13 Game Lenses for Designing Diverse Interactive Jogging Systems

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ABSTRACT
HCI is increasingly interested in designing technology for being physically active, and in many cases focuses on jogging. We find that many current approaches seem to view jogging only through a lens of athletic performance. However, jogging is multifaceted, yet there is so far no collated list of alternative lenses through which jogging could be viewed at by designers. In this paper, we draw on game design thinking to articulate 13 lenses through which designers can examine jogging. These 13 lenses are derived from related work and our combined experience of having designed and studied three different jogging systems. The lenses enable a structured articulation of key opportunities that interactive technology offers for jogging designers. With our work, we aim to support designers who want to create diverse interactive jogging systems so that more people can profit from the many benefits of jogging.

Author Keywords
Jogging; running; whole-body interaction; sport; exertion.

ACM Classification Keywords
H5.2. Information Interfaces and presentation (e.g., HCI): User Interfaces.

INTRODUCTION
Jogging – a prevalent sporting activity – has sparked a wide variety of interactive jogging support systems including many mobile apps (e.g. RunKeeper [6], Nike+ [7] and MapMyRun [38]) and also an array of different wearables (e.g. sports watches [64], sensing sport socks [2] and sports smartglasses [30]). Interaction design research also has its fair share of systems exploring how interactive technology can support the jogging experience (e.g. [11, 18, 20, 32, 40, 43, 51, 54, 56, 60, 61, 79, 80, 81]).

We, the authors, have also designed several novel jogging systems and studied them over the years as well as engaged in jogging ourselves (three of us went from no jogging to completing marathons).

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Experiential lenses:	
1. The jogger's challenge	How to facilitate a jogging flow?
2. The jogger's play	How to support movement as play?
3. The premise of the jog	How to support the setting of the jog?
4. The jogger's character	Who is the jogger?
5. The story of the jog	How to support the jog as a narrative?
Instrumental lenses:	
6. The social jogger	Who is involved in the jog?
7. The jogger's objective	What is the jogger striving for?
8. The procedure of the jog	What actions are required?
9. The rules of the jog	What actions are allowed?
10. The jogger's resources	What assets can the jogger use?
11. The jogger's conflict	What is in the jogger's way?
12. The boundaries of the jog	Where does the jogging start and end?
13. The outcome of the jog	What is the result of the jog?

Fig. 1. 13 lenses when designing for jogging

We decided to come together to collate our experiences and discuss where the field is heading, which was where we found that it appears that many current approaches seem to view jogging only from the perspective of improving athletic performance, i.e. helping joggers to run further and faster. We acknowledge that striving for athletic performance improvement can be a key driver for many joggers, however, jogging is multifaceted [32], and we believe there are many more design lenses through which designers can examine jogging. However, to our knowledge, so far, there does not exist a structured articulation of what these design lenses could be. We believe that such an articulation could enable the beginning of a systematic inventory of the opportunities that interactive technology can offer to joggers, and with our work, we hope to begin such an inventory.

In order to structure such perspectives through which to view jogging, we believe we can learn from game design thinking, as jogging, like most sports, can be regarded as a form of play. Inspired by this parallel, we have drawn significantly from game design literature, being especially inspired by its language (such as the labeling of our lenses with game design terminologies like "rules", "challenge", or "objective"), which we appropriate in the articulation of

our design lenses. Furthermore, the choice of using lenses was also inspired by game designer Shell [71] who has previously used lenses to articulate how interactive and playful experiences can be viewed from multiple perspectives, which in turn has been used to support designers of these experiences. We therefore believe the jogging community can learn from the CHI PLAY community (and vice versa) when it comes to supporting the playfully active human.

Our aim is to inspire and guide designers to create diverse interactive jogging systems. To achieve this, we present a set of 13 experiential and instrumental lenses through which jogging can be viewed, and place a particular focus on identifying technology opportunities (we present 26 opportunities in total, 2 for each lens). With our lenses, which we created to be readily accessible and actionable for practitioners, we want to help designers think differently about jogging, departing from the prevalent approach that sees exertion only as a mechanical activity for improving physiological functioning; instead, expanding the focus to also consider a set of instrumental and experiential aspects.

Designers can use our lenses as guidance when it comes to creating novel jogging systems to check whether they have considered different aspects of the multifaceted experience that jogging embodies. However, we do not think a system can cover all perspectives, but believe that having a set of perspectives can structure an initial ideation process. Furthermore, we believe our 13 lenses do not represent a complete set that covers every possible jogging support system nor will they accommodate all joggers (for example joggers who do not like using technology), but rather, we see them as a starting point towards future investigations. In particular, we compile knowledge from three future-oriented systems to inform the future of the jogging-technology phenomenon. We believe the 13 lenses could not have been deduced by simply observing a single case study.

Furthermore, we build on our personal jogging experiences from engaging with jogging for over 15 years as well as intimate knowledge of having conducted over half a dozen jogging studies over the years. This includes findings not previously reported in our papers, such as what we learned from pilot studies, early prototypes and failed technology attempts. We also acknowledge that our own jogging experiences might taint our findings with particular jogging preferences. In fact, they offer an intimate account across a range of 4 researchers from 3 countries, all being both joggers and HCI designers. As such, our work echoes HCI trends in autobiographical design [55], designing for movement through moving oneself [27, 39] and autoethnography [63], all of which highlight that bodily experiences are best understood when experienced by oneself, while allowing no information to be lost in communication or interpretation between participant and researcher. Furthermore, autoethnography allows for rapid design iterations that capitalizes on the designer's tacit knowledge which is a key benefit of reflective practice [63].

Our lens development was aided by the authors' prior work with sports scientists, physiologists and related literature. However, we provide a designer's perspective that especially draws from insights gained from the collated design practice. This designer's perspective is grounded in practice-based design research, promoting the diversity of enquiry methods in HCI, and in particular answers calls for more design-led enquiry [25]. Our primary contribution therefore sits in the design research tradition [28] taking the form of 13 guiding lenses and 26 opportunities for the design of future jogging support systems. The paper also introduces previously unpublished jogging work "PaceTunes", thus also offering a system and study contribution.

We believe our findings are timely as there is an increased attention, both commercially and academically, on advances in technology to support jogging. We believe our work can aid the design of a range of technologies to support jogging and other endurance activities, possibly even extending to sports in general [58, 82, 84, 85, 86]. As such, we present knowledge in the design research tradition [28] in the form of 13 experiential and instrumental lenses when designing for jogging. These lenses are derived from an examination of the literature and from practical experiences of having designed and studied three jogging systems.

A note on "jogging"

A distinction can be made between walking, jogging/running and sprinting in terms of biomechanics [37], however differentiating between jogging and running is not so easy. Sometimes jogging is considered a lower speed version of running [26], however, based on our experiences across 3 different cultures (Australia, UK and Germany), it seems that the use is culturally influenced [75]. For the purpose of this paper, we use the word jogging to encapsulate running at a slow pace for a longer period, within an amateur setting (therefore excluding professionals but include enthusiasts who participate in amateur races).

RELATED WORK

Jogging has been examined through particular lenses previously. For example, sports psychology examined jogging through a motivational lens [15, 54]. Prior work has also examined jogging through the experience of *going* jogging [73], taken up in our set of experiential lenses. Designing for jogging can also learn from perspectives of being physically active. For example, several movement-focused research projects [23, 34, 36, 45, 72, 83] highlight the expressive power of bodily movement and its potential in a public context. These works led us to lenses that consider the larger public space, such as jogging in a park.

