forms of play is perhaps the most common type of more or less sports-related work in recent interaction design. The literature offers a wide range of examples where the playful, competitive and motion-based character of sports has inspired new, ICT-enabled forms of play such as exertion games [19], and a similarly varied range of examples using ICT-enhanced sports equipment as props for new forms of play, e.g. [7, 13]. Recent work on motion-based interaction and ICT-enhanced movement in domains such as dance or computer games [11, 14, 27] can also be seen as tangentially related to sports.

Socio-motivational systems refer to the use of ICT to motivate people to move or exercise, for example by providing social support [2, 21, 22], or through gamification [6]. Social consumer services for planning sports (biketastic) and managing exercise (adidas micoach), as well as general activities and achievements (lifekraze) also belong in this category, which is largely distinguished by focusing on creating social and/or competitive layers for motivation rather than engaging deeply with augmenting the sports activity as such.

Thus, when it comes to supporting, enhancing or augmenting actual sports through deep engagement with the details of their execution, it turns out that very little work has been reported. Isolated examples include the iSport project in Århus [9, 16] leading to an innovative training device for advanced psychomotor skills in handball; the work by Stienstra et al. [32] on sonification of speed skating; and Spelmezan's [30] system for snowboarding instruction.

3.1 METHOD

To start exploring the domain of sports and interaction design, we have worked in parallel with technical design explorations and deep interviews. We have built two systems, one for golf and one for running, and we have conducted ten deep interviews on how people use existing consumer products for sport such as heart-rate monitors and GPS watches. Below, we will briefly describe the systems and how we conducted the interviews.

3.2 SwingSound

SwingSound [25] is implemented as an iPhone app using an external sensor attached to a golf club that sends accelerometer data to the phone, see figure 1. The phone generates an audio mirror and plays it back to user as feedback. We implemented a direct mapping of downwards acceleration of the club to pitch of the sound feedback, compensating for gravity. Higher acceleration generates a higher pitch sound. The system has been tested in three single user sessions and one group session.

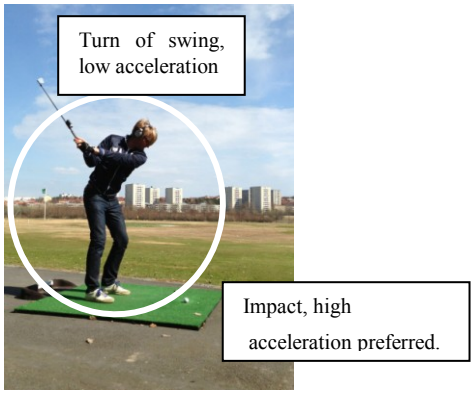

Figure 1: After the turn of the swing the acceleration increases reaching maximum sometime during the down swing. The higher the acceleration the higher the pitch

3.3 RunRight

RunRight [24] is a system that gives feedback on running technique, implemented as an Android app that used a wearable accelerometer sending data to the phone, and generated and displayed graphical feedback on the phone. We implemented a non-interpretive visual representation where each accelerometer reading is mapped to a star in a two dimensional grid, see figure 2. The system does not interpret or value the data in any way, but lets users create their own interpretation.

The visualization is created during a ten second window and shows the acceleration in the horizontal and the vertical plane. Stars go paler and fade at the end of the ten second window. The system logs data on the phone to allow post-analysis if desired.

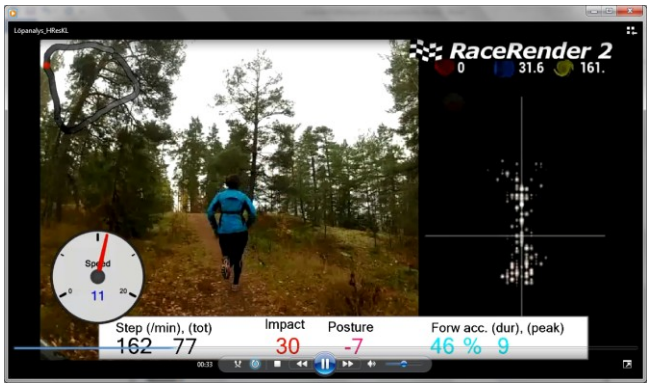

Figure 2: Data from RunRight, including visualization, the Zephyr heart-rate monitor, and head camera shown together.

