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Self-tracking while Doing Sport: Comfort, Motivation, Attention and Lifestyle of Athletes Using Personal Informatics Tools

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ABSTRACT

The spread of wearable technologies is paving the way for the mass-scale adoption of self-tracking instruments, which are progressively integrating into different social practices. Among these, sport seems to be a promising domain in which Personal Informatics tools can support individuals in performing their activities and in achieving their situated goals. In this article, we conducted semi-structured interviews with amateur and elite athletes to explore what they seek in their trackers, how such instruments may impact on their "mind", by affecting their motivation and attention during workouts and races, and how sports data are intertwined with other information pertaining to their lifestyle. On the basis of these findings we discussed three themes that may be relevant for Personal Informatics, also proposing a series of implications for design that may help researchers in designing self-tracking tools for sport.

Keywords: Personal Informatics, Quantified Self, self-tracking, sport, elite athletes, amateur athletes, wearable devices, information visualization; physical activity; activity trackers

Declarations of interest: none

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1. INTRODUCTION

Progresses in wearable technology and the growing popularity of self-tracking tools are changing how individuals engage in sports activities. Personal Informatics (PI) systems, "those that help people collect personally relevant information for the purpose of self-reflection and gaining self-knowledge" (Li et al. 2010, 558), are gradually permeating the sports context: athletes have been monitoring themselves since a long time (Currell and Jeukendrup, 2008; Saw et al. 2015b), by using tests, self-reports and questionnaires, and tracking technologies may improve this activity by providing continuous measures of their performance and physical condition.

Building upon Human-Computer Interaction (HCI) interest in the use of technology in the sports domain (Ishii et al. 1999; Slovák et al. 2012; Pijnappel and Mueller 2013; Mauriello et al. 2014; Mueller and Muirhead 2015; Kosmalla et al. 2016), this article examines how amateur and elite athletes use self-tracking instruments to manage their sports practices.

The study contributes to research in PI that examines how people track themselves. Most of such research focuses on "generic" kinds of users, exploring differences in usage patterns on the basis of their level of previous experience (i.e., experienced vs. inexperienced) in self-tracking (e.g., Li et al., 2010; Fritz et al., 2014; Gouveia et al., 2018; Choe et al., 2014; Lazar et al., 2015; Rapp and Cena, 2016; Rapp et al., 2018).

This focus on generic users, however, overlooked the situated use of PI technologies, undermining the opportunities for designing tools within specific practices (Rapp et al., 2017). Moreover, by paying attention mainly to "experienced" and "inexperienced" trackers HCI research clouded the exploration of other, potentially relevant, factors that may affect the usage of PI devices.

This article fills an important gap in current PI research, by exploring how athletes intertwine the use of PI tools with the activities and challenges they face within their sports practices: going beyond the idea of "generic PI users", it describes how a specific population like the athletes use PI technology to achieve their situated goals. In so doing, the study also explores the different usage patterns and conceptualizations of PI devices among athletes, by comparing the tracking activities of amateurs and elites. Research in disciplines spanning from sports psychology to neuroscience show that expert athletes differ consistently from amateurs with regard to a variety of perceptual, cognitive and strategic aspects of behavior (Müller et al., 2010; Williams & Ford, 2008; Eklund & Tenenbaum, 2014). They carry out different activities, are embedded in different social contexts, and have different levels of knowledge of the sport they perform (Swann, Moran, & Piggott, 2015): in sum, they are engaged in different practices. It seems thus reasonable to ask ourselves whether these differences may lead to different usages of PI tools.

Understanding how amateur and elite athletes differently use PI instruments may not only shed light on how their usage patterns may vary on the basis of the practices in which the user is engaged, but also provide suggestions on how we can design better PI tools not only to fulfill athletes' unmet desires (e.g., the elites' search for more comfort), but also to support amateur athletes. At present, amateurs might find it difficult to pursue their situated goals, such as changing their behavior through their tracker to improve their sports performance or using the device to fulfill their contextual needs: this might be due to their lack of knowledge about their sports practice. Instead, elites might not encounter the same issues, as they may well know how to behave and achieve their objectives. Therefore, the insights collected among the elites may be useful to design devices addressed to the amateurs, when the aim is to increase their knowledge about the sport they perform (which may make the use of their trackers more effective).

Building on top of our recent work investigating how athletes interpret their performance and physiological data (Rapp & Tirabeni, 2018), in this article we aim to widen our perspective on the use of PI instruments in sport, moving beyond the focus on sense-making and sports data. First, we will explore the situated use of trackers in sports practices. Second, we will deepen themes that could be inspiring for the design of PI instruments also outside the sports context. Third, we will outline a series of design implications that can inspire the design of novel PI tools addressed to the sports domain.

The article is structured as follows. Section 2 provides a picture of previous research related to PI tools usage. Section 3 outlines the method we used, whereas Section 4 describes the findings of our study. Section 5 discusses the results introducing themes relevant for the PI discourse. Finally, Section 6 proposes a series of suggestions for design, and Section 7 concludes the article.

2. BACKGROUND

2.1 Personal Informatics users

Since the first life logging projects (Cheng et al. 2004; Gemmell et al. 2006; Mann et al. 2004), technology has been seen as a means to record behavior. In the last ten years, HCI researchers started exploring how self-tracking instruments may favor the modification of behavior, with a special attention to the physical activity context, or to the medical domain: several prototypes have been deployed, showing that personal data may be effective in increasing the level of physical activity (Toscos et al. 2006; Consolvo et al. 2008; Bentley et al., 2013; Gouveia et al. 2015); other scholars highlighted that self-tracking may support therapeutic interventions such as the management of a chronic disease (Karkar et al., 2017; McKillop et al., 2018).

HCI research has also explored how commercial trackers are used by individuals with and without previous experience in self-tracking. Li et al. (2010, 2011) first identified barriers that users expert in collecting data about themselves find in using PI technologies. Choe et al. (2014) pointed out that even Quantified Selfers, a user group extremely focused on collecting personal data, find some difficulties in managing such data. Choe et al. (2017) emphasized that supporting flexible data selection, filtering, and comparison can help users formulate questions and see things from a different perspective. In this vein, Ayobi et al. (2016) examined the role of reflection in PI data exploration.

Rooksby et al. (2014) and Epstein et al. (2015a) stressed that expert users may have different motivations to track. Fritz et al. (2014) further highlighted that long-term trackers focus on numerical feedback, goals and rewards provided by their devices, gathering data and exploring them afterwards. In this vein, HCI researchers commonly focused on designing PI systems that allow for an easier, more efficient and engaging post-hoc analytical examination of personal data (e.g. Bentley et al. 2013; Epstein et al. 2014; Nafus et al. 2016), paying less attention to interactions with trackers used "in the course of action". Recently, Gouveia et al. (2018) highlighted that long-term trackers may also use their devices by reflecting and learning in action. They argued that glanceable feedback, i.e., designs that can be accessed by 5-second interaction sessions, may support this interaction modality (Gouveia et al., 2016).

Although not specifically connecting their study with the PI discourse, Lazar et al. (2015) explored processes of disengagement of inexperienced users from wearable trackers, finding that their management is burdensome and that the gathered information is seen as not useful by them. Rapp and Cena (2016) and Rapp et al. (2018) confirmed these issues among the inexperienced population, who may be not highly motivated to track, thus rapidly abandoning their device when their curiosity is not satisfied.