Tholander et al. presented an ethnographic study of joggers' use of sports gear and found that joggers embrace the

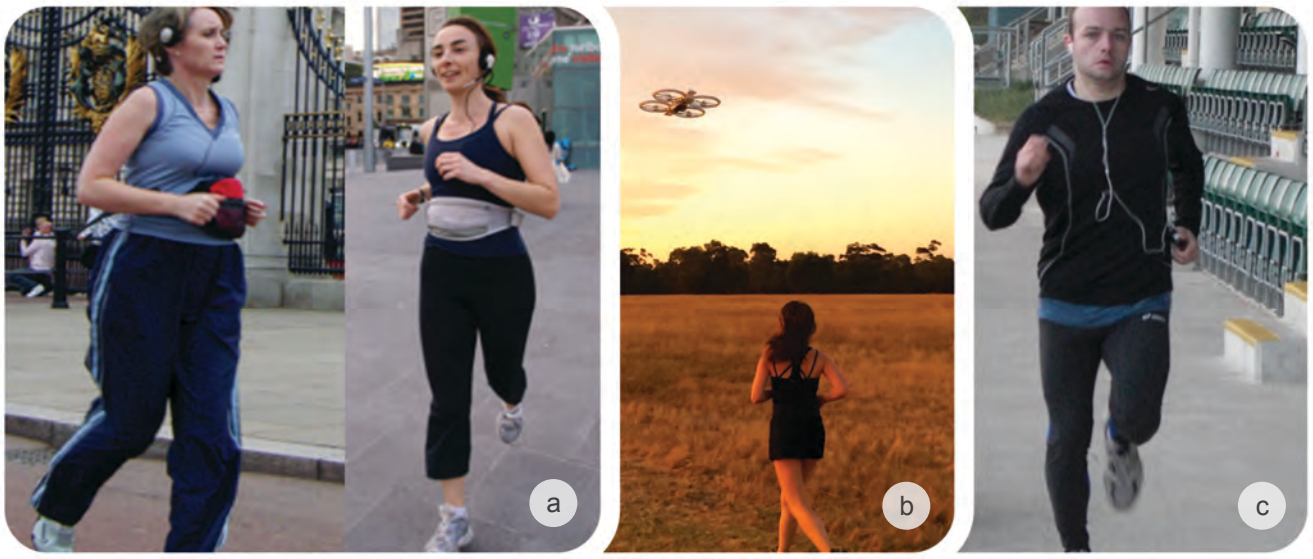

Fig. 2. a) Jogging over a Distance, b) Joggobot & c) PaceTunes

opportunity to engage with technology [76]. Interaction design researchers have therefore developed their own jogging systems; we can differentiate between the following key approaches: instructional technology, gamification and social facilitation. Instructional technology aims to improve a jogger's technique, for example by giving gait feedback through sound [57] (considered under our *procedure* lens). Other research has aimed to gamify jogging, offering virtual worlds to transport joggers into alternative realities [62] (considered under *premise*). Design research has also aimed to support the social aspect of jogging, for example by sharing heart rate data with fellow joggers [41] and audience members [18, 20] (considered under *social*). Unfortunately these distinct lenses rarely cross over, for example, instructional technology systems do not usually consider social support and vice versa. Furthermore, some facets of jogging mentioned in the ethnographic literature (such as the need for replenishing water) have not yet been fully explored by design research (for a starting point see Khot et al. [31]). We see an opportunity to bring the field forward by presenting a collated design-focused articulation of a set of lenses researchers can look through when designing for jogging.

THREE JOGGING SYSTEMS

The three novel jogging systems (the first two have been described previously [47, 49, 52]) all highlighted a different technology, accommodated different jogging contexts with a focus on different social experiences (Fig. 2 a, b, c).

Jogging over a Distance

Jogging over a Distance (JoD) connects two joggers in different geographical locations and with different athletic abilities through the use of heart rate data (Fig. 1a) [46-49]. An initial 18-person study with mono-audio connections [59] and a subsequent 32-person study using stereo audio [47] showed how the system was able to support "social joggers" i.e. people who use exercise to socialize and socialize through the exercise [59]. With JoD, two joggers plan to run at the same time, each equipped with a mobile phone, headphones, microphone and heart rate monitor. Each jogger can hear live audio of their jogging partner while they run. Relative to their target heart rate (which the joggers enter beforehand), the jogger's heart rate affects the audio location in a 2D plane (oriented horizontally around the jogger's head). If the other jogger is "in front", the sound appears to come from the front, and the further "in front", the softer the audio volume. If both joggers perform at their preferred heart rate (or have both slowed at the same percentage from their baseline), they hear the audio right beside them, as if running side-by-side. This way, the jogger is able to detect whether the partner is putting in more, the same, or less "effort" based on relative heart rate.

Joggobot

Joggobot (JBot) is a flying quadcopter that serves as an embodied jogging companion for solo joggers (Fig. 1b). It uses assisted GPS to fly along a fixed path at a speed the user determines beforehand. A study with 13 joggers revealed that participants found jogging with a quadcopter exciting, as Joggobot not only served as pacemaker, but also as an entertaining companion (sensor inaccuracies combined with wind made the quadcopter sometimes appear to have "a mind of its own" [52, 53]). Furthermore, they described the quadcopter as a fellow partner that also invested physical effort since it also made noise and showed signs of exertion, facilitating a sense of connectedness between the jogger and quadcopter.

PaceTunes

PaceTunes (PT) is designed to support joggers who set themselves objectives for their run (e.g. distance runners). In order to achieve such objectives, controlling one's pace is often crucial. PaceTunes aims to support joggers keeping their desired pace by combining the joy of listening to music with the objective of controlling pace (Fig. 1c). The jogger's pace is calculated via GPS and compared to a baseline the jogger can set him/herself. The jogger listens to music which is spatialized similar to the microphone-captured voices in JoD: the music appears to be in front of the jogger if jogging too slow, behind if jogging too fast, or surrounding the jogger when the pace is as desired.

A study with six joggers revealed that all participants could easily detect the music "distance" and were able to use it to pace their jog. Overall, they described the system as useful and intuitive [12]. In particular, the study highlighted how the music was used as a platform for the unfolding story of the jogging experience as participants became fatigued. The study also highlighted that music is not for everyone, for example, it was noted that some joggers preferred "listening" to their own body, e.g. breathing.

Method used in developing the lenses

Based on related work, our own jogging experiences and our collated experiences designing and studying these three systems, we formulated a set of lenses that can be used for designing future jogging systems, which we complemented with easy-to-remember questions designers can ask (Fig. 1).

Our process began by articulating what we have learned and what we thought were missed opportunities. Then we compared our experiences with findings from related work and results from our studies. Subsequently, three of the authors came together into the same location and discussed over the course of two months commonalities and differences of their experiences, which often resulted in heated discussions, as jogging can be a very personal and affective experience (for example, the authors each have very different opinions about which jogging apps they prefer). We then further refined our findings by thinking-through-writing. We discussed our written results and tried to find logical groupings. These groupings formed the basis for our lenses, which we supplemented with opportunities derived from further discussions, iterative articulations, assemblages of our past jogging experiences, design explorations and related work, with a particular focus on what the future may hold for interactive jogging systems.

We believe that jogging designers can learn from game design thinking, hence we also drew from our 15 years of combined experience in teaching game and play design. In particular, as our discussion evolved, we began to notice strong parallels between our central findings and how well they relate to Fullerton et al.'s work, which we used both when naming our lenses and to highlight the instrumental and experiential aspects of play and leisure [24]. Our lenses include a set of questions because we were inspired by the work on designing for movement, where practitioners appreciated an easy-to-remember format that also appeals to industry [50]. We selected lenses that we believe are underexplored and felt that 13 lenses allowed us to reach a natural saturation that is in line with prior work [24] and a suitable number to both capture the necessary principles and remain manageable for implementation within design practice. We suggest to designers to read through all the lenses, but also acknowledge that not all lenses can (or should be) be implemented in a single system.

THE JOGGING LENSES

We present 5 experiential (1-5) and 8 instrumental (6-13) lenses. The experiential lenses are concerned with the visceral aspects that unfold throughout the jogging experience, whereas the instrumental lenses are aimed to provide an underlying structure to support the jog. The experience-focused view on jogging aligns with current popular jogging culture accounts [44] that recommend shifting our perspective of seeing jogging as a task to be accomplished (such as when doctors prescribe physical activity) to seeing jogging as an opportunity to facilitate personal growth [3, 83]. By considering the instrumental lenses, designers can support the "mechanics" of jogging. Therefore the instrumental lenses can be thought of as the "usability" tools in the designer's toolkit, while the experiential lenses are the "experiential" tools.

