Towards an Interactive-Movement-Learning Movement

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Abstract: In this position paper we share our view on learning sport specific movements using interactive technology. We build upon our experience with playful and embodied technology for HCI, and link our views to related work from a sport-related and non-sport related view. Aiming to bring these together in new future research on learning sport specific movement, this brings us to address our view on five main points in this paper. One, as the most obvious, the end-user should give input as often as fitting. Two, within this new domain there are different types of contributions focusing on technology, interaction, and context, where each brings its own benefits. Three, to make use of the power of entertainment computing (e.g., gamification) entails more than just "adding points as rewards". Four, one can view new technology in relation to the trainer, ranging from a tool in the hands of the active trainer to a 24/7 available independent "stand-in" for a trainer (being configured and controlled by the trainer); this relation should be taken into account in design and research. Five, technology can of course solve problems (while leaving the core of sports training unchanged), but in order to really *transform* the domain and fundamentally change sports training practice we need to consider that "potential for change" is different from "actually achieving a useful system in-context"; how technology fits the real world and what it actually benefits is not known beforehand. We conclude the paper with an outlook on our research and design activities in the near future, through educational projects as well as research projects.

Keywords: embodied interaction, sports, movement training, play, interaction technology

1. Introduction

In recent decades we have witnessed an enormous increase of technological enhancements in sport. Referees in many sports are now supported with systems like the Hawkeye or video referees. Coaches are supported with data analytic systems. Data is collected from sources such as tracking position and motion of athletes in ice hockey and basketball (cf. Thomas et al., 2017; all NBA teams use SportVU), using object trackers in football, biophysiological sensors in cycling, and match stats (for, e.g., baseball and football; Stensland et al., 2014). Often, the focus is on better understanding optimal body motion or optimal match performance to increase competitive performance. Individual runners, rowers, and cyclist are supported with tracking their performance data with popular apps like Strava and Runkeeper. Furthermore, we see research projects and newer systems where the technology is more and more focused on the *real-time interaction* of athlete and technology during the exercises and is no longer just providing post-hoc feedback. For instance, there are dozens of research projects that use virtual environments to train aspects of sports such as swinging a bat during baseball, throwing a ball during rugby, or goalkeeping during handball, using monitors, projections, and in some cases head-mounted displays to provide real-time feedback (Miles et al. 2012). We view that this step towards real-time interaction, in virtual environments or with other interaction technologies, brings opportunities for transforming how we train people to perform movements.

Nevertheless, adding interactive technology does not automatically lead to improvements in sports practice. That technology *can* be used for training sport skills, does not mean that it *should* be used, nor that it *will* be used. A system that does what the trainer could have done themselves is not necessarily a useful innovation. A system that is only helpful to a sports team when its automatic sensing algorithms function at near 100% perfection is not likely to become a feasible innovation. A system that takes 10 minutes to set up for one-hour training will not be used much. In short, there are numerous factors beyond the purely technological innovation to take into account when researching interaction technology for sports; a critical attitude is needed to develop technological innovations that also have an impact in practice.

In this position paper we primarily focus on real-time systems with embodied interaction ("using bodily movements to control, or interact with, the digital system") for training movements in sports. We discuss related work underlying this domain, including our own past research. Then, we discuss five lessons we have learned over the years. We conclude by reflecting on the near future of our research and education activities in the domain of interactive movement learning.

2. Related work: Playgrounds and digital-physical sports systems

Our work on teaching and learning sport specific movements builds upon embodied interactive playgrounds, systems that use a variety of sensors such as depth cameras (e.g. Kinect), motion sensors (e.g. Wii), and microphones, in combination with feedback equipment (e.g. projections), to offer interactive experiences where bodily motion is used to interact with games (Poppe et al. 2014). Sturm et al. (2008) mentioned four categories of forms that such interactive playgrounds can have: physical (outdoor) installations, a set of digital-physical playgrounds props, interactive floors, and interactive walls. All of these types of systems can be found in literature; for example Back et al. (2016) combine an outdoor installation with mobile digital-physical props; Snibbe and Raffle's early work (2009), preceding many researchers working on similar systems, combines cameras and projectors to make interactive walls and floors; many others can be found in an extensive survey published elsewhere (van Delden et al, to appear 2017b). Hundreds of interactive camera-projection systems for walls and floors are also sold around the world commercially by companies such as Lumo Play, MotionMagix, Play-Lü, and Vertigo systems, and commercial systems also exist of physical interactive outdoor playground installations (e.g. Kompan, Yalp/Lappset, PlayAlive, Playdale, and Playworld®Systems).