In order to address the difficulties encountered by both experienced and inexperienced trackers researchers focused on designing PI systems that allow for an easier, more efficient and engaging analytical reflection on personal data (e.g. Bentley et al. 2013; Epstein et al. 2014; Nafus et al. 2016). For instance, they focused on the readability of displayed data (Epstein et al., 2014) and accuracy (Yang et al., 2015), as well as the different ways in which data can be recounted (Hilviu & Rapp, 2015) or made actionable (Rapp et al., 2018). Moreover, recent research has proposed tangible interfaces for self-reporting personal data, such as chronic pain (Price et al., 2018; Adams et al., 2018), or emotions (Cena et al., 2014). Whereas others explored how to transform PI data, such as DNA information, into "objects" that can be worn by the user (Alireza & Jared, 2014).

These works provide a quite clear picture of the challenges and pitfalls that people may encounter when using currently available trackers, as well as propose several design solutions to address them. Nevertheless, they either stress almost exclusively behavior change or therapeutic purposes (Rapp & Tirassa, 2017), or narrow the focus on "generic" user groups (experienced vs.

inexperienced) (Rapp et al., 2017), whereby a relevant factor affecting the tracker usage is identified in the user's previous experience in managing her own data.

As a result, we know a lot about the act of tracking *per s*e, and how data can be used for modifying behavior or treating health conditions, but far less on the situated use of these instruments in specific practices, especially within communities that have their own situated goals.

2.2 PI and athletes

Athletes have been engaged in self-monitoring practices for a long period of time (Halson 2014), to increase their performances (Kirschenbaum et al. 1982; Saw et al. 2015a), and to support self-awareness and self-regulation in training (Oliver et al. 2010). Self-tracking allows coaches to better tune training loads (Saw et al. 2015b) and reduce the risk of overtraining (Coutts and Cormack 2014). The recent spreading of PI technologies lowered the burden of these activities, which may span from great efforts expended in analyzing data to long time spent in collecting them (Saw et al. 2015b). On the one hand, prototype wearable technologies are progressively allowing for the automatic detection of more and more complex behaviors relevant to the sports domain (e.g., Michaelles and Schiele, 2005; Lapinski et al., 2009; Stamm et al., 2013; Kooyman et al., 2013; Zhou et al., 2016; Kosmalla et al., 2015). On the other hand, commercial wearable devices and self-tracking applications have enabled athletes to gather data about their location, distance, and heartbeat, as well as specific parameter for different sports, such as cycling (Power Meter), ski mountaineering (Suunto Ambit3 Vertical), and basket (OptimEye S5 Catapult).

Despite all these technological opportunities, sports science missed to thoroughly explore the situated use of PI devices in sports. Research did investigate different methods, also involving technology, that can be used to quantify sports activities and parameters, such as performance and fatigue (Thorpe et al., 2017; Edwards et al., 2018). Nonetheless, it focused on how such data can be collected for answering precise research questions about sports performance (Ripoli et al., 1997), or identify performance differences among athletes. Di Salvo et al. (2007), for instance, monitored the distance run of 300 elite soccer players to assess the demands placed on each player according to her positional role at different work intensities. Whenever sports science showed interest in athletes' self-monitoring, it mainly paid attention to how they use "non-automated means" (e.g., questionnaires) to self-report their response to training (Saw et al, 2015b). For example, Lee-Taylor et al. (2017) recruited 100 participants involved in coaching or sports science support roles asking them about self-report questionnaires and performance tests.

Similarly, HCI research seldom tried to understand the situated use of PI instruments in sport. On the one hand, HCI researchers preferred to investigate their technical aspects (Mencarini et al., 2019), like feedback modalities (Kosmalla et al., 2016), sensing opportunities (Franke et al., 2011), and wearability, namely the capability of an object to be worn on the body adapting to its shape (Gemperle et al., 1998; Dunne et al. 2014; Harrison et al., 2009).

On the other hand, a variety of research in disciplines like motor learning/skill acquisition, cognitive psychology, neuroscience, sports psychology, and kinesiology have engaged in the scientific study of sports expertise, and stressed elite-amateur differences in sport (Ericsson, 1996, Swann et al., 2015). It has been highlighted that "compared to their novice counterparts, expert athletes tend to have a more extensive knowledge-base of sport-specific information and to be more adept at using this knowledge efficiently to identify, remember and manipulate relevant information in their specialist sport" (Swann et al., 2015, 3). The HCI community, however, missed to connect the use of self-tracking tools to such differences, ignoring how amateur and elite athletes may differ with reference to their sports practices.

Wakefield et al. (2014), for instance, interviewed eight amateur endurance athletic coaches who tracked athlete-related data, pointing to the importance of contextual information in enabling coaches to adjust their training programs: nonetheless, they did not compare their use of trackers with those of professional coaches. Actually, Tholander and Nylander (2015) interviewed three elite and seven recreational endurance athletes to explore the use of heart rate monitors during their trainings, finding that these tools improve their performance and connect them closer to their body.

Nevertheless, the small sample size, its homogeneity (only endurance athletes or endurance coaches are recruited, and a limited number of sports is considered), and the lack of precise inclusion criteria (the training load used by Tholander and Nylander seems insufficient to define an elite athlete, as noted by Swann, Moran, and Piggott, (2015)), limited the applicability of their findings.

To overcome some of these limitations, we conducted twenty semi-structured interviews with amateur and elite athletes, focusing on how they make sense of sports data (i.e., physiological and performance measures) collected by PI devices: the former believe that the objective measures gathered through self-tracking are the most important thing to be considered to evaluate the sports performance, whereas the latter know when it is necessary to trust in subjective sensations more than in PI "numbers" (Rapp & Tirabeni, 2018). In that study, we stressed the notion of "sensation": elites use mostly this term to refer to a world of subjective feelings that cannot be reduced to quantitative measures. Another element we found is related to the use of the devices' social features, since as long as the level of eliteness raises, athletes show to be more interested in using data sharing for strategic aims, whereas amateurs share their data for strengthening their intimate connections (Rapp & Tirabeni, 2018).

Despite all the insights emerged from these study findings, their focus may provide a partial perspective on PI in sport. On the one hand, they did shed light on how athletes interpret the physiological and performance data they collect, which is essential to understand how self-tracking technologies are currently changing the athlete's situated practices. On the other hand, however, they may frame the PI device as a mere data repository, overlooking other relevant usages that athletes develop during their sports activities.

In other words, we need to widen our perspective, moving the focus beyond sense-making and "sports data" (i.e., physiological and performance data) in order to identify the different uses as well as effects that PI devices may have within the sports practices. A variety of research questions remained unanswered in Rapp & Tirabeni (2018): Is the PI device seen by athletes in other ways than a data repository? For instance, is it conceived also as an "object" that can be worn in social occasions and bump into aesthetics matters? What kind of "internal dynamics" are impacted by PI devices beyond sense-making? For example, are PI tools able to affect athletes' motivation? What kind of data do athletes consider beyond sports data? For instance, how and why do they relate their sports data to other data that are connected with their everyday life?.