3.4 Interviews on practices with current technology

We conducted seven interviews with advanced recreational athletes and three elite athletes. The advanced recreational athletes exercised 3-7 times a week and the elite athletes had 9-13 sessions a week. Their main sports were running and cross-country skiing.

The interviews were conducted in locations suggested by participants and lasted about an hour.

Participants were asked to bring their technology, and possibly documentation of their exercise. The most common technology used was heart-rate monitors in combination with GPS watches. Video analysis tools and specific tools for analyzing GPS trails were also used.

4. THEMES FOR FUTURE RESEARCH

Below, we will outline some aspects we have found interesting in our research when it comes to sports and movement and that we would like to pursue further.

With respect to the individual bodily experience of performing sports, our work so far has pointed us to the central role the subjective feeling of the activity plays in the performance of sports and how important it was for our participants to focus on their sport without being distracted. We also noted that many of our participants had had problems balancing their exercise since a majority of them reported being injured.

With respect to design and computational modeling of sports we will discuss our experiences of non-interpretive feedback that allows users to make their own interpretation of the system feedback as well as different aspects of temporality that comes into play when designing for sports. We will also discuss the limitations of current consumer products for sports. Finally we will describe how our system for running has been transferred to other sports.

4.1 The Subjective Feeling is Central

Our interviewees constantly came back to the importance of having the right feeling during exercise. They all used heart-rate monitors and GPS watches and the majority of them had structured exercise plans which usually contained a level of exertion in terms of a target heart-rate, heart rate threshold, or heart-rate interval. However, they reported that the common way of using the feedback from the heart-rate monitor was to confirm their own experience or feeling of the situation. They claimed to be able to accurately feel that they were at the targeted level of exertion without technical support but still appreciated the confirmation they could get from their devices.

From the interviews we conclude that technology cannot replace the knowledge and subjective inner feeling that is needed to perform well. To some extent technology can help athletes in constructing this feeling by providing external feedback with measures that they can use to interpret their own feeling, e.g. compare heart-rate to subjective exertion.

4.2 The Core of Sports is Enough

A second interesting theme from our interviews was that our participants wanted to focus on their sports activity with everything that comes with it such as exertion, challenge, pain as well as nature, peacefulness and weather. They were not interested in being distracted from this by using services like Run zombie, run! or listening to music. This is a gap in existing consumer technology for sports and a rather sparsely populated design space even in research. We believe there is room for more research around the details of executing various sports and support athletes' engagement in details of technique.

4.3 Feeling did not Prevent Injury

Despite our participants' confidence in having a nuanced subjective feeling of how they were doing during exercise and how it should feel when they were doing well, a majority of them at the same time reported being injured in various ways. It seemed like their enthusiasm for their sport sometimes took them beyond the limit for what their bodies could take, even though none of our participants were extreme athletes.

We believe there is room for designing technology that helps people balance their exercise, support them in developing a technique that does not cause injury, as well as supporting rehabilitation.

4.4 Non-Interpretive Representations

Based on the themes presented above, we believe that technology for sports perhaps should focus more on supporting athletes to construct their subjective feeling rather that provide objective measurements which is what most of the consumer products are doing. In the research community, there are some attempts to create systems that give instructional or correctional feedback on specific aspects of certain sports (e.g. [3, 30]). We have taken a different path in this. Our systems provide a mirror of users' movements, for SwingSound manifested as sound and for

RunRight manifested as a visualization. The feedback from the systems to the athletes are based on a dynamic and continuous mapping of the movement to the feedback, without interpretation from the system. By letting users interpret the feedback themselves, engage with the activity and reflect over their movement we believe that the technology can support them better in improving their body awareness and constructing their inner subjective feeling. In addition, a mirroring feedback does not depend on users doing "the correct" movement to generate meaningful feedback but encourages experimentation.

4.5 The Shortcomings of Logging Biodata

A majority of our interviewees always used a heart-rate monitor and GPS to log their exercise sessions. They all saved their data, and many of them uploaded their data to the online community of their heart-rate monitor provider such as Polar or Garmin.