Interactive systems can be used to learn sport and movement skills. This might range from detailed form and timing of movements, power and endurance to strategy, team coordination, or game insight. One of the first systems to bring interactive technology developments to the sports domain was PingPongPlus by Ishii et al. (1999). In this system, spots or water ripples could be projected on the table where the ball bounced, or the Ping-Pong game could be enhanced with additional game interactions, projected on the table and interacted with through the bouncing of the Ping-Pong ball. Ishii et al. used these different implementations to point out that there is a spectrum ranging from augmentation to transformation. Jensen et al. (2015a) created a football lab play-space with responsive goals, a scoreboard, and sound and light cues, with which they targeted skills such as ball handling, acting and responding to opponents, and anticipating changes in and having overview of the pitch. De Graaf et al. (2009) also targeted football skills but instead created "SmartGoals" in the form of smart pylons. These pylons responded to a ball passing between them, and could cue the next target using LEDs mounted on top of it. This system is now sold commercially and, according to the company, is used by professionals football clubs. Jensen et al. (2015b) used the dynamic capabilities for training handball, by having the system, upon approaching the goal in an attack, indicate different areas in the goal as target. Last moment changes in this indicated area could be used to train last moment decision making during attacks. Also related to handball was the TacTowers system developed by Ludvigsen et al. (2010), a multiplayer game where segments of poles had to be quickly touched to train "improvising to the behavior of an opponent". Finally, the review of Miles et al. (2012) on training sports in virtual environments also mentioned various other examples of installations targeting training sport skills for archery, tennis, table-tennis, handball and rugby.

Another interesting direction we see in human computer sports interaction are *sports over a distance*, or having playing fields distributed over multiple locations connected through technology. Examples include interactive projections for kicking/throwing a ball (Mueller et al. 2003), telecommunication for facilitating simultaneous jogging on different continents (Mueller et al. 2010), and using camera-projections systems to play table-tennis together on three different locations (Mueller and Gibbs, 2007)

Many sports related systems have also been made available commercially. The Yalp Sutu is an interactive football goal wall that can light up several parts with LEDs and that measures impact of the ball to estimate the speed with which the ball was shot. The Yalp Toro is a smaller version suitable for football and field hockey. Cyclist can climb the Mount Vertoux from their living room, by pedalling on their racing bike placed on a Tacx. Rowers using RowPro are immersed in a virtual rowing boat on a screen. There are interactive squash walls allowing for new kind of games to be played. In a somewhat less interactive variant, the Pulastic LED-court offers indoor courts that only light up the field lines of one sport at a time. On the highly interactive end of the spectrum is an interactive pressure sensitive LED floor that tracks stats of players, shows walking lines in real time, and provides interesting visuals for spectators. This floor was built by AKQA and Rhizomatiks for Nike's House of Mambo Rise campaign; we did not yet find permanent or commercially available installations of this.

Gamification of movement skills training also adds value in other movement domains. For example, in rehabilitation and physiotherapy, much promise is seen in a gamified approach with digital means (Janssen et al., 2017). The fact that digital-physical games address multiple senses simultaneously, in parametrisable exercises in an active task, contributes positively to rehabilitation (Tinga et al., 2016); this is likely to also transfer well to the sports domain. The digital aspect of these games make it possible to introduce adaptive personalisation. This can be used to balance gameplay between unequally skilled players, for example by assigning a handicap or using dynamic difficulty adjustments (Altimira et al., 2016; Hunicke, 2005; Stach et al., 2009; Van Delden et al., 2014), allowing people from different age groups or with different skills to play together in harmony (Moreno et al., 2013). Finally, it has been shown that the *virtual skills* addressed by such games might be transferable, if they are close enough to the targeted real skills, although more studies are needed (Göbel, 2010; Geiger et al., 2013).