In this article, we want to fill this gap giving a response to these questions. To this aim, we reanalyzed the data gathered in our previous study (first study[1]) that were connected to these questions, and conducted ten additional interviews in a new study (second study) in order to deepen them. The findings depicted in this article extend our previous research on PI in sport by reporting five original themes that were not published in Rapp & Tirabeni (2018), tackling topics that go beyond the interpretation of sports data. This would increase our knowledge on how PI instruments are integrated into sports practices, offering a more nuanced perspective on how PI devices are used in sport, as well as pointing out the varied effects they may have on athletes. In the following Sections we will thus recount: i) how amateur and elite participants differently conceptualize their device; ii) whether and how they switch their devices; iii) the motivational effects of PI tools on them; iv) the devices' impacts on their attention and distraction; v) and the role that lifestyle data may play in their sports activities.

3. METHOD

3.1 Sample

The *first study* included 20 participants recruited by emails and snowball sampling, split into two groups. The "elites" group (females=5; mean age=32,5; SD=6,9) was composed of 12 elite athletes (E1-E12), defined by following Swann et al. (2015), i.e., considering the athlete's highest standard of performance, achieved successes, and years of experience at the athlete's highest level, as well as the competitiveness of the sport in the athlete's country and globally. The inclusion criteria were the

[1] With *first study* we refer to the research published in Rapp & Tirabeni (2018).

following: i) the athlete had been using one (or more) PI instrument for at least three months and were still using it; ii) she had competed at least nationally during her career; iii) she had had successes at least at regional level; iv) she was still involved competitively in sports events. In the "amateurs" group (females=3; mean age=30,4; SD=6,1) we recruited eight amateur athletes (A1-A8). The inclusion criteria were that: i) the athlete had been using one PI tool (or more) for at least three months and were still using it; ii) she was exercising at least three times a week; iii) she was spending at least five hours a week practicing. Even if competing at amateur level was not a requirement, five amateurs participated to amateur tournaments.

The *second study* involved 10 participants, 6 elites (females=2; mean age=30,7; SD=5,4) (E13-E18) and 4 amateurs (females=1; mean age=30,5; SD=5,5) (A9-A12), with the same recruitment modalities and inclusion criteria used in the first study.

Table I. Sample – Elite Athletes

Elite athletes: First Study									
ID	Age	Gender	Highest standard of performance	Success at the athlete's highest level	Experience at the athlete's highest level	Sport	PI Tool	Experience of use	Main data collected
E1	28	Male	2nd tier professional league	Success at 2nd and 3rd tier[2]	8 years	Soccer	Polar Heart Rate Monitor	2 years	Heart rate
E2	28	Male	2nd tier professional league	Success at 2nd and 3rd tier	7 years	Soccer	OptimEye S5 Catapult	2 years	Distance, sprints, position
E3	32	Female	International level	Success at 2nd and 3rd tier	10 years	Long-distance running	Garmin fēnix 3 HR	10 years	Time, distance, routes, pace, heart rate
E4	41	Male	National level	Success at 2nd and 3rd tier	5 years	Long-distance running	Timex Ironman Trainer GPS with CARDIO T5K575	4 years	Time, distance, pace, heart rate
E5	35	Female	International level	Sustained success in intern. competition	6 years	Cycling	Garmin fēnix 3 HR; Power Meter	7 years	Time, distance, speed, heart rate, watts

[2] Second and third "tier" refers to second order national competitions like English Championship Division football or B and C Italian series professional leagues in basketball (Swan et al., 2015).

E6	21	Female	International level	Sustained success in intern. competition	4 years	Free climbing	Moonboard application	1 year	Boulders
E7	28	Male	International level	Sustained success in intern. competition	8 years	Ski mountaineering	Suunto Spartan; Suunto Smart Sensor	12 years	Time, altitude, distance
E8	48	Female	International level	Sustained success in intern. competition	12 years	Cycling	Suunto Spartan; Power Meter	8 years	Time, distance, speed, watts
E9	32	Male	National level	Success at 2nd and 3rd tier	15 years	Cross-country skiing	Garmin Forerunner 735XT; Suunto Ambit3 Vertical;	15 years	Time, altitude, heart rate, position
E10	34	Female	International level	Sustained success in intern. competition	5 years	Ski mountaineering	Suunto Ambit3 Vertical; Suunto Smart Sensor	4 years	Time, altitude, heart rate, position
E11	32	Male	National level	Success at 2nd and 3rd tier	14 years	Sprint	Garmin Forerunner 735XT	11 years	Time, pace, heart rate
E12	31	Male	International level	Sustained success in intern. competition	3 years	Ski mountaineering	Suunto Ambit3 Vertical; Suunto Smart Sensor	3 years	Time, altitude, heart rate, position
Elite athletes: Second Study									
E13	30	Female	National level	Success at 2nd and 3rd tier	3 years	Swimming	Garmin Swim; HRM-Swim	1 year	Stroke count/rate, heart rate
E14	27	Male	National level	Success at 2nd and 3rd tier	2 years	Triathlon	Garmin fēnix 3 HR	3 years	Heart rate
E15	26	Male	2nd tier professional league	Success at 2nd and 3rd tier	4 years	Soccer	OptimEye S5 Catapult	1 year	Distance, sprints, position
E16	31	Male	National level	Success at 2nd and 3rd tier	4 years	Triathlon	Garmin Forerunner 735XT; Power Meter	8 years	Time, pace, heart rate
E17	41	Female	International level	Sustained success in intern. competition	6 years	Long-distance running	Garmin fēnix 3 HR	8 years	Stroke count/rate, heart rate
E18	29	Male	International level	Sustained success in intern. competition	5 years	Sprint	Garmin Forerunner 735XT	6 years	Time, pace, heart rate

Table II. Sample – Amateur Athletes

Amateur Athletes: First Study									
ID	Age	Gender	Profession	Weekly workouts	Competitive amateur events	Sport	PI Tool	Experience of use	Main Data collected
A1	43	Male	Information Technology Consultant	6 times / week	National	Triathlon	Garmin Forerunner 735XT; Garmin Edge 800; Soft	7 years	Speed, pace, heart rate, calories, steps,

							strap heart monitor		sleep, stroke count/rate, routes
A2	31	Male	Teacher	2-3 times / week	none	Alpinism	Garmin Forerunner 235	3 months	Position, steps, distance
A3	28	Female	Office worker	2 times / week	none	Trekking	Garmin Vivo Active HR	3 months	Distance, heart rate, sleep, calories, steps
A4	22	Male	Technical office personnel	3 times / week	none	Middle-distance running	Garmin fēnix 3	2 ½ years	Distance, altitude, routes, steps, sleep
A5	31	Male	Insurance Broker	7 times / week	Local	Swimming	Garmin Swim	7 years	Lengths, pace, distance, stroke count/rate, calories
A6	32	Female	Manager	6 times / week	National	Triathlon	Garmin Forerunner 910XT	8 years	Speed, pace, time, distance, routes, strokes
A7	26	Female	Office worker	3-4 times / week	Local	Free Climbing	Moonboard Application	3 months	Boulders
A8	30	Male	Freelance professional	6 times / week	National	Sprint	Garmin Forerunner 310XT	2 years	Pace, time, distance, calories
Amateur Athletes: Second Study									
A9	26	Female	University student	2 times / week	none	Long-distance running	Garmin Forerunner 235	1 year	Speed, pace, heart rate, calories, steps, sleep
A10	36	Male	Academic researcher	3-4 times / week	Local	Long-distance running	Garmin Forerunner 235	6 years	Speed, pace, heart rate, calories, steps, sleep
A11	24	Male	Designer	7 times / week	National	Sprint	Garmin fēnix 3	5 years	Speed, pace, heart rate, sleep
A12	36	Male	Office worker	3 times / week	none	Cycling	Garmin fēnix 3; Garmin Edge 810	8 years	Speed, distance, heart rate, calories, steps, sleep

To increase the heterogeneity of the sample, we considered different sports, recruiting both endurance (swimming, cycling, triathlon, ski mountaineering, cross-country skiing, alpinism and trekking) and non-endurance (soccer, free climbing, and sprint running) athletes. Table 1 and Table 2 provide a snapshot of the participants' characteristics.