In each lens below, as well as posing a design inspiring question, we articulate two exemplar key opportunities (labeled "O1" and "O2") interactive technology offers to designers. We complement each lens with an "additional insight" section in order to provide designers with practical suggestions from our work in the field. Where applicable, we also describe next to each heading which of our 3 system's research stage (or combination thereof) the lens relates to most pertinently: the design process (D), the evaluation (E) or post-reflection that included moments such as "we wish we would have considered more of this (lens)" (R).

EXPERIENTIAL LENSES

1. The jogger's challenge

JoD JBot PT

How to facilitate a jogging flow?

D DE E

The jogger's challenge can be thought of as the difficulty of the jog. Most often this challenge is not constant, but rather dynamic, i.e. a jog usually gets increasingly challenging over time. Csikszentmihalyi describes an appropriate level of challenge as one that is "just enough" to require an amount of effort that creates a sense of both accomplishment and enjoyment [17]. Designers have an opportunity to craft the circumstances that lead to the right amount of challenge over the course of the jog in order to facilitate "being in the zone" or "flow" [17, 32].

O1: Managing challenge through sensing bodily responses

The jog gets more challenging as a person's resources diminish; we find that managing this challenge can benefit from tracking these resources. JoD is an example of the

opportunity of technology to sense bodily responses (such as heart rate) to facilitate the right amount of challenge: JoD utilized the relative (instead of absolute) heart rate to balance joggers' abilities, which was welcomed by study participants. Faster joggers could run with slower joggers allowing both of them to experience an optimal challenge, facilitating the emergence of flow.

O2: Facilitating challenge by drawing from a history of jogs

When studying PaceTunes, we asked joggers about their past jogs in order to identify a challenging pace that could promote the emergence of flow. Similarly, most mobile jogging apps show how a jogger's pace changes over multiple jogs in order to allow the setting of new goals. Technology supports this facilitation of an optimal challenge through the ability to record and analyze a history of jogs. A current limitation, however, is that there are insufficient analysis models to suggest appropriate future challenges (for example, there is no good algorithm to automatically set a route or pace based on previous jogs, the weather, or how the jogger "feels" before the run).

Additional insight

Our interviews suggest that joggers actively seek the appropriate challenge that puts them into a state of flow, however, getting into this state is not easy. In particular, the beginning of the jog can often be dis-engaging. In response, we point out that challenge changes over time as the jogger experiences fatigue, and designers should therefore consider and take advantage of this inherent dynamic.

2. The jogger's play *JoD JBot PT*
How to support movement as play? *DE E DR*

The jogger's play can be thought of as the freedom to act within the structured rules of jogging (see lens 9). This self-regulation [44] presents an opportunity for playful engagement, through highlighting the joy of movement and supporting self-expression through movement.

O1: Highlighting the joy of movement

Our Joggobot study and subsequent experience of exhibiting the device at various venues taught us that technology has the potential to remind people of the "joy of movement" [72]. When people experienced Joggobot for the first time, they often tried a wide range of "feel-good" movements in order to interact with the device. An analogy that highlights this joy of movement is the recent barefoot jogging trend. Although jogging barefoot may appear to be physically risky and hence seen as detrimental to enjoyment, the freedom to move one's toes and feel the terrain is believed to facilitate a richer experience than running with shoes. We agree with Segura et al. that highlighting the joy of movement can be key to supporting being physically active [72].

O2: Supporting self-expression through movement

Jogging can also be supported via the idea of self-expression, where technology can help joggers express themselves through their jogs. For example, we find it intriguing that some joggers use the GPS tracking functionality of their jogging apps to create low-fidelity etch-a-sketch-like drawings using their jogging route, which they then share on social media [21]. Opportunities lie in designing technologies that facilitate the creation of these art forms instead of currently being "user hacks".

Additional insight

One of our JoD participants appropriated the technology to give her remote jogging partner a (verbal) guided tour through the park she was jogging in. This included spotting some horses, to which she enthusiastically ran to in order to describe them over the headphones. It appeared that moving through the park was a form of play for her that she enjoyed sharing with her jogging partner. However, this conflicted with her partner who wanted to treat the jog more "seriously", as she was training for a 10k run. This anecdote exemplifies that designers can engage technology to support the joy of movement, however, they also need to manage any conflict arising from existing objectives joggers (or their partners) might have.

3. The premise of the jog *JoD JBot PT*
How to support the setting of the jog? *ER E R*

For most joggers the setting is a park, an urban footpath or a running track. We identify two key ways for how technology can support the setting of the jog: transforming the existing premise or introducing a new premise.

O1: Transforming the existing premise

The introduction of objects that distort the perception of a setting can often transform a premise. Designers can exploit this to offer novel and interesting experiences [69]. For example, the use of a quadcopter transformed the existing premise of a jog in a park into a futuristic scenario: participants told us they felt like they were in a sci-fi movie, promoting the emergence of a jogging fantasy world that they said assisted in motivating them.

O2: Introducing a new premise

Digital games are typical examples of how technology can introduce a new premise, often putting the player in alternate universes via visuals and sounds. Similar opportunities exist for jogging designers. Park et al. [61] and Campbell et al. [13] both demonstrated how joggers can be introduced a new alternate premise through virtual worlds. Consolvo et al. [16] introduced a virtual flower garden to nurture by means of physical activity, while Lin et al. [35] provided virtual fish as a way to introduce an aquarium as a new premise. Commercially, Pokémon Go introduced a world full of Pokémon to catch.

Additional insight

We see great potential for technology to engage with premise when designing for jogging. However, we also note that the original premise (the setting of the actual jog) should remain part of the experience, even if only for the purpose of safety: for example, a VR headset might introduce a highly immersive new premise, however, could be outright dangerous for urban joggers.

4. The jogger's character *JoD JBot PT*
Who is the jogger? *DR ER R*

The jogger's character refers to the embodied being within the technology-supported jogging experience. Technology can support the development of existing characters, allowing participants to take on various roles as seen in role-playing games [24], but also introduce new characters.

O1: Developing the existing character

In the GoodGym project [5] the existing character is quite cunningly developed: joggers are paired with isolated elderly people, where the jogger commits to jog by regularly delivering small items such as milk. The GoodGym website uses character development quite cleverly: it addresses the jogger as "the athlete" and the elderly as "the coach" (rather than simply as "the delivery person" and "the elderly") to engage both users tightly into the GoodGym experience.

O2: Introducing a new character

Joggobot is one example of how technology can introduce a new character. It presented a quadcopter as an embodied jogging companion, sometimes resulting in the joggers affectionately naming their quadcopter and assigning it a gender ("*She* made me work hard today"). This is in stark contrast with interactions joggers usually have with most other jogging systems, such as jogging apps.

Additional insight

By addressing the participant as "the jogger" (rather than "the user"), jogging systems can contribute positively to character development that follows a trajectory from "going jogging" to "becoming a jogger". However, challenges can arise when developing a fictitious character as there is potential that participants might transfer fantasy abilities to their own abilities and overestimate them, leading to over-exertion and injury. Designers should therefore develop the character (and associated fictitious abilities) in conjunction with joggers' existing and improving abilities.

5. The story of the jog *JoD JBot PT*
How to support the jog as a narrative? *DE ER D*

By supporting the jog as a narrative, designers are reminded that a key characteristic of the jog is that the jogger can ask "what happens next if I …?" [70]. As such, the jogging experience can be articulated as a story that is filled with uncertainty, and as a consequence, it motivates people to participate in order to address this uncertainty [33].

O1: Introducing a new interactive story

We believe the idea of a story offers opportunities to use technology to transform an "ordinary" jog into a "dramatic" experience. One of the few examples that uses this is "Run, Zombies!" [4], which audibly depicts an apocalyptic world infested by zombies. Slowly unfolding the audio story allows a jogger to become engrossed in that alternate universe. In the "I Seek the Nerves Under Your Skin" project the system plays a poem to its end only if participants keep running [40]. Similarly, PaceTunes introduced a new "story" in the form of an MP3 song, where the participants needed to keep running in order to hear the entire song. We can envision future systems where the run and the story are even more tightly linked, for example where changes in jogging direction affect how the story unfolds, similar to the "Choose Your Own Adventure" novels from the 1980s.

