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Contents

A Framework for Interactive Sport Training Technology

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ABSTRACT

Participation in organized sport has many physical, mental, and social benefits, but there are a variety of obstacles in joining and continued participation including access to adequate coaching, equipment, and training facilities. These obstacles lead to inequitable access to high-quality and engaging training, which is a critical problem because adequate training is the main gateway to learning and participating in a sport. Increasingly, technology is used to augment sports training by improving its effectiveness, accessibility, and/or making it more engaging. However, the vast and disparate number of fields contributing to these advancements make it difficult to comprehensively understand technology's current and potential impact on sport training. This review synthesizes work across fields, including human-computer interaction, computer science, sport science, engineering, psychology, and health sciences, into a classification of research and findings regarding interactive sport training technology organized around four characterizing dimensions: (1) Why augment sport? (the goal); (2) Which sport skill is being supported? (the target); (3) Which training method is used?

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(the method); (4) How is training augmented (the form). From this synthesis, we identify gaps in training technology research and propose a framework that can provide a common base for the design and creation of future interactive technologies for sport training.

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Introduction

Organized sport encompasses a diverse set of activities that promote physical activity, social connections, and economic stimulation through both recreation and competitions [2]. Despite clear societal benefits, barriers to participating in or enjoying a sport exist, including tedious and time-intensive training, expensive equipment and facility requirements, slow proficiency development, and/or discrimination (e.g., based on gender, race, or economic status). Coaches and sport scientists have addressed these problems in a variety of ways, often using new technology. The use of digital technology to improve the experiences of sport stakeholders can broadly be considered "sports interaction technology" [194], although the term is most often used to describe games or other applications that promote vigorous exercise or motor learning through gamification [70], [159], [176].

While these are valuable conceptualizations for envisioning technological solutions to overcome barriers to participation in sport, they overlook many important aspects of what athletes spend most of their time doing: training. Training encompasses a variety of activities that hone an athlete's physical and cognitive capabilities. An athlete's performance in competition is highly correlated to the effectiveness of their training regime [166], [265]. Due to the prevalence and importance of

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training in sport, special consideration should be made for the application of digital technology to support sport training. Furthermore, although there are restrictions to how technology can be incorporated into sport competitions (e.g., banning the use of performance-enhancing swimwear in competitive swimming), it can be freely applied to make training more enjoyable, accessible, equitable, safe, or effective. Sport training is therefore an exciting domain where HCI researchers and practitioners can make meaningful and lasting contributions that help more people engage with and have positive experiences in sport.

This monograph extends prior work in sports interaction technology [194] to create a framework describing digital systems that specifically support sport training, with our framework focussed on athlete-facing systems in particular. For brevity, we will often refer to these systems as "training technology" or "training systems." This encompasses a vast array of sport training activities, from motor skill training to understanding optimal strategy [194]. For example, since strategy is critical to victory in most competitive, team-based sports (e.g., American football or soccer), prior research has developed novel technology to train decision-making skills [61], [94]. Training technology, therefore, is not limited to scenarios that involve exertion (which has been a focus of many sport-centric HCI projects and commercial products such as Zwift [20]). The HCI community has expressed interest in enhancing sport with technology through workshops held at the ACM CHI Conference [179], [208], but previous reviews of the space have also been limited in scope or applicability; see Table 1.1. Specifically, previous HCI work describes training technology in broad strokes that aren't easily actionable or generalizable for the design of new systems [159], [195], or constrain themselves to a small subset of characteristics that limit a reader's appreciation of the possibilities for synergies between sport training and technology [207]. A recent review by Postma *et al.* [194] describes the theory behind many facets of training technology in great detail; however, its focus on defining the breadth of interactive technology in sport led to it overlooking key elements specific to sport training (e.g., injury management, nutrition) and it being difficult to extract practical design knowledge from their framework for designing training technology.

Table 1.1: Description of prior literature reviews related to sport training technology

Title	Scope	Detail of Synthesis	Number of Systems Analysed	Gap addressed by our training technology review
14 Years of Self-Tracking Technology for mHealth—Literature Review: Lessons Learned and the PAST SELF Framework [280]	Self-tracking of physical activity	High	>100	Automated systems, non-physical or motor learning activities
A literature review on the effects of 6-Dimensional virtual reality's sport applications toward higher presence [147]	Virtual reality in training	Low	<10	Other technologies
A literature review on the usage of Technology Acceptance Model for analysing a virtual reality's cycling sport applications with enhanced realism fidelity [148]	Acceptance of virtual reality in cycling	Moderate	<10	Other technologies & sports
A review of research on the Integration of Information Technology and Physical education curriculum abroad [252]	Physical education	Low	<10	Training activities beyond exertion, athlete-focused
A Review on Augmented Reality applied to Sports [233]	Augmented reality in sports	Low	>100	Other technologies
A systematic review of the application of interactive virtual reality to sport [171]	Virtual reality systems	High	<50	Other technologies
Application of applied computer technology in modern sports field [290]	Technology in sport	Low	<10	Detail of synthesis, training focus
Application of Computer Virtual Technology in modern sports training [291]	Virtual reality in sport training	Low	<50	Other technologies

Continued.