In short, we can see that new technological implementations in the movement learning domain (with a focus on sports) are growing beyond providing fun and beyond post-hoc feedback of measured performance. Furthermore, we see that training skills obtained in virtual games and environments might transfer to real life.

3. Our work

Over the past years we collaborated in a number of projects that focused on playful and embodied interaction with smart environments, for entertainment, education, health and care applications. Such environments use sensors (e.g., cameras and microphones) to detect and interpret the physical and social behaviour of players. The game then responds to the actions and behaviour of the users; video screens, floor and wall projections, and digitally enhanced toys and props are used to display the system's response to the user.

The systems that we built include rope pulling via the internet (Beelen et al., 2013), interactive playground floors (Moreno et al., 2016), or a game of interactive embodied pong (van Delden et al., 2016b). We contributed to the state of the art in researching how we can steer player behaviour in a way that does not interfere (too much) with the prime game task, but does lead to predictable changes in in-game behaviour of players (van Delden et al., 2014a). We introduced the conceptual distinction between strategies that *require that people change their behaviour, *insist that people change their behaviour, or *entice people to change their behaviour. We introduced enticing strategies for steering behaviour as a new concept, and showed that we could use this to deliberately steer player behaviour in multiple ways, with only limited interference with the prime game task (van Delden et al., 2017a).

We also collaborated to explore healthcare related systems, such as encourage more movement for children with asthma (Klaassen et al. 2017, Cabrita et al. 2017), or offering entertaining movement experiences for people with Profound Intellectual and Multiple Disabilities (van Delden et al., 2014b). We also build upon recent developments in rehabilitation and physiotherapy, where interactive systems are developed to offer gamified physical activities for rehabilitation (see, e.g., Janssen et al. 2017). Earlier, we developed a number of games addressing different exercise and outcome metrics in gait rehabilitation, and argued the importance of "walk on" solutions like an interactive floor (for acceptance, ease of use, and freedom of movement) and the necessity of having "suites of parametrizable games" to address a large range of user skills, characteristics, and goals (van Delden et al., 2016a).

The central theme in these projects is the potential for playful technology to influence social and physical behaviour and perception of the user. This is done via unobtrusive measurement; tailored feedback; tailored and parametrized exercises and activities fitting the skills and characteristics of the user; and adaptive intervention mechanics for explicit and implicit steering. Evaluation of the *impact* of the interventions is done using mixed methods, combining objective, automatic measurements and game action logs with subjective self-report questionnaires and annotation of recorded game sessions (van Delden, to appear 2017b). For such systems to actually have a lasting effect, stakeholders such as teachers, trainers, or therapists should take a leading role in the implementation in practice. Therefore, such people are generally involved in the projects from early on, in requirements elicitation, context analysis, and explorative prototype evaluations.

While developing and researching these systems, a number of lessons repeatedly came up for us; we will discuss these further in the remainder of the paper. These lessons will inform our work as we are moving towards more sports-related projects using similar technologies and interaction mechanisms.

4. Lessons learnt through our work

4.1 Lesson 1: User involvement

As the most obvious lesson, a form of input of the end-user is required for any domain, also for sports. False assumptions during implementation are easily overlooked when they are not tested to reality and practice. We have tutored dozens of student projects and many of them only got their idea straightened out once they did a reality check of their assumptions with actual children, patients, coaches, therapists, etcetera. Is the problem really what we think it is? Does the situation that we target with our system actually occur often enough that it is worthwhile to solve the problem? Are there no other problems in the way of our envisioned solution that need to be solved first? The large majority of HCI experts will recognize this essential lesson and it is unfortunately not just limited to students to have false assumptions. Build on existing knowledge, observe in context, and involve both coaches and players, and perhaps even policy-makers when larger more transformative systems are to be developed. A realistic view from all end-users and sports experts about technological possibilities and limitations is not realistic to expect; therefore it is important that several types of experts and end-users work together in order to gain insights and to mitigate false expectations. When moving from conceptual ideas to practical systems, it turns out that even small practicalities can break implementation in practice. For example, a 2-minute start-up sequence of a game system in physical therapy can be a deal breaker for a therapist, as this takes fully 10% of the time that is available for one patient. So the user involvement extends beyond initial requirements gathering to continually testing early prototypes and variations of systems in real life, with actual users.