O2: Highlighting the existing story of the jog to support storytelling

Jogging systems such as those by Garmin highlight the existing story of the jog: they make GPS and heart rate data available online after the jog, allowing for storytelling around the jog. Many joggers share this data with jogging community websites and articulate their associated experience in a story-like format, for example the following "jogging story" is supplemented with location, pace, elevation and heart rate data: "This was by far my toughest run in a long time. The run was going swell into [sic] I turned the corner to head west, straight into 30-40mph wind gusts. The eighth mile was probably the slowest and most excruciating 7:42 I've ever ran…" [1].

Additional insight

We found "Zombies, Run!" helped us turn our monotone jogs into interval training by making us repeatedly intersperse short sprints in order to escape the zombies. As such, the system reframed the jogging activity through the means of the narrative.

INSTRUMENTAL LENSES

We now articulate the 8 instrumental lenses.

6. The social jogger *JoD JBot PT*
Who is involved in the jog? *DE DER DER*

Jogging is often a solo activity, but it is also undertaken with friends, in a jogging group or with complete strangers (e.g. during a race). Furthermore, joggers share their paths with others (often non-joggers). Joggers also often plan their jogs with others both on- and offline regarding where and when to jog. In this sense jogging is a social activity even when a jogger jogs alone. Considering this social aspect can be key in motivating exercise [42]. We therefore suggest that designers ask: "Who is involved in the jog?"

O1: Supporting jogger-jogger and jogger-spectator relationships across distance and time during the jog

JoD demonstrated that technology can enhance the jogging experience by connecting joggers in geographically distant locations (jogger-jogger), while the Nike+ system [7] connects joggers across time by enabling comparisons asynchronously. As such, technology offers an opportunity to support the social jogger across both distance and time. Furthermore, Joggobot participants noted how their jog was affected when by-standers commented on the quadcopter (jogger-spectator). We therefore highlight the opportunity to use technology to incorporate spectators (as with most interactive experiences [65]); for inspiration see the work that relays a jogger's heart rate to remote audience members [19]. Most current jogging apps support jogger-jogger and jogger-spectator relationships, focusing on

relationships *after* the jog. In contrast, we highlight an opportunity to also support the jogger *during* the run.

O2: Balancing different jogging abilities

One key hindrance for people to join their jogging friends can be their different fitness levels [47, 59]. Technology can offer an opportunity to balance joggers of different abilities by a) either connecting them while jogging at different speeds (like in JoD) or b) altering the effort required for one of the joggers (for example by using an exoskeleton that gives a jogger a physical "boost").

Additional insight

We have found that in general joggers welcome technology that enables them to embrace jogging as a social experience (i.e. JoD and Joggobot). In particular, we found that joggers appreciate technology that allows them to be in control of the extent to which they engage socially, rather than prescribe the social interaction [49], especially as social interaction becomes more difficult with increasing fatigue.

7. The jogger's objective
What is the jogger striving for?
JoD D JBot ER PT DR

This lens highlights what the jogger is striving for. Sports science has previously identified health and fitness, well-being, athletic challenge and social reasons as common objectives [15] with more recent research [32] highlighting that joggers often have more than one objective. Therefore it can be necessary to consider multiple objectives, including in-the-moment objectives concerned with the immediate jog as well as across multiple jogs.

O1: Introducing new objectives

Technology can facilitate the introduction of new objective(s). For example, both JoD and PaceTunes introduced the new objective of regulating heart rate and pace to maintain virtual audio locations. Participants indicated that these new objectives offered opportunities for engagement, thus reducing the monotony that can sometimes occur when jogging.

O2: Divide and conquer

It has been previously argued that dividing larger objectives into smaller ones can help users achieve their objectives [66], including in exertion activities [9]. Technology can help joggers achieve their larger objective by dividing it as well, as in PaceTunes, where the system allowed joggers to increase the target pace between runs in small increments in order to achieve their overall target pace.

Additional insight

JoD showed that joggers can welcome the introduction of new objectives, such as maintaining a partner's relative pace [46]. However, our study also highlighted that participants' personal jogging objective (such as jogging for a specific duration) could clash with a newly introduced objective, such as when the jogging partner did not want to jog for the same duration. This conflict could have been managed by matching up participants with similar goals. Similar to guideline 3 in the work by Knaving et al. [32], we make designers aware that they should consider any existing objectives before introducing new ones while managing any conflict that may arise.

8. The procedure of the jog
What actions are required to achieve the objective?
JoD DR JBot ER PT DR

The procedure of the jog consists of the sequence of actions required by the jogger to achieve his/her objective(s). Designers should ask how they could support the jogger in achieving his/her objective through specific actions, in particular the "ongoing action" and the "special action".

O1: Ongoing action

We refer to the action of putting one foot in front of the other as the predominant ongoing action and highlight the opportunity of technology to support this, for example by providing guidance on running technique through sonification [10, 57]. In order to support this ongoing action most systems require a "starting" and "resolving" action such as a button-press that turns the system on and off respectively. For example, PaceTunes participants had to take the device out of their pocket and press the start button when they began their jog. They also had to press a button when the jog was complete. As designers we need to be aware that "in the wild" [67] a jogger's ongoing action is not necessarily always clearly encapsulated by an obvious start and finish. With PaceTunes issues arose when participants had to pause at a traffic light: the joggers did not know if they should pause the system and how this would affect their target pace. The Strava app addresses this by automatically pausing after a few seconds of inactivity. Therefore we highlight the opportunity to utilize starting and resolving actions to support the ongoing action.

O2: Special action

With the introduction of technology, "special actions" become important. A "special action" refers to any action external to the core mechanic of jogging. One example is raising the wrist to check one's heart rate on a sports watch. Another example is from an early version of JoD where the balancing functionality that triggered the audio spatialization had to be manually activated. This special action disturbed the core jogging mechanic, and hence in the subsequent version, activation was made automatic.

Additional insight

Designers can use special actions to create new jogging experiences, for example Park et al.'s work required joggers to flail their arms during their jogs to control virtual characters [62]. Knaving et al. [32] recommended that designers minimize the use of special actions that could interfere with the ongoing jogging action, otherwise joggers might perceive the activity as "not jogging anymore" and rather see it as a new activity (e.g. an upper arm workout).

9. The rules of the jog
What actions are allowed?
JoD D JBot ER PT E

The rules of the jog define allowable actions for the jogger. A typical rule for many joggers is to not stop running, even

when it gets very challenging to do so. The jogger voluntarily adheres to the rules [74], as this can facilitate a strive for competence [66]. We identify two key technology opportunities when it comes to rules: technology can a) help enforce existing rules and b) enable new rules.

O1: Enforcing rules

In professional running competitions judges enforce the rules, however, casual joggers are often their own enforcers. Technology can help here: for example, the Runkeeper app has a virtual trainer that enforces the rules, i.e. the distance is non-editable. It also has a mode where the jogger can specify his/her own rules, i.e. set a target time, and the tracking system enforces these user-set rules.

O2: Enabling new rules

With technology, designers can consider enabling new rules. For example, PaceTunes prescribed that participants had to jog outdoors due to the system's dependence on GPS. Participants willingly adhered to this new rule as the system awarded them with a novel jogging experience, however, designers need to be aware that new rules might be perceived as restricting, contrasting the rather "open" nature of jogging (compared to most other sports activities that have plenty of rules, e.g. basketball).

Additional insight

With PaceTunes, we found that the new rule of having to jog outdoors led to an emergence of play around the GPS's limitations: participants tried to jog under trees to explore the limitations of the system, and how the music would be affected. This phenomenon of exploring sensing "seams" (i.e. the borderline between where sensing works and where it does not) and its positive effects on user experiences has been previously articulated [14], and we highlight the opportunity to facilitate this by enabling new "seams".