All the interviewees owned a smartphone and were open to technology. Only two amateur athletes were moderately adept at data analysis. Reasons for participation in the research span from talking about the used devices to recounting sports experiences. Most interviewees were relatively affluent. Two of them stopped studying in middle school. Eight athletes held a high school diploma, twelve a bachelor's degree, and eight a master's degree.

Sample size has been aligned with the common practices in qualitative research (Marshall et al. 2013) and with other qualitative HCI studies with similar design and goals (e.g. Li et al. 2011; Rooksby et al. 2014; Lazar et al. 2015). However, the decision of stopping at 20 interviewees in the first study and at 10 interviewees in the second study came when we became aware that additional data would not have produced substantial new findings for the ends of our research (i.e., understanding sports data sense-making in the first study, and exploring athlete's conceptualizations and usages of PI devices and their impacts on their activities in the second study), following a data saturation criterion (Bowen, 2008).

3.2 Procedure

Both the studies followed the same procedure. The interviews were semi-structured, lasting an average of 58 minutes (first study) and 46 minutes (second study). Twenty-four were conducted face-to-face, while six were completed via Skype. Participants had to bring their tracker with them. Before starting the interview, the researcher introduced the goals of the research. Then, he began by requesting that participants describe the role of sport in their life, the meaning they ascribed to it, and their "career" as athletes. He invited the interviewee to recount her habitual modalities of use of PI instruments by showing her the trackers' functionalities she used the most and her collected data: walkthroughs of her data-troves and sharing of specific instances exemplifying how she used her device in a particular training/race were elicited as well.

In the *first study*, interviews aimed to develop an understanding of the athletes' sense-making practices enacted to interpret and manage their own sports data. The questions asked were: e.g., *What kind of role has sport in your life? When and why did you start using a self-tracking device?*

How do you use your device during workouts and races? When do you look at your sports data? What do you seek in them? Why the collected data are important? How did having such data available impact on your sports practices? Do you share your data and why? How is the relationship with your coach (if you have any)? Did you look at your data together with your coach? As participants were free to talk about matters not foreseen in the question list, they also reported interesting insights about topics we did not think in advance. Such topics, however, were not included in the recount of the results published in Rapp & Tirabeni (2018), as they needed to be further investigated.

More precisely, some participants pointed out that PI devices may be considered not only as data repositories, but also as "objects" that may be valued for their aesthetics. Nonetheless, what were the features that athletes seek in their devices and how they are conceptualized by them were not completely clear. Moreover, participants signaled that the tracker may play different "roles", sometimes having impacts on their motivation and attention. Nevertheless, a more nuanced exploration of the effects that trackers have on the athletes' "mind" seemed in need. Finally, some participants reported to be interested in collecting lifestyle data. However, we were not able to find completely clear insights about how and why such data were "used" by the participants.

In sum, the first study made emerge some germinal topics (i.e., conceptualizations of the device, effects of the device on the athlete's internal states, and lifestyle data) that remained unpublished and we considered worthy to be deepened in a second study.

The *second study* aimed to widen the perspective on self-tracking by moving the focus beyond sports data interpretation: while we maintained unaltered the first part of the interview, investigating the role of sport in the athlete's life and the importance of self-tracking for her sports activity, we explored the different expectations she has towards the PI device, the impacts it may have on her "mind", as well as how lifestyle data my affect her sports activity. The new questions asked were: e.g., *How do you choose your device? What is important for you? What is the device for you? What kinds of effects it had on you? Does it have impacts on your "internal states"? Are* *there other data, beyond sports data, that you consider important for your sports activity and why?*. Even in this study, we left participants free to explore themes not foreseen in the initial list of questions.

Participants were not compensated. Each interview was audio recorded and transcribed verbatim. The data analysis involved standard techniques of coding and thematic analysis for qualitative research (Saldaña, 2013). More precisely, a threefold coding process has been adopted involving open, axial and selective coding (Miles & Huberman, 1994). The first and the second authors conducted the open coding step separately, by comparing incidents and naming like phenomena with the same term. These initial codes were based on interviewees' viewpoint on the use of self-tracking instruments in their sports practices. Examples of initial codes were "emphasis on devices' aesthetics", "attempts of changing behavior", and "dealing with fatigue". The two authors reviewed the results segment by segment to assess consistency between them in defining the beginning and end of segments and the application of codes (MacQueen et al., 2008). Then, all inconsistencies were resolved. Inconsistencies were mainly related to differences in labeling the same concepts (e.g., "being under control" for the first coder and "emphasis on stress" for the second one, which resulted in the decision of keeping the latter as the best label to describe the underlying concept). The resulting codes were grouped independently by the two researchers, labeled and then compared again to solve inconsistencies. This yielded 16 abstracted categories (axial coding), one of which was discharged as not directly related to the use of self-tracking instruments in sports practices.

Axial coding categories from open coding were amalgamated to create a more defined hierarchy forming key related categories (selective coding): These (*Conceptualization of the device, Device switches, Motivational effects of the device, Device's effects on attention and distraction, Connections among different kinds of data*) are the central themes formed from the participants' recounts. As soon as we circumscribed the main themes, we systematically went through the data to identify different patterns in the interviewees' understandings and usages of self-tracking devices with reference to such themes, by categorizing the data on the basis of the participants' characteristics. During the analysis we were completely open in finding similarities and differences across the sample due to other factors than diversity in the subject population (amateurs vs. elites). Actually, we actively searched for alternative hypothesis or negative cases (Brink, 1993). However, we did not find key differences with reference to demographics (age, gender) and expertise with data analysis, as well as between endurance and non-endurance athletes. By contrast, the main differences in understandings and usage patterns of PI devices were found between amateurs and elites.

3.3 Limitations

The two samples (amateur and elite athletes) involved in our study were quite homogeneous with reference to relevant variables that could affect the usage patterns of PI tools, such as demographics, the device usage length, the sports considered, and the previous experience of the participants in data tracking. Moreover, during the analysis these factors appeared not to have a particular influence on the conceptualization and usage of PI devices. Actually, the main diversities can be traced back to differences in the two populations. Even when other variables (e.g., device usage length) seemed to play a role in differentiating the practices around PI instruments, amateurs and elites looked at their devices through different lenses. This somehow confirms what we found in our previous study, namely that amateurs and elites "live" and understand their sports practices differently and this has consequences on the use of PI tools.