4.2 Lesson 2: Cross-Domain research

Within this domain there are different types of contributions provided by researchers, each with different focus (technology, interaction, and context) and with different approaches. We need to consider these in parallel, where each brings its own benefits. Only by addressing all of them can we hope to make a lasting impact. For design as well as research purposes, interaction oriented and context oriented foci are not less important than the technological improvement angle. The researchers focusing on technological improvements often work on set problems, improving systems capabilities, and realizing new capabilities of systems. The context-oriented research focuses on what problem to actually solve and whom would benefit from this. Based on current approaches they can investigate what becomes possible and might anticipate what transformations this might result in for a domain. The interaction oriented research is more focused on envisioning and creating new types of interactions that might become possible with certain new technology. In the longer run the interaction oriented researcher is often interested in what (observable) behavior change results from these new interactions. Without new and improved technology it is hard to create new interactions, the technology also needs to work in a context (and not just in the lab), new interactions might create new technological issues to overcome, without interactions it is hard to show value of many technologies, and appropriate information from the context is needed as input for successful interactions. It is important to see that all these elements build upon, and strengthen, each other.

4.3 Lesson 3: Gamification; risks and rewards

Our systems are examples of entertainment computing, and as such rely on gamification principles. In our projects, as with probably many others as well, it has become abundantly clear that this entails more than “just adding points as rewards”. The idea of gamification is that one uses the power of games to make an application or activity more fun and thereby more effective. This can work very well: the introduction of Pokemon Go led to an increase of movement for users (e.g., Xian et al., 2017; Wong et al., 2017). But it is not a guarantee for success. Sometimes, “adding game principles to make an activity more enjoyable and engaging” is like “putting chocolate on the Brussels sprouts to make the child finish their plate1”. The sprouts will not taste much better -- probably the child will fish them out of the chocolate, put them aside, and finish the chocolate. If you are unlucky, the game elements even distract the attention from what the activity is about. The person doing the gamified sports, in their desire for bonus points and achievements, might lose attention for the right motion techniques; they might become better at the game instead of better at the sports activity. This also matches experimental results on the difference between easy and hard fun: people who want to win the game might “game the mechanics” to win, rather than attempt to become good at the intended game

[1] Thanks to Lars Elbaek, personal communication, for this particular phrasing

actions and activities (cf. Bianchi-Berthouze, 2013). Furthermore, there might be a matter of diminishing return: "getting them into the store" is different from "keeping them in the store and buying something[2]". Gamification is potentially useful, but not a panacea, and requires careful application.

4.4 Lesson 4: Impact and transformation

Ultimately, the kind of projects that we hope to carry out, aim for real impact in the sports domain. In our view, there are two types of impact from technology. Firstly, technology can solve challenges in sports training while leaving the core of the training unchanged. For example, improvements in goal line technology can lead to less errors in determining whether a ball is in or out of the field. It ameliorates a potential problem (arbiter errors) but does not change the essence of the matches or the training sessions: the athlete remains focused on keeping the ball within the field lines. Secondly, and for many people more attractively, technology has the potential to *disrupt*, to transform the domain and fundamentally change sports practice. For example, in several sports, the collection and use of the right sensor data seems nowadays to lead to a complete transformation of how an athlete trains towards a match. We need, though, to consider that "potential for change" is different from "actually achieving a useful system in-context". Achieving the second kind of impact is not a matter of coming up with the right idea and making it; one needs an ongoing programme of trying out different ideas in order to map the space of possibilities for transformation of the domain. One does not know beforehand how a specific new technology fits the real world and what it actually benefits; the existing context changes when you put the technology in.