10. The jogger's resources *JoD JBot PT*
What assets can the jogger use to accomplish the objective? *DE R DER*

The jogger's resources are assets that the jogger can use towards accomplishing his/her objective(s). The main internal resource is the finite amount of stamina that the jogger has in order to complete the run. External resources include a sports drink or a downhill section of the running course. Technology offers unique opportunities to manage internal resources and to introduce new external resources.

O1: Managing internal resources

Although humans have a good sense of what tiredness feels like, joggers often want more precision on the limit of their internal resources. Systems can measure them (e.g. biofeedback) while allowing joggers to compare them with others' and their own prior data. For example the JoD heart rate data gave joggers an indication of internal resources.

O2: Introducing new external resources

Prior jogging support systems have shown that technology offers the opportunity to introduce new external resources, for example GPS jogging watches provide navigational information [43] for joggers to regulate their jogging routes. Another example is the "power-song" resource by the Nike+ app where the jogger can press a button to play a motivational song to gain a psychological boost.

Additional insight

We highlight that resources should have real utility, i.e. they need to be useful for the jogger to achieve the objective. For example, we find virtual resources, such as the health packs in "Zombies, Run!" [78], can fall short when it comes to utility as they often focus on providing utility in a virtual world which may or may not match up with any jogging objective in the physical world.

11. The jogger's conflict *JoD JBot PT*
What is in the jogger's way? *DER E DER*

Conflicts are obstacles that prevent the jogger from accomplishing his/her objective(s). Research on motivation has previously examined obstacles that prevent people from engaging in jogging [42]. These obstacles are mostly seen from a health intervention perspective and are therefore considered negative, however, flow theory reminds us that obstacles are not necessarily always negative, and can in fact contribute to a sense of challenge that is key to attaining a positive flow experience [17]. These obstacles can be categorized as both internal and external.

O1: Internal obstacles

In our studies, the participants sometimes experienced a form of obstacle internal to their bodies, such as stitches, mental fatigue or cramps. Technology offers an opportunity to highlight the range of possible internal obstacles that might occur and thereby help participants cope with them. For example, we can envision sensing systems enhanced with machine learning algorithms that could predict cramps. We noticed during testing JoD that the technology amplified breathing difficulties. Participants said they used the amplified breathing noise of their partner (the microphone was close to their mouths) to assess when their partner was exhausted and as a consequence slowed down.

O2: External obstacles

This concerns obstacles which are external to the jogger's body. An example is the physical jogging environment that could include cars (on the road) or bicycles (on jogging paths), causing the jogger to slow. This external obstacle became particularly pertinent in PaceTunes, where pausing due to traffic was conflicting with the system asking for a consistent pace. Technology can highlight these external obstacles, or implement ways around them. For example, we can envision a future version of PaceTunes that suggests alternative jogging paths with fewer cars, using a combination of GPS and traffic data. Alternatively, the jogger could be encouraged to slow down, such as in Monster and Gold [11], by introducing virtual monsters as external obstacles the jogger is encouraged to avoid.

Additional insight

One of our JoD participants almost could not participate on the day of our study due to an injury that restricted him

from jogging. However, since he was able to use a bicycle we were able to test the design on the bicycle instead. We did not consider this in our initial design, but in hindsight, could have exploited the opportunity to support multiple sports activities thanks to the use of heart rate as the input mechanism, hence reframing the obstacle.

12. The boundaries of the jog
Where and when does the jogging start and end?
JoD ER JBot ER PT DE

The boundaries of the jog are what separate the jogging activity from "everything else", both pragmatically and conceptually. This highlights boundary aspects such as whether a jogging system should also include any stretching exercises, or whether running to catch a bus could be sensed as part of the training regime. Conceptually, the start and end of a jog can be seen as play boundaries that demarcate the "magic circle" [70]. Designers can utilize technology to either highlight or blur these boundaries.

O1: Highlighting boundaries

In PaceTunes, the music demarcated when the jog "was happening", essentially highlighting via audio the magic circle. Similarly the raising and lowering of the Joggobot suggested when the jogging activity was about to begin and end, communicating it clearly not only to the jogger, but also to bystanders.

O2: Blurring boundaries

Joggobot interviews suggested that technology could also blur these boundaries. Participants expressed that they would like to take Joggobot home after the jog, so that the quadcopter would hover near their door when identifying opportune times for jogging. Some commercial systems similarly blur the boundary of the jog: they not only analyze the jogging activity but also the jogger's sleep patterns, suggesting that a good jogging session begins with a good night's sleep.

Additional insight

We found that for many joggers, jogging is a way of life that extends beyond the jogging track. To support this, joggers can now use a range of devices to monitor other aspects of their life to identify opportunities that will support their jogging activities (what food to eat, how long to sleep, etc.). We find that incorporating such devices to encompass wider boundaries is an interesting way forward, especially how to make sense of the devices' data in a way that is meaningful to the jogger.

13. The outcome of the jog
What is the result of the jog?
JoD DE JBot E PT DER

A typical outcome of a jog is the successful completion of a route, but it can also be an enhanced mood. We believe technology can support the outcome of a jog in two key ways: by articulating outcomes and by quantifying them.

O1: Articulating outcomes

Joggobot interviews revealed that participants appreciated when the battery of the quadcopter went dead, as it communicated to them that the quadcopter was "tired", and that it was therefore just as acceptable for them to also be tired. We can see this as an example of the quadcopter as a human training analogue, where the trainer explicitly gives their permission for the jogger to rest. On the other hand, joggers may perceive the robot as a "buddy" and feel that when the quadcopter is tired, they too are free to admit they are also tired, and thus exhaustion becomes an acceptable outcome of a jog.

O2: Quantifying outcomes

Many mobile jogging apps and wearables (e.g. MapMyRun, Fitbit devices [22]) allow joggers to log quantified outcomes like distance and step count, therefore facilitating awareness of quantified physical activity outcomes [68]. Interviews with JoD participants revealed that the joggers wanted to know what their heart rate was during the run. While the system did not reveal this data, in a future version of the system we could make this data available.

Additional insight

Our findings suggest that it is important to contextualize outcomes, for example, jogging apps can connect to digital scales, articulating the outcome of the jog in weight loss. However, since jogging and weight loss have a complex relationship, it is important to inform joggers what the newly articulated and quantified outcomes can mean.

TEMPORAL ASPECTS

The jogging experience often changes significantly over time: in the beginning of a session, jogging is mostly easy, but at the end, it can be very difficult. In response, we now extend our 13 lenses across a time-based structure, inspired by previous work around time-based structures for embodied interactions [8][29].

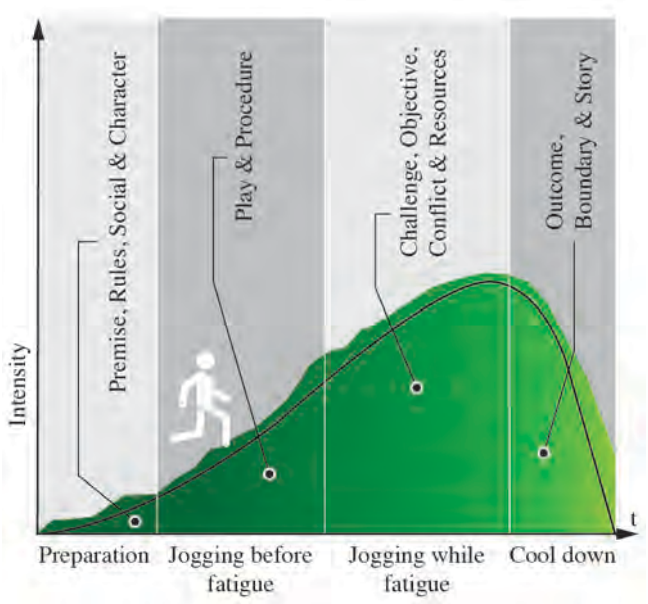

Fig. 3. The lenses across time

We focus on the following key stages of the jog: preparation, jogging before fatigue, jogging while fatigue, and cool down. We acknowledge that these stages could be

further categorized (such as distinguishing between different heart rate zones), however, leave this for future work. Furthermore, we confine our discussion so that each lens is covered just once in the entire jog (Fig. 3).