However, the qualitative and explorative nature of the study and the still limited number of the recruited participants do not allow us to exclude that other possibilities and factors that were not explored in this research could have influenced the findings, and thus that the differences that were observed could not be exclusively due to the differences in the two groups (amateurs vs. elites). For instance, some divergences from the trends we identified were due to the peculiarities of specific sports (e.g., cycling): considering sports that we did not include in our sample, or focusing on a specific sport, could then lead to different results. Individual differences in the athletes' sports experience could also have an impact on the way they used and conceptualized their devices.

Therefore, even though we believe that the study findings may have wider applicability, they are specific to the group of participants we interviewed, and thus limited to and framed within the individual experiences and specific sports practices in which they were gathered.

However, the goal of this study, like most of qualitative research, is not to generalize the findings to the entire population of amateur and elite athletes, but rather to provide a rich, contextualized understanding of some aspects of athletes' interaction with PI devices through the thorough exploration of particular cases (Polit & Beck, 2010). Actually, further research is in need to confirm or disconfirm the results coming from this study.

4. FINDINGS

The study findings show that the main differences in the understandings and usage patterns of PI tools are observed between amateur and elite participants. Obviously some exceptions are present. For instance, some of the amateurs that are engaged in national competitions show a competitive attitude (against others) close to that of the elites. Such attitude is completely absent in those not engaged in competitive events and almost absent in those participating to local competitions. This may be due to the fact that, as long as the efforts in the sports activity and the experience with / knowledge about the practiced sport raise, the amateurs may show some traits characterizing the elites.

Table III. Summary of our findings compared with previous research

Key points	Amateur participants	Elite participants	Previous research
Conceptualization of the device	The device is conceived as a technological object, whereby accuracy and novelty are essential. Focus on precision, discovery and novelty.	The device is conceived as a comfort object, which involves practical, physical and social dimensions. Focus on comfort.	Experienced users show attachment to their trackers (Fritz et al., 2014) and different styles of tracking (Rooksby et al., 2014; Epstein et al., 2015); inexperienced users seek serendipity and surprise (Rapp and Cena, 2016; Rapp et al., 2018; Lazar et al., 2015).

Device switches	They stick to the same device for long time. Switch when a breakage occurs. No abandonments or lapses.	Frequent switches, especially when new devices are available. No abandonments or lapses.	Experienced PI users switch or abandon when a tool does not meet their expectations (Li et al., 2010), their goals changed or were met (Clawson et al., 2015); Quantified Selfers can even build their own tools (Choe et al., 2014); inexperienced PI users abandon their devices because they encounter barriers, (Rapp and Cena, 2016), or the data collected are perceived to not be useful (Lazar et al., 2015).
Motivational effects of the device	The device is a *motivator*: impacts on motivation to put more effort into the sports activity and adhere to the scheduled workouts; or to compete against oneself. The device is also a *stressor*: it may turn the sports activity into a work.	Almost no effects on motivation. The device is a training *companion*.	Effects on motivation to change behavior (Li et al., 2010, 2011) and strong motivational effects on doing more physical activity (Fritz et al., 2014; Gouveia et al., 2018)) among experienced users; scarce impacts on motivation in doing more physical activity or change behavior in inexperienced ones (Lazar et al., 2015; Rapp and Cena, 2016); impacts on motivation of the measurable results provided by the device (Tholander and Nylander, 2015) among amateur athletes.
Device's effects on attention and distraction	No consideration of attention and distraction matters. The device is a *regulator of performance*.	The device is an *enhancer* of the athlete's attention. The device is also an *entertainer* distracting from the sports activity when it becomes boring or particularly demanding in terms of fatigue.	No previous reports on how PI tools can be used or non-used during an ongoing performance for affecting attention or distraction.
Connections among different kinds of data	Lifestyle is seen as something *external* that should be modified to better the sports performance. Interest in connecting lifestyle data with sports data, and in relating behavioral insights to the sports performance for behavior change purposes. Trackers do not support them in finding useful correlations.	Lifestyle is completely *integrated* into the sports activity. Almost no interest in monitoring and correlating different data as well as in behavior change.	Quantified selfers engage with self-experimentation practices to find useful correlations (Choe et al., 2014); experienced users interweave different trackers monitoring different aspects of life but have problems in integrating them (Rooksby et al., 2014); inexperienced users find it difficult to discover useful correlations among diverse data (Rapp and Cena, 2016; Rapp et al., 2018); coaches want to correlate performance data with contextual information (Wakefield et al., 2014).

Table III summarizes the findings of our study briefly comparing them with relevant previous PI research. In the following sub-sections, we will extensively recount the themes emerging from the data analysis.

4.1 Conceptualization of the device

The amateur and elite athletes we interviewed conceptualize their tracker differently. This is particularly evident when they explain their criteria for choosing a device, which express their requirements and expectations about technology development.

For the amateurs, the PI device is an "object of technology", being expected to "progress" over time in its technical capabilities. They report that they rely mainly on functional and technical criteria for selecting a specific instrument, whereby two main factors have an influence on their decision.

The first factor relates to the device's accuracy and sensing capabilities. A6, for instance, expresses that "*I'd like some more immediacy, namely the GPS isn't as precise as I'd like… I'd like that it would be capable of precisely detecting a ten meters acceleration, without doing anything, unfortunately it misses acceleration and deceleration. I'd like it to be more precise*". The focus on accuracy is also visible in how the decision of buying a new device is made. Most of the amateurs recount that they consider their friends' suggestions before buying a wearable. Such exchanged opinions often revolve around the device's precision, as well as failures in collecting accurate measures under certain conditions (e.g., when there is a sudden change of velocity, as A6 points out). Actually, half of the amateur athletes we interviewed wished for more precision of their instruments allowing for a more fine-grained control on their training.

The second factor is connected with the availability of new functionalities. A11 and A12, for example, reaffirm an opinion also reported by A1 and A6, stressing that they would find appealing the availability of novel features for manipulating data in advanced ways: "*I'd like to correlate different variables and to discover something unexpected*", A12 says, emphasizing the need for surprise. The amateurs we interviewed, in fact, tell that they are driven by a sense of discovery when buying a novel instrument. A10, for instance, highlights a common opinion among them (8 out of 12): "*Even if you talked with your friends, sometimes you discover something that your friends did not consider important, but you do*". They see the device as a continuously evolving technical object, whereby a new model may embed unforeseen technological advancements that may open new opportunities for their sports activity. This may be due to the fact that amateurs do not have perfectly clear objectives and do not have a deep knowledge on how to use the tracker to reach them: albeit they consider the PI device essential for improving their performance, they seem to proceed through trial and error, hoping for new functionalities granting them unexpected useful insights.

The athletes belonging to the elites group, instead, conceptualize the PI device as an object of "comfort", which may evolve toward a greater convenience, whereby comfort has different meanings involving practical, material, and social dimensions.