What struck us was that they did very little analysis of their collected data, and used very small subsets of the functionality their technology provided. This is perhaps significant for the current generation of consumer technology for exercise, focus is on planning and data collection, while the parts of exercise where athletes need the most support is on execution and analysis. Some of our participants had coaches, but not even the coaches looked at the collected data to any extent. The participants who kept a diary of their exercise mostly looked at their own personal comments when they went back and analyzed.

To us it is obvious that today's technology makes it easy to collect biodata such as heart-rate, and contextual data such as speed, distance, GPS trail etc. but most athletes need support to understand, interpret and make use of this data.

4.6 Temporality of Feedback

Several aspects of temporality is relevant for the design of interactive sports technology. Firstly, the studies of SwingSound and RunRight showed tensions between athletes' attention on the activity and their attention on the technology. On a more general level, this means that timing of feedback given during the activity must be tweaked according to specific requirements of the activity. This pinpoints the difference between experiencing externally introduced feedback and focusing on the activity as such. This can be described as interactive technology requiring athletes to shift between an internal and external locus of attention. This is a factor that needs to be taken into account in interaction design for sports technology. Feedback that allows athletes to shift their attention in ways that do not interfere with the activity makes it possible for them to connect the experience of their technique with the external feedback and thus improve their awareness of the movement. If the feedback does not allow for the shift but instead distracts the athlete, it will not contribute to an improved technique.

Another aspect of temporality regards how the duration of the feedback maps to the duration of the performed action. For rapid non-cyclic movements, such as a golf swing with a duration between one and two seconds, it turned out to be difficult for athletes to handle a one-to-one mapping between the duration of the swing and the duration of the feedback. In SwingSound, the one-to-one mapping we initially used was often so short that players did not get sufficient time to interpret and relate it the action just performed. In RunRight on the other hand, we created a representation of the running that was not a moment's snapshot but that captured a window of ten seconds. This made it possible to see changes in the technique over those ten seconds.

4.7 Transfer to Other sports

As a final reflection we might mention that we have tried to apply the visualization of accelerometer data in RunRight, designed for running, to other sports. Horseback riding is a sport where control of the upper body movement is important, and RunRight has shown to be promising in giving feedback to riders, see figure 3.

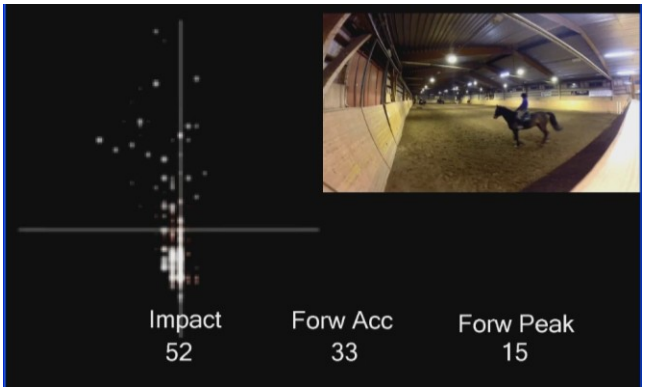

Figure 3: Data from RunRight worn by a rider.

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6. CONCLUSIONS

Our current interview studies with endurance athletes as well as our early empirical work with golfers and runners both suggest that athletes want technologies that are true to their sport, and not those that transform the activity into something playful or game-like. This stands in contrast to the pre-dominant approach of much technologies in this area such as the highly successful "Zoombies, Run!" or the early "PingPongPlus" from MIT MediaLab. The endurance athletes for instance emphasized that the experience of painful elements such as fatigue and lactic acid gave them a sense of achievement that were central to their enjoyment of the sport, and hence not a part of the experience that they would want technology to "design away". In a similar vein, the golfers from our workshop studies were open not only to specialized training aids but also to new forms of playful competitions and practice, but they still repeatedly emphasized that interactive technology should not step over the boundary so that the activity would be redefined into something different. The nature of this 'boundary' is not clear-cut for all users, but supposedly varies between situations and kinds of sports. Our interpretation of these findings is that there is an unexplored space that regards the design technologies that give users "more of the same", technologies that start out from such central elements and thereby give athletes an even stronger connection to their sport.

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