Premise, Rules, Social & Character

The lenses "premise", "rules", "social" and "character" can be applied particularly in the preparation stage, the period right before the actual jogging activity. Establishing how to support the setting of the jog (*premise*) can contribute towards the jogger's initial motivation. For example, an app could make the jogger aware of a more scenic route in a nearby park rather than using the road. The app could also stress what actions are allowed (*rules*), such as staying within a certain heart rate zone. Furthermore, the system could involve other *social* actors, such as avatars of professional athletes that demonstrate stretching exercises, fostering the development of the jogger seeing him/herself as a "world-class athlete" *character* in response to the question "Who is the jogger?"

Play & Procedure

The lenses "play" and "procedure" can be applied particularly in the stage before fatigue kicks in. Joggers have a big opportunity to experience movement as *play* while they are not yet exhausted. Technology can highlight opportunities for play, for example by allowing joggers to "create" music through mapping running actions to sounds. Asking what actions are required (*procedure*) can inspire designers to think about how to support a good jogging technique e.g. by providing joggers with feedback to minimize their vertical displacement. Such motor-sensory feedback systems [77] seem to be particularly useful for this stage, as the jogger is not yet at a high exhaustion level and can therefore process cognitive information more easily when compared to the next stage.

Challenge, Objective, Conflict & Resources

The lenses "challenge", "objective", "conflict" and "resources" can be applied particularly in the stage where fatigue kicks in. Entering the "flow zone" is likely during this stage, so designers should consider how technology can ensure joggers are neither over- or under-*challenged*; for example, by measuring fatigue indicators, or introducing additional *objectives* that the jogger can strive for. Technology could predict through advanced sensors what is in the jogger's way (*conflict*) in the form of potential injury, warning the jogger. Lastly, designers might want to ask what assets the jogger can use (*resources*), for example to make the jogger aware of any water fountains nearby.

Outcome, Boundary & Story

The lenses "outcome", "boundary" and "story" can be applied particularly in the "cool down" stage after completing the jogging action. Designers could think about how the result of the jog is presented (*outcome*), for example, an outcome could be the average pace. By looking at where the jogging starts and ends (*boundaries*), designers can identify opportunities to incorporate benefits of the jog into other, everyday activities. For example, a system could identify the geographical location where the jog concluded to suggest activities after the run such as a recovery treatment nearby. By considering the jog as a narrative (*story*), designers could think about how they conclude the experience and transition it to the next jog.

LIMITATIONS

We acknowledge that our work only tangentially considers specific forms of running such as long-distance and cross-country. Nevertheless, as we see our work as a starting point towards further investigations into other sports, we believe our lenses still have strong utility. Furthermore, as this work focuses on the jogging activity itself, we only indirectly address any activities in-between jogging (e.g. strength training, injury rehabilitation, or negotiations with family members about how much time is available for jogging). Opportunities for exploration in regards to this have been highlighted elsewhere [32, 76], nevertheless we hope our lenses could be extended to incorporate such aspects in future work. Lastly, although some of our joggers jogged multiple times [47], many of our personal insights are based on single exposures of our systems; we acknowledge that additional and longer term engagements could reveal further insights.

CONCLUSIONS

In sum, our work contributes to the emerging area of designing for technology-supported jogging as made popular by recent mobile and wearable technology trends. Based on related work, our own jogging experiences and having designed, built and studied three jogging systems, we present a set of 13 lenses designers could examine jogging through when designing technology to support it. The strength of our work lies in its practical design focus, articulating the first structured understanding of 26 opportunities for jogging designers. With this work we aim to aid designers in creating novel and diverse systems that support joggers. In consequence, we hope jogging participation increases, and ultimately, more people profit from the many benefits of jogging.

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REFERENCES

1. Dailymile. Retrieved January 10, 2017 from http://www.dailymile.com/people/Jzelm9/entries/13139370.
2. Sensoria Fitness. Retrieved January 10, 2017 from http://www.sensoriafitness.com/.
3. Florian Mueller and Sarah Jane Pell. 2016. Technology Meets Adventure: Learnings from an Earthquake-Interrupted Mt. Everest Expedition. In *Proceedings of the Joint Conference on Pervasive and Ubiquitous Computing*. ACM, 2971683, 817-828. http://dx.doi.org/10.1145/2971648.2971683
4. Zombies, Run! Retrieved January 10, 2017 from http://www.zombiesrungame.com.
5. Goodgym. Retrieved January 10, 2017 from http://www.goodgym.org/.
6. Runkeeper. Retrieved January 10, 2017 from http://runkeeper.com.
7. Apple. Apple - Nike + Ipod. Retrieved January 10, 2010 from http://www.apple.com/ipod/nike.
8. Steve Benford, Gabriella Giannachi, Boriana Koleva and Tom Rodden. 2009. From Interaction to Trajectories: Designing Coherent Journeys through User Experiences. In *Proceedings of the Conference on Human factors in computing systems*. ACM, 1709-718. http://doi.acm.org/10.1145/1518701.1518812
9. Ian Bogost. 2005. The Rhetoric of Exergaming. In *Proceedings of Digital Arts and Cultures (DAC) Conference*.
10. Jordi Bolíbar and Roberto Bresin. Sound Feedback for the Optimization of Performance in Running. *SMC Sweden 2012 Sound and Music Computing, Understanding and Practicing in Sweden* (2012), 39.
11. Fabio Buttussi and Luca Chittaro. Smarter Phones for Healthier Lifestyles: An Adaptive Fitness Game. *IEEE Pervasive Computing* 9, 4 (2010), 51–57. http://dx.doi.org/doi:10.1109/MPRV.2010.52
12. Richard Byrne. Adapting Running Pace with Music. Unpublished thesis, 2008.
13. Taj Campbell, Brian Ngo and James Fogarty. 2008. Game Design Principles in Everyday Fitness Applications. In *Proceedings of the Conference on Computer supported cooperative work*. ACM, 249-252.
14. Matthew Chalmers, Marek Bell, Barry Brown, Malcolm Hall, Scott Sherwood and Paul Tennent. 2005. Gaming on the Edge: Using Seams in Ubicomp Games. In *Proceedings of the Conference on Advances in computer entertainment technology*. ACM, 306-309. http://dx.doi.org/10.1145/1178477.1178533
15. Peter J Clough, John Shepherd and Ronald Maughan. Motives for Participation in Recreational Running. *Journal of Leisure Research* (1989).
16. Sunny Consolvo, David W. McDonald, Tammy Toscos, Mike Y. Chen, Jon Froehlich, Beverly Harrison, Predrag Klasnja, Anthony LaMarca, Louis LeGrand, Ryan Libby, Ian Smith and James A. Landay. 2008. Activity Sensing in the Wild: A Field Trial of Ubifit Garden. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. ACM, 1357335, 1797-1806. http://dx.doi.org/10.1145/1357054.1357335
17. Mihaly Csikszentmihalyi. *Flow: The Psychology of Optimal Performance*. New York: Harper and Row, 1990.
18. Franco Curmi, Maria Angela Ferrario, Jen Southern and Jon Whittle. 2013. Heartlink: Open Broadcast of Live Biometric Data to Social Networks. In *Proceedings of the SIGCHI conference on Human Factors in computing systems*. ACM, 1749-1758. http://dx.doi.org/10.1145/2470654.2466231
19. Franco Curmi, Maria Angela Ferrario and Jon Whittle. 2014. Bioshare: A Research Tool for Analyzing Social Networks Effects When Sharing Biometric Data. In *Proceedings of the 2014 companion publication on Designing interactive systems*. ACM, 101-104. http://dx.doi.org/10.1145/2598784.2602793
20. Franco Curmi, Maria Angela Ferrario, Jon Whittle and Florian Mueller. 2015. Crowdsourcing Synchronous Spectator Support: (Go on, Go on, You're the Best)^{N-1}. In *Proceedings of the Conference on Human Factors in Computing Systems*. ACM, 757-766. http://dx.doi.org/10.1145/2702123.2702338
21. EJ Dickson. 2014. Woman Uses Nike+ App to Draw Penises All over San Francisco. Retrieved January 10, 2017 from http://www.dailydot.com/lol/nike-plus-penis-drawing/.
22. Fitbit. 2012. Retrieved January 10, 2017 from Fitbit. http://fitbit.com.
23. Maiken Hillerup Fogtmann, Jonas Fritsch and Karen Johanne Kortbek. 2008. Kinesthetic Interaction - Revealing the Bodily Potential in Interaction Design. In *Proceedings of OZCHI '08: Conference of the computer-human interaction special interest group (CHISIG) of Australia on Computer-Human Interaction*. ACM.
24. Tracy Fullerton, Christopher Swain and Steven Hoffman. *Game Design Workshop*. Morgan Kaufmann, 2004.
25. William Gaver. 2012. What Should We Expect from Research through Design? In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. ACM, 937-946. http://dx.doi.org/10.1145/2207676.2208538
26. Marnix GJ Gazendam and At L Hof. Averaged Emg Profiles in Jogging and Running at Different Speeds. *Gait & posture* 25, 4 (2007), 604-614.
27. Kristina Höök, Martin Jonsson, Anna Ståhl and Johanna Mercurio. 2016. Somaesthetic Appreciation Design. In *Proceedings of the Conference on Human*