Table 1.1: Continued

Title	Scope	Detail of Synthesis	Number of Systems Analysed	Gap addressed by our training technology review
Application of Intelligent Sports Goods Based on Human-Computer Interaction Concept in Training Management [91]	Wearables in sport training	Low	<50	Other technologies
Application of wearable devices in sports: behavior change and result effect [279]	Wearables in sport	Low	<100	Other technologies, applicability of synthesis
Artificial Intelligence Technology in Sports Application: The Chinese Experience [83]	AI in sport	Moderate	<25	Other technologies, scope of training
Augmented Foot: A Comprehensive Survey of Augmented Foot Interfaces [54]	Foot-based technologies	High	>100	Technologies for other limbs, non-physical activities
Big Data Analyses and New Technology Applications in Sport Management, an Overview [152]	Video and wearable systems for training and officiating	Moderate	<50	Other technologies, generalizable to all sports
Construction of Digital Dynamic Sports System Platform Based on VR Technology [273]	Virtual reality in sport training	Moderate	<50	Other technologies
Mixed and Augmented Reality Applications in the Sport Industry [218]	Virtual and augmented reality in sports	Low	<50	Other technologies, training focus
Online Teaching Mode of College Sports Dance Course under the Background of Internet Plus [82]	Technology for dance training	Low	<10	Other sports, non-physical activities

Continued.

Table 1.1: Continued

Title	Scope	Detail of Synthesis	Number of Systems Analysed	Gap addressed by our training technology review
Opportunities and Challenges of Smart Sports Development in China under the Background of 5G [188]	Networks for sport technology	Low	<10	Feedback loop to athlete
Research on the Application of Artificial Intelligence Technology in Physical Training [277]	AI technology in sport training	Low	<10	Other technologies, depth of synthesis
Research on the auxiliary application of computer-based virtual reality technology in sports training [248]	Virtual reality in sport training	Low	<10	Other technologies, depth of synthesis
Role of Wearables in Sports based on Activity recognition and biometric parameters: A Survey [175]	Wearables in sport training	Moderate	<100	Other technologies
The Cost of Reward: A Critical Reflection on the 'What', 'How', and 'Why' of Gamification for Motivation in Sports [196]	Gamification in sport training	Moderate	<100	Other augmentation methods
The Design Space of Wearables for Sports and Fitness Practices [262]	Wearables in sport training	High	>100	Other technologies
Use of Wearable Technologies for Analysis of Activity recognition for sports [225]	Wearables in sport training	High	>100	Other technologies
Exertion games [159]	Exergames	High	>100	Other training activities
Custom-designed motion-based games for older adults: A review of literature in human-computer interaction [70]	Exergames for older adults	High	<50	Other training activities

Continued.

Table 1.1: Continued

Title	Scope	Detail of Synthesis	Number of Systems Analysed	Gap addressed by our training technology review
10 Lenses to design sports–HCI [161]	Motivations for designing physical activity systems	High	<100	Other training activities
Sonification approaches in sports in the past decade: A literature review [207]	Sonification in sport training	High	<50	Other feedback methods

As such, while our monograph may be viewed as a detailed extension of a subset of their work, it is important to note that the frameworks differ in both organization and content [194]. We see value in both perspectives and encourage the reader to engage with their work as well. The focus of our work is to provide a conceptualization of the design space for training technology to make clear where previous work has been done, and where further research is needed. We believe that it is important to distinguish training technology from more general intersections of sport and technology in order to have a comprehensive and actionable framework to describe and envision interactive systems for the important subdomain of sport training. Throughout this monograph, we exemplify how design knowledge can be applied to the design of training technology systems to increase the utility of the monograph for the design of new systems and new scenarios.

This monograph offers insights that can easily be applied to create or analyse interactive systems for sport training. We synthesize works from diverse fields such as engineering, sport science, psychology, and computer science through an HCI lens to develop four main dimensions that characterize interactive sport training technology:

1. Goal: Why augment sport training with technology?

2. Target: Which sport skill is being supported?

3. Method: Which training method is used?

4. Type: How is training augmented by technology?

The remainder of this monograph compiles and synthesizes relevant training technology contributions into a framework based on these 4 dimensions. These dimensions are largely independent of each other, so each section identifies distinct gaps that can be addressed by future training systems. In addition to highlighting gaps in training technology knowledge, we exemplify how one might use our framework to develop new interactive systems to address specific training needs. Our work provides a new starting point for researchers, trainers, coaches, athletes, and system designers to better understand and use current findings

and to identify gaps in the field of interactive sport training technology. Sport provides critical and global societal benefits, and this work aspires to provide actionable information that can facilitate the development of new technology for sport training to make it more equitable, engaging, and effective for future generations of athletes at any level.

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