The first meaning of comfort refers to the *practical* comfort that the device may offer by collecting the data. Here, the automated tracking allows to avoid effort/time for manual tracking, also enabling to perform activities that would require much more effort if accomplished otherwise. E5 explains that "*without it, for sure it wouldn't jeopardize my activity, but it would be an extra issue, I mean, I should think of another system to know these data… It would be a comfort that would go missing*"; and E3 adds "*with this device you can do more sophisticated trainings, like the repeats… I mean, you could do them without the device but you'd have to run on the track, and for me that's a real drag, while with the device you can go everywhere, on a route that you've never done, and you can do the repeats anyway… if you're used to this comfort it's hard to go back*". Automated tracking has thus eased how the elites perform their workouts, so that it has become an habitual behavior. This kind of habituation can be observed even among the amateurs (especially those that have been using their tracking instrument for long periods of time). However, whereas the participants belonging to the amateurs group emphasize the availability of more analytical tools and accurate data than those that would be collectable through manual tracking, the elites highlight savings in effort and time.

The second meaning refers to the *physical* comfort that the device can give to the body, which is connected with its physical "shape" and the used materials. This is the most important dimension of comfort in the elites' eyes, as the device needs to be pleasant on the body and must not interfere with its movements. E14 emphasizes that he has just changed his device because "*it has a steel case, and it's protected by a sapphire crystal*", and this is more comfortable on his skin, whereas E16 explains that "*the first one that I had was heavy, square-shaped, and the problem is that I use it also when I'm cycling and it was very uncomfortable for the hand, for the mobility of the wrist, but also for running*". Most of them (12 out of 18), therefore, wish for a better designed shape, less cumbersome, that is better worn by the body.

The last meaning is connected to the *social comfort* that a PI instrument may deliver. The device may bump into aesthetics issues that can negatively affect its social acceptability, as E8 highlights "*For a girl it's too big, actually it's a matter of aesthetics… I mean, if I wear a sweater I've to take it off, because I'm always trying to… get away from it, because the watch hooks into the sweater, I wish it will become thinner*". The PI instrument has a visibility that makes it not suitable to every social context, and the elite participants appear to be concerned by how it may affect their social life. Such matters may contribute to prevent athletes from using their device outside the sports practice, when they are not so motivated to collect their data: E17 explains "*I don't wear it because it's heavy, and I'm afraid of breaking it when I do some handwork... And because I can't go around with the same accessory on the wrist every day, it's too visible... I use it only during the workouts*".

In sum, despite some exceptions (two amateurs lingered over the aesthetics/comfort aspects of the device, rather than over its technical characteristics) the need for accuracy and the focus on the device's sensing capabilities signal a "technical frame" through which the participants of the group of amateurs look at their devices; whereas the desire for novelty and serendipity points out a playful attitude. Instead, for the elites we interviewed accuracy is not a major problem, since they commonly do not consider singular "absolute" values, but they differentially compare them.

There are differences, nonetheless, among specific sports. In cycling the availability of instruments precisely measuring the work the cyclist is doing with her legs allows for tracking measures that are extremely close to the meaningful performance metrics. In such cases, accuracy may be relevant, even for the elites.

4.2 Device switches

Both the amateur and elite athletes we interviewed do not show any sign of disaffection toward their PI devices, keeping using them without any abandonment or lapses. However, they show a different attitude when switching their device: this likely stems from the different conceptualizations of their tracker, which we have seen in the previous sub-section.

The amateurs' focus on the instrument's sensing capabilities leads them to wear the device during their everyday activities, in the hope that collecting information about every aspects of their life will positively affect their sports performance, as we will also see in 4.5. The focus on technological advancements also yields a constant desire of finding new instruments capable of detecting novel or more fine-grained data: A9, for instance, explains "*You can't collect the lactic acid. I'd like to have this information, knowing at what percentage you're running, if you are in aerobic threshold, anaerobic threshold. You don't have this, because you would have to measure the lactic acid in real time. There are many tests to calculate the threshold but they are empirical, they are not deterministic*". As a result, they wish for (or dream about) instruments that increase the number of the parameters automatically collected: nonetheless, they can rarely afford frequent changes of their device, so that they keep the same wearable for long periods of time, switching mainly when a breakage occurs.

By contrast, the elite participants think that the PI instrument is simply a positive convenience, albeit not essential, and tend to wear it only when strictly necessary. As they conceive the device as an object of comfort, they do not use it when they feel that it may be uncomfortable from the practical, physical or social point of view. The search for comfort leads them also to not stick to the same instrument indefinitely, but to switch as more comfortable and pleasurable technology becomes available.

4.3 Motivational effects of the device

Effects on motivation of self-tracking devices are more pronounced in the amateur athletes we interviewed. A5, for instance, thinks that "*you're more motivated because you know that you're registering yourself, whereas before I went out without it and I knew that there wasn't someone up there measuring me… and maybe this thing pushes you to do more… before you could also say 'well even if I stop here, it doesn't change anything*'".

The amateur athletes, here, ascribe the role of an external *motivator* to the tracker, whereby two different underlying factors may contribute to its action, namely the *visibility* of the sports activity, and the sense of *competition* it may engender.

As for the first factor, A4 emphasizes that "*they help, and provide you with an incentive, because it's something visible*". It is this visibility of the efforts spent, as well as the more "concreteness" of the goals visualized by the tracker together with a sort of commitment towards it, that almost all the amateur athletes consider a key factor in supporting their motivation during trainings. A1, for example, highlights that trackers "*might give you a discipline and allow you to follow it*". Impacts on motivation in putting more efforts in the sports activity are more pronounced in those amateurs that have recently started to track; whereas the amateurs with a long history of tracking emphasize more the role of the device in keeping their effort constant.

As for the second factor, A1 says that "*For example, Strava, as well as Garmin Connect, allow you to see your contacts and what they've done in the previous days. Thus, yes it's funny and I do it… Sometimes I also look at people that I don't personally know, but it's only a matter of curiosity*". A5 explicitly adds that "*I think that this* [sharing data] *didn't increase my competition against others at all, because you know more or less those that are at your level… Against yourself, yes, it's more stimulating*"; while A6 explains, "*having data that you can confront from time to time pushes you to do better*". The amateurs we interviewed are mostly not inserted within a frame that makes them compete against other athletes, like the elites are; rather they may compete against themselves in overcoming their previous limits and the device may help to this aim. However, the amateurs engaged in national competitions report a more competitive attitude (similar to that of the elites) and may explore the data coming from other athletes to match their performances. This might reflect the fact that as amateurs are engaged in contexts and practices closer to that of the elites they also start using differently their devices.

For some amateurs participants, however, the self-tracking tool may also play the role of a *stressor*, inserting the athlete's activity in a "working" frame, by constantly reminding progresses, achievements, and objectives that may blur the recreational aspects of the sport. A2, for example, notes that "*from a mental point of view, sometimes the device constrains you to do some things that you wouldn't do otherwise, like keeping rhythms that you wouldn't keep. If you are doing sport only to relax, well, then the device could be counter-productive*". A1 basically agrees with this perspective adding that "*if I want to jog at the park with no stress I don't wear it but, if I'm preparing a race, an event, I of course wear it*".