Factors in Computing Systems (CHI'16), San Jose, CA, USA.

28. Kristina Höök and Jonas Löwgren. Strong Concepts: Intermediate-Level Knowledge in Interaction Design Research. *ACM Trans. Comput.-Hum. Interact.* 19, 3 (2012), 1-18. http://dx.doi.org/10.1145/2362364.2362371
29. Amy Huggard, Anushka De Mel, Jayden Garner, Cagdas Chad Toprak, Alan D Chatham and Florian Mueller. 2013. Understanding a Socially Awkward Digital Play Journey. In *Proceedings of DiGRA 2013*. ACM.
30. Recon Instruments. 2015. Recon. Retrieved January 10, 2015 from reconinstruments.com.
31. Rohit Khot, Jeewon Lee, Larissa Hjort, Deepti Aggarwal and Florian Mueller. 2015. Tastybeats: Designing Palatable Representations of Physical Activity. In *Proceedings of the Conference on Human Factors in computing systems*. ACM. 2933-2942. http://dx.doi.org/10.1145/2702123.2702197
32. Kristina Knaving, Pawel Wozniak, Morten Fjeld and Staffan Bjork. 2015. Flow Is Not Enough: Understanding the Needs of Advanced Amateur Runners to Design Motivation Technology. In *Proceedings of the Conference on Human Factors in Computing Systems*. ACM, 2013-2022. http://dx.doi.org/10.1145/2702123.2702542
33. R. Scott Kretchmar. *Practical Philosophy of Sport and Physical Activity*. Human Kinetics Publishers (Champaign, IL, USA), 2005.
34. Astrid Larssen, Lian Loke, Tony Robertson, Jenny Edwards. 2004. Understanding Movement as Input for Interaction–a Study of Two Eyetoy Games. In *Proceedings of OzCHI '04*.
35. James Lin, Lena Mamykina, Silvia Lindtner, Gregory Delajoux and Henry Strub. 2006. Fish'n'steps: Encouraging Physical Activity with an Interactive Computer Game. In *Proceedings of UbiComp 2006: Ubiquitous Computing*. 261-278.
36. Lian Loke, Astrid Larssen, Toni Robertson and Jenny Edwards. Understanding Movement for Interaction Design: Frameworks and Approaches. *Personal and Ubiquitous Computing* 11, 8 Special Issue Movement-Based Interaction (2007), 691-701.
37. Roger A Mann and John Hagy. Biomechanics of Walking, Running, and Sprinting. *The American Journal of Sports Medicine* 8, 5 (1980), 345-350.
38. mapmyrun.com. 2010. Mapmyrun. Retrieved January 10, 2017 from http://www.mapmyrun.com/.
39. Elena Márquez Segura, Laia Turmo Vidal, Asreen Rostami and Annika Waern. Year. Embodied Sketching. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems*. ACM, 6014-6027.
40. Joe Marshall and Steve Benford. 2011. Using Fast Interaction to Create Intense Experiences. In *Proceedings of the Conference on Human factors in computing systems*. ACM, 1255-1264. http://dx.doi.org/10.1145/1978942.1979129
41. Matthew Mauriello, Michael Gubbels and Jon E Froehlich. 2014. Social Fabric Fitness: The Design and Evaluation of Wearable E-Textile Displays to Support Group Running. In *Proceedings of the Conference on Human Factors in Computing Systems*. ACM, 2833-2842.
42. Mary McElroy. *Resistance to Exercise: A Social Analysis of Inactivity*. Human Kinetics Publishers (Champaign, IL, USA), 2002.
43. David K McGookin and Stephen A Brewster. 2013. Investigating and Supporting Undirected Navigation for Runners. In *Proceedings of CHI'13 Extended Abstracts on Human Factors in Computing Systems*. ACM, 1395-1400.
44. Stu Mittleman and Katherine Callan. *Slow Burn: Burn Fat Faster by Exercising Slower*. HarperCollins, 2001.
45. Jin Moen. Kinaesthetic Movement Interaction: Designing for the Pleasure of Motion. Unpublished PhD thesis, Stockholm: KTH, 2006.
46. Florian Mueller, Shannon O'Brien and Alex Thorogood. 2007. Jogging over a Distance: Supporting a "Jogging Together" Experience Although Being Apart. In *Proceedings of CHI '07: Conference on Human Factors in Computing Systems*. ACM, 2579 - 2584.
47. Florian Mueller, Frank Vetere, Martin Gibbs, Darren Edge, Stefan Agamanolis, Jeniffer Sheridan and Jeffrey Heer. 2012. Balancing Exertion Experiences. In *Proceedings of SIGCHI Conference on Human Factors in Computing Systems*. ACM, 1853-1862.
48. Florian Mueller, Frank Vetere, Martin Gibbs, Stefan Agamanolis and Jennifer Sheridan. 2010. Jogging over a Distance: The Influence of Design in Parallel Exertion Games. In *Proceedings of Sandbox '10: the 5th ACM SIGGRAPH Symposium on Video Games*. ACM, 63-68.
49. Florian Mueller, Frank Vetere, Martin Gibbs, Darren Edge, Stefan Agamanolis and Jennifer Sheridan. 2010. Jogging over a Distance between Europe and Australia. In *Proceedings of the symposium on User interface software and technology*. ACM, 189-198. http://dx.doi.org/10.1145/1866029.1866062
50. Florian Mueller and Katherine Isbister. 2014. Movement-Based Game Guidelines. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. ACM, 2191-2200. http://dx.doi.org/10.1145/2556288.2557163
51. Florian Mueller, Joe Marshall, Rohit Ashok Khot, Stina Nylander and Jakob Tholander. 2014. Jogging with Technology: Interaction Design Supporting Sport Activities. In *Proceedings of the extended abstracts of the ACM conference on Human factors in computing*