4.5 Lesson 5: The trainer

Sometimes there is technology that claims to replace the need for a trainer, or to serve when a trainer is not available at all, but in our experience that is not the most feasible strategy. This claim often scares away the end-user, but also most of the time makes no sense -- you will be quickly confronted with limitations of technology that is not able to operate so independently without any supervision. In the kind of systems that we make, quite often therefore we see two complementary categories of end user. There is the athlete (patient, student, …) who uses the system for their own further development, and the trainer (teacher, therapist, …) who "prescribes" using the system, and who is responsible for part of the adaptation of system settings to user skills and characteristics. The new technology then ranges from *a tool in the hands of the active trainer* to *a 24/7 available independent "stand-in" for the trainer* (being configured and controlled by the trainer). At either end of the spectrum, the trainer should feel competent and motivated to use the technology. And at either end, a primary design question becomes: "what can we make possible for trainer and athlete that is not possible without the technology, and how does this contribute to the primary aims of the athlete?" Sensors can perceive things that cannot be seen with the naked eye, even with experience. For example, biometric data sensors for stamina e.g. in cycling can provide novel insight in training schedules and tactical approaches in a match, or think of super speed cameras and accelerometers providing precise insight in gait, changing how we make a certain movement. Interactive gamified systems can enhance motivation, but a good trainer does this as well so it is important to show how this goes beyond good training practice-without-technology. Technology can also help a trainer to provide *more precisely tuned* dynamic challenges and more precisely controlled and systematic variations of exercises. Finally, technology used at home, when the trainer is not there, can provide a modicum of supervision / coaching feedback while practicing -- although such should probably be under control of the trainer to ensure the right level of quality. In that case, the trainer might also benefit from summaries of user activities as measured by the home training system.

5. Types of research questions pursued in these projects

The above lessons all frame in a certain way the quest for added value from interactive technology. This added value is achieved and investigated through different types of (knowledge, design, and evaluation) research questions. In our projects, three groups of research question come together. **Technology** related questions: How should the technology be built? Which algorithms are needed? What is a good system architecture? **Interaction** related questions: Which technology and interface do we give to the user (apps, VR, AR, etcetera)? What new types of interaction become possible through new technology (e.g. based on new automatic recognition of actions and behaviours)? How does the technology influence the immediate actions of the users? How does it influence perception and attitude of the user? And, finally, questions addressing the **application domain**: What

[2] Again well-phrased by Lars Elbaek, personal communication

is the real improvement that we achieve, which problems do we solve? What does become possible, that could not be done at all earlier? What is the added value of that? For example, in our research on interactive playground (floors), we looked at all three types of questions. We developed technology: software to track user behaviour on a floor, and to make the moving images respond intelligently to where users are and what they are doing. We also developed new types of interaction: by adapting the moving images to the behaviour of the playing children, we steered their physical behaviour in the field (make them move faster, get closer to each other of stay farther away, make the tagger chase a particular runner, etcetera. This influences the way the game goes: for example, the balance of the game shifts; someone is tagged less, or more, often; or one child gets an easier game than another. Finally, we need to look at what this means for the application domain. The steering of physical game behaviour has implications for the *social* behaviour and perception of the children. Is unequality in sports and play always bad? Clearly not; it is also a big part of what children (should) learn from at the playground. So it becomes important to research when and how such manipulations have added value; for example when the balance is so unequal that children completely drop out (it gets too easy or too hard and the child loses interest because of that). This kind of question becomes increasingly important in our work.

6. Education of ICT professionals as well as domain experts

When trying to solve problems in a domain, we need the typical methods of user centered design: talk to users and experts, observe them, do lofi prototype testing with them, and converge towards both a better insight into the nature of the problem and a better insight in whether a specific solution direction is the right one. But the more we move towards the above mentioned *transformation* of a domain, the harder it is to do this as long as end users and experts are solely used as informants. Instead, they should be in the driver's seat regarding the direction, which new potential is explored through the technology, and we should leverage the existing domain specific (non-technological) research as well. This draws our attention to two educational innovations. Firstly, regarding our own technology design students: the athletes and sports researchers should not just be considered as passive recipients of technology or straightforward providers of necessary information in a user centered design process; our students should learn how to make such end users a real partner in the research with their own design and research questions from their own perspectice. Secondly, regarding professionals in the domain: they should learn how they can take a proactive role setting and leading the design agenda and research agenda. This means that they as well should receive training in technology design skills. Where both sides of the education equation are covered, we expect to find the strongest collaborations for real impact of innovation in interactive movement training.

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