For the elites participants, instead, the device assumes a different role. It represents a *companion* rather than a motivator. This might be due to the fact that the elites we interviewed have a deep knowledge of their limits and of how to manage their physical condition during trainings, so that they do not need to be motivated by the instrument. E9, for instance, tells that "*having the awareness at the end of the workout of having made this kind of work… this makes you conscious of how well you've worked*": such influence, however, is always limited and circumscribed to workouts. The majority of the elites (14 out of 18) deny that the device had any impact on their motivation and goals: "*it doesn't influence at all. It's only a help. It's not a guide, it has to be, let's say, a training companion*", as E12 specifies. E17 well explains that "*If I don't feel well, I'm not stupid and I don't run more, if I feel well I give 100% to it, the device doesn't play any role in this, I perfectly know how much I can give and how much I must give*".

4.4 Device's effects on attention and distraction

The elite participants agree on the fact that PI instruments allow for an unobtrusive monitoring and registration of interesting parameters without requiring any attention, an element that might free cognitive resources to spend on the ongoing performance. The self-tracking device, here, acts as an *enhancer* of the athlete's attention, as it supports her concentration, since, as E5 highlights, "*you don't have any other thing to think about. You can focus on the run and the device takes care of everything else*". Especially in short races, concentration is considered a fundamental requirement: "*I did competitions with very high rhythms where you don't have to get distracted… I believe you must even be focused on the exertion, rather than getting away from it, because if you lose your focus you risk to slow down*", E11 says.

However, a help is given by the device only provided that it is used in a "passive mode". The elite athletes, in fact, specify that they usually do not look at their device during competitions, because it could distract them from the race. They take the tracker with them, but they prefer to keep it away from the sight, e.g. turned upside down, or placed in a closed space (e.g., in a backpack), only to passively record their performance: "*during the race you push as much as you can, and you don't have time to look at it, you don't even want to look at it*" says E10; while E9 emphasizes how he is interested in analyzing his data, but only after the end of the competition. However, it is worth noting that this disposition towards the device also depends on the practiced sport: for example, in cycling the device can be put on the handlebars facilitating an intermittent, but constant, look at some specific, essential, parameters, as noted by E5 and E8. In ski mountaineering, instead, the athlete may feel the need of checking her "difference in height", as pointed by E7, which justifies a brief focus shift from the activity to the tracker.

In sum, the device may help the athletes by relieving them of recording and analyzing their ongoing activity and by enhancing their attention. If not used in a passive mode, however, it may also become a source of distraction from the sports activity, which may negatively impact the athlete's performance during races requiring high levels of concentration.

An opposite attitude toward distraction, nonetheless, is showed during workouts, when the elites get easily distracted or even actively search for distraction from the sports activity to enjoy more in training. In this context, the tracking device may function as an *entertainer*, an object that can divert the athlete for a while: this kind of use is explicitly mentioned by E4, who says that "*well, what can you do while running? Either you look at it or you look at the landscape*", and by E12, who further specifies that "*you have something to think of while training, thus you don't feel the fatigue as much*".

Attitudes towards attention and distraction are somehow inverted when trainings assume the form of races, for the efforts and the attention required, and races become similar, in certain moments, to workouts, due to their long duration. For example, speedwork sessions require an intense effort and an extreme focus on the ongoing performance: in such occasions distraction from the sports activity is consciously avoided, and the use of the device mirrors that in the competition. On the other side, distraction from the sports activity plays an important role in dealing with boredom, as well as in pushing away the feeling of exertion, especially in very long races for endurance athletes: "*I used to sing* – says E3 - *sing mentally, and still now I think of what I have to do during the day* [...]. *Basically, I do it during the workouts. During the race, for sure, in a marathon, at times I sing something in my head like in trainings, simply because it's a very long distance and the first part has to fly by*"; while E9 adds that "*in long races maybe the rhythms go down, and then you might feel the exertion, and maybe you inevitably have to search for some ways to prevent this thought saying 'well in five kilometers I'll feel better' or 'Come on, think of that in a while*".

In sum, the elites we interviewed look for distraction from the sports activity when workouts and races become boring, and when fatigue becomes pressing, knowing how to use the device to increase their engagement and distance the sense of exertion. They are aware of the strategies that might be needed to deal with contextual needs and adapt their performance (both mental and physical) accordingly: in this work, trackers can play an important role.

The amateurs, instead, miss to engage in such strategies. In fact, they (11 out of 12) show to use the PI tool during both races and workouts, independently of the specificity of the sports activity required, in order to check current data and regulate performance accordingly: A10, for instance, says that "*I think that the tracker may give you the idea of how you are doing, so it's important to have it always with you* [...]. *During the races it may help you calculate how much effort you spent, and the rhythm that you have to keep*". This, on the one hand, may jeopardize their attention during short races and speedworks; on the other hand, by being used not as an entertainer, but as a *regulator of performance*, the device may make them focus even more on their fatigue during long workouts and competitions. This might show how the amateurs have less awareness of how their device can be appropriated and used for aims that go beyond its "proper" scope.

4.5 Connection among different kinds of data

The amateurs we interviewed are interested in gathering information about different aspects of their life. In their perspective, their "lifestyle behaviors" (e.g., food intakes, sleep, physical activity) are a sort of "external factor" that may impact their sports performance, so it makes sense to them to use their tracker for tuning their lifestyle in order to achieve better sports results. However, this activity does not turn into real benefits for their sports practices because of two main reasons.

First, for the interviewed amateurs it is difficult to connect lifestyle information with their sports activities due to issues in finding useful correlations among data. Some of them (6 out of 12) express to have monitored some data for a while, then rapidly abandoned this particular functionality of the instrument. A11, for instance, recounts that "*I looked at my sleep time sometimes, at the beginning, but now, I don't do it anymore*".

Second, they recount that rarely the tracker is effective in modifying their lifestyle. Some of them (5 out of 12) keep track their food, sleep and physical activity data also with multiple instruments for producing a change in their behavior, as they think that this may influence their sports performance. However, the tool does not give certainty about this relation, nor is able to suggest changes that may visibly impact on their sports practice. "*In my opinion, the sleep is crucial for training. So I pay attention to my sleep. And the device provides you with an overall idea if you slept well or not, it may also suggest how much time you need to recover"* says A10, but he adds *"I'm not sure about how much I should sleep in relation to specific trainings, I can look at the data and say well I slept well, but is it enough for my training, for my body? ... And I'm not sure about why these suggestions are provided, on what they are based, I follow them sometimes but I'd like to know the reason*".

In sum, as lifestyle data remain separated from the core functionalities of the trackers (e.g., the heartbeat monitoring feature), they are displayed merely out of curiosity, without positively affecting the athlete's performance. When they are used to provide recommendations e.g., on how much to rest after a training, they do not explain their rationale, missing to help the amateurs in learning useful relations among data.

The elites we interviewed, instead, are not concerned with the monitoring of "lifestyle" parameters. This may be due to the fact that they already follow a strict discipline, tuned on the basis of their coaches' suggestions and on the knowledge they have about their body. Lifestyle and sport are much more integrated in their perspective: they have an holistic view of the sport they practice, which practically permeates all the aspects of their everyday life. In these participants' eyes, there is almost no distinction between "sports behaviors" and "lifestyle behaviors", which are all integrated in a unique "conduct of life". E16 highlights that "*I had this focus on my lifestyle far before I started using this*", whereas E15 specifies that "*When you're a professional athlete you try to perfect every aspect of your life as a function of competition, so everything is connected. But the instrument didn't improve this, I didn't change my food and sleep habits, for example, on the basis of the instrument*". The elite participants, therefore, are not interested in changing their behavior on the basis of the collected data and "external advice". They know well how they have to behave, and how specific aspects of their life are intertwined with their sports performance: this may lead to ignore the lifestyle data and the "behavior change functions" provided by their device. E18 explains that "*I've always been a clock, I mean, I pay attention to my body, to the quality of my sleep... I know when I sleep well and when I don't, I have a very regular life*".