systems. ACM, 1131-1134. http://dx.doi.org/10.1145/2559206.2559209

52. Florian Mueller and Matthew Muirhead. 2015. Jogging with a Quadcopter. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems*. ACM, 2023-2032. http://dx.doi.org/10.1145/2702123.2702472
53. Florian Mueller and Matthew Muirhead. 2014. Understanding the Design of a Flying Jogging Companion. In *Proceedings of the adjunct publication of the 27th annual ACM symposium on User interface software and technology*. ACM, 2658786, 81-82. http://dx.doi.org/10.1145/2658779.2658786.
54. Lama Nachman, Amit Baxi, Sangeeta Bhattacharya, Vivek Darera, Piyush Deshpande, Nagaraju Kodalapura, Vincent Mageshkumar, Satish Rath, Junaith Shahabdeen and Raviraja Acharya. 2010. Jog Falls: A Pervasive Healthcare Platform for Diabetes Management. In *Proceedings of Pervasive Computing*. Springer, 94-111.
55. Carman Neustaedter and Phoebe Sengers. Autobiographical Design: What You Can Learn from Designing for Yourself. *interactions* 19, 6 (2012), 28-33.
56. Shahriar Nirjon, Robert F Dickerson, Qiang Li, Philip Asare, John A Stankovic, Dezhi Hong, Ben Zhang, Xiaofan Jiang, Guobin Shen and Feng Zhao. 2012. Musicalheart: A Hearty Way of Listening to Music. In *Proceedings of the 10th ACM Conference on Embedded Network Sensor Systems*. ACM, 43-56.
57. Stina Nylander, Mattias Jacobsson and Jakob Tholander. 2014. Runright: Real-Time Visual and Audio Feedback on Running. In *Proceedings of CHI '14 Extended Abstracts on Human Factors in Computing Systems*. ACM, 583-586. http://dx.doi.org/10.1145/2559206.2574806
58. Stina Nylander, Jakob Tholander, Florian Mueller and Joe Marshall. 2014. Hci and Sports. In *Proceedings of CHI '14 Extended Abstracts on Human Factors in Computing Systems*. ACM, 2559223, 115-118. http://dx.doi.org/10.1145/2559206.2559223
59. Shannon O'Brien and Florian Mueller. 2007. Jogging the Distance. In *Proceedings of the SIGCHI conference on Human Factors in computing systems*. ACM, 523-526.
60. Nuria Oliver and Fernando Flores-Mangas. 2006. Mptrain: A Mobile, Music and Physiology-Based Personal Trainer. In *Proceedings of the 8th conference on Human-computer interaction with mobile devices and services*. ACM, 21-28. http://dx.doi.org/10.1145/1152215.1152221
61. Taiwoo Park, Uichin Lee, Bupjae Lee, Haechan Lee, Sanghun Son, Seokyoung Song and Junehwa Song. 2013. Exersync: Facilitating Interpersonal Synchrony in Social Exergames. In *Proceedings of the 2013 conference on Computer supported cooperative work*. ACM, 409-422.
62. Taiwoo Park, Chungkuk Yoo, Sungwon Peter Choe, Byunglim Park and Junehwa Song. 2012. Transforming Solitary Exercises into Social Exergames. In *Proceedings of the ACM 2012 conference on Computer Supported Cooperative Work*. ACM, 863-866. http://dx.doi.org/10.1145/2145204.2145332
63. Sebastiaan Pijnappel and Florian Mueller. Year. 4 Design Themes for Skateboarding. In *Proceedings of the SIGCHI conference on Human Factors in computing systems*. ACM, 1271-1274.
64. Polar. 2015. Polar. Retrieved January 10, 2015 from polar.com.
65. Stuart Reeves, Steve Benford, Claire O'Malley and Mike Fraser. 2005. Designing the Spectator Experience. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. ACM, 1055074, 741-750. http://dx.doi.org/10.1145/1054972.1055074.
66. Scott Rigby and Richard Ryan. *Glued to Games: How Video Games Draw Us in and Hold Us Spellbound*. Praeger, 2011.
67. Yvonne Rogers. Interaction Design Gone Wild: Striving for Wild Theory. *interactions* 18, 4 (2011), 58-62. http://dx.doi.org/10.1145/1978822.1978834
68. Brenda Rooney, Kathy Smalley, Jennifer Larson and Sarah Havens. Is Knowing Enough? Increasing Physical Activity by Wearing a Pedometer. *WMJ-MADISON*- 102, 4 (2003), 31-36.
69. Daniela K. Rosner, Hidekazu Saegusa, Jeremy Friedland and Allison Chambliss. 2015. Walking by Drawing. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems*. ACM, 2702467, 397-406. http://dx.doi.org/10.1145/2702123.2702467
70. Katie Salen and Eric Zimmerman. *Rules of Play: Game Design Fundamentals*. The MIT Press (Boston, MA, USA), 2003.
71. Jesse Schell. *The Art of Game Design: A Book of Lenses*. Morgan Kaufmann, 2008.
72. Elena Marquez Segura, Annika Waern, Jin Moen and Carolina Johansson. 2013. The Design Space of Body Games: Technological, Physical, and Social Design. In *Proceedings of the SIGCHI conference on Human Factors in computing systems*. ACM, 3365-3374. http://dx.doi.org/10.1145/2470654.2466461
73. Richard Shipway and Immy Holloway. Running Free: Embracing a Healthy Lifestyle through Distance Running. *Perspectives in public health* 130, 6 (2010), 270-276.
74. Bernard Suits. *The Grasshopper: Games, Life and Utopia*. Broadview Press, 2005.
75. Jonh R. Taylor. On Running and Jogging. *Cognitive Linguistics (includes Cognitive Linguistic*

Bibliography) 7, 1 (1996), 21. http://dx.doi.org/10.1515/cogl.1996.7.1.21

76. Jakob Tholander and Stina Nylander. 2015. Snot, Sweat, Pain, Mud, and Snow: Performance and Experience in the Use of Sports Watches. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems*. ACM, 2913-2922.
77. Jelle van Dijk, Remko van der Lugt and Caroline Hummels. 2014. Beyond Distributed Representation: Embodied Cognition Design Supporting Socio-Sensorimotor Couplings. In *Proceedings of the 8th International Conference on Tangible, Embedded and Embodied Interaction*. ACM, 181-188.
78. Emma Witkowski. 2013. Running from Zombies. In *Proceedings of The 9th Australasian Conference on Interactive Entertainment: Matters of Life and Death*. ACM.
79. Pawel Wozniak, Kristina Knaving, Staffan Bjork and Morten Fjeld. 2015. Rufus: Remote Supporter Feedback for Long-Distance Runners. In *Proceedings of the Conference on Human-Computer Interaction with Mobile Devices and Services*. ACM, 115-124. http://dx.doi.org/10.1145/2785830.2785893
80. Mahmoud Hassan, Florian Daiber, Frederik Wiehr, Felix Kosmalla, Antonio Krueger. Footstriker: An Ems-Based Foot Strike Assistant for Running. *Proc. ACM Interact. Mob. Wearable Ubiquitous Technol.* 1, 1 (2017), 1-18. http://dx.doi.org/10.1145/3053332
81. Chek Tien Tan, Richard Byrne, Simon Lui, Weilong Liu and Florian Mueller. 2015. Joggar: A Mixed-Modality Ar Approach for Technology-Augmented Jogging. In *Proceedings of SIGGRAPH Asia 2015 Mobile Graphics and Interactive Applications*. ACM, 2818434, 1-1. http://dx.doi.org/10.1145/2818427.2818434
82. Florian Mueller, Darren Edge, Frank Vetere, Martin Gibbs, Stefan. Agamanolis, Bert Bongers and Jennifer Sheridan. 2011. Designing Sports: A Framework for Exertion Games. In *Proceedings of the Conference on Human Factors in Computing Systems*. ACM, 2651-2660.
83. Florian Mueller and Damon Young. 2017. Five Lenses for Designing Exertion Experiences. In *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems*. ACM, 3025746, 2473-2487. http://dx.doi.org/10.1145/3025453.3025746
84. Florian Mueller, Joe Marshall, Rohit Ashok Khot, Stina Nylander and Jakob Tholander. 2015. Understanding Sports-HCI by Going Jogging at Chi. In *Proceedings of the 33rd Annual ACM Conference Extended Abstracts on Human Factors in Computing Systems*. ACM, 2727688, 869-872. http://dx.doi.org/10.1145/2702613.2727688
85. Florian Mueller, Joe Marshall, Rohit Ashok Khot, Stina Nylander and Jakob Tholander. 2016. Jogging at CHI. In *Proceedings of the 2016 CHI Conference Extended Abstracts on Human Factors in Computing Systems*. ACM, 1119-1122.
86. Florian Mueller. Digital Sport: Merging Gaming with Sports to Enhance Physical Activities Such as Jogging. In *Digital Sport for Performance Enhancement and Competitive Evolution: Intelligent Gaming Technologies*, 2009, 150-166.