5 DISCUSSION AND IMPLICATIONS FOR DESIGN

The findings outlined above preliminary identify ways of understanding and usage patterns of PI devices across amateur and elite athletes. They seem to suggest that PI usage might vary on the basis of the practices in which the user is engaged and her expertise in the practice itself (amateurs vs. elites), rather than on the basis of her experience in data tracking and analysis (experienced vs. inexperienced).

A way to tie the results together is precisely to highlight that the elites we interviewed have a deeper knowledge about their sports practice than the amateurs, and such knowledge may affect the way they understand and use PI tools for their situated goals.

The elites appear to be keen on changing their instrument over time, valuing more "comfort" than accuracy, "wearability" than data analysis. They know how to use the tracker to ease the achievement of their sports goals (e.g., doing the repeats), without considering it essential for their sports performance. The amateurs, instead, seek more data, more accuracy, and more serendipity. Their use of PI tools partially resembles that of generic users having no experience in self-tracking, who look at novelty and surprise (Rapp and Cena, 2016). This might be due to the lack of in-depth knowledge about how to use the device to reach precise sports objectives. The "technical frame" through which they conceptualize their device may result in the desire of frequently changing it. Designs, then, may account for this desire of novelty, considering the scarce affordability of recurrent device switches (e.g., through a modular approach allowing for the connection of add-ons that offer supplementary views and analysis tools, or the substitution of specific sensors).

The study findings further suggest that PI instruments may impact on athletes' "mind", being differently used and appropriated by the amateurs and the elites while doing sport. The amateurs we interviewed ascribe them the role of *motivators*, being positively influenced in putting efforts in the sports activity. However, they seem not to be capable of using the tracker to focus their attention or distract themselves, as well as of identifying those occasions in which the device may jeopardize their activity (e.g., during competitions or long workouts).

By contrast, the elite participants seem to be already intrinsically motivated in achieving their objectives, having a profound knowledge about the degree of effort required to succeed, so that they may not need an external support coming from the tool. They rather prefer to use their trackers to focus their attention on their ongoing practice, or to engage with distractive activities, showing that they are able to contextualize the use of their instruments even going beyond the designers' intentions.

Finally, the amateurs and the elites we interviewed also express diverse attitudes toward the opportunities for widening the tracking activity to other life domains. On the one hand, amateurs participants would like to connect sports data with lifestyle information, looking for opportunities for changing their behavior, but without knowing exactly how to do so. On the other hand, elite participants already follow a strict discipline that is completely integrated with their sports activity and are not interested in modifying their own lifestyle: they already perfectly know "how to behave" and they do not ask for help from the tracker.

Therefore, diversities between the amateur and elite athletes appear present in each of the themes we analyzed, showing that individuals with different degrees of knowledge about a given practice may differently integrate PI instruments into their activities. This said, it is possible that other factors may intervene in producing differences in the usage patterns of PI devices for sport. The specificity of the sport, for instance, may influence how PI tools are used by the athletes. We have seen that in cycling the availability of devices allowing for tracking measures that are extremely close to the meaningful performance metrics may make accuracy matters relevant also for the elites, further encouraging them to use the device during competitions. Differences in the usage patterns of PI tools might thus be due to factors that were not explored in this study: more research is in need to completely understand how athletes of different sports and with different backgrounds may differently integrate specific PI instruments into their sports activities.

We will now focus on three relevant themes that can be identified across our findings, which we think are worth to be discussed further. We will highlight how self-tracking instruments may impact on the "internal world" of individuals, such as comfort perception, metacognitive strategies, and willingness to change, also suggesting some implications for designing PI systems. Table 4 briefly surfaces the insights emerging from such discussion and the proposed design implications.

Table IV. Insights and implications for design

Theme	Theoretical/Practical insights	Design implications	Related research
Wearing the PI device	Wearables for sport can satisfy the need of *physical*, *practical* and *social* comfort expressed by the elites by investigating novel shapes and materials, as well as by taking into account the user's social context.	Display the data through the device's stiffness, sharpness, roughness; allow for changing the device's location on the body depending on the practical everyday activities in which it is engaged. Sports wearables adapting to the user's varying social contexts; modular devices changing their aesthetics/functionalities according to the user's social situation.	Tangible interfaces for self-reporting personal data (Price et al., 2018; Adams et al., 2018; Cena et al., 2014), and data materialization (Alireza & Jared, 2014). Self-changing interfaces or shape memory materials (Qamar et al., 2018)
Metacognitive strategies	PI systems for sport may support the elites in carrying out strategies about attention and distraction, as well as the amateurs in learning them, by designing interaction with the tracker used "in the course of action".	"Hypnotic" representations of data; design for different modes of use (e.g., "entertainment mode", "record-only/mute mode", "limited access mode").	Glanceable feedback (Gouveia et al., 2016)
Changing behavior	PI tools for sport may help amateurs develop the knowledge on "how to behave" owned by the elites by fostering self-reflection on their behavior.	Tools for forecasting the impacts of habit changes (e.g., diet) on the athlete's body and sports performance. Questions prompted about the collected data; invitations to annotate the data; highlights on "failures". Other athletes' stories collected through crowdsourcing.	Flexible data selection, filtering, and comparison features (Choe et al., 2017). Reflection in PI (Ayobi ey al., 2016).

5.1 Wearing the PI device

Our findings point out that for certain practices, and for certain users, the physical form of PI instruments may be essential and an enhanced comfort may represent an important advancement, much more than the increased number of available functionalities, or clarity in visualizations. The elite athletes we interviewed reported that they wish for smaller devices, able to make them forget their "presence", and a smoother tactile perception on their body.

Such results stress the need of tying more strictly the investigation of the instrument's shape to that of the displayed data in PI research, as studies on the PI "object" are currently circumscribed to the wearable technology community. For PI, it could be interesting to explore how the physicality of the device interacts with the visualization of dematerialized data. This could be relevant for all those PI domains where personal data are not simply visualized on a screen, but are connected with the user's body and "read" on it (e.g., PI devices that allow for the continuous collection of physiological parameters for medical purposes).

In this perspective, wearables addressed to self-track could benefit from being framed not as objects to be put "on" the body, but as extensions of the body itself, whereas data could be seen as extensions of the individual's mind.

5.1.1 Design for materiality

Emphasizing that PI tools for sport can be considered as *material extensions* of the athlete's body may yield two different lines of research with different design implications.

First, it could frame them as extensions of the body's perceptual capabilities and possibilities of actions, leading to the investigation of novel shapes and materials that closely interact with the body. We may think of exploiting the materials of which wearables are made to "display" the user's data through changes e.g., in the device's stiffness, sharpness, roughness. We may also envision non-objects that cannot be perceived by the athlete (because, e.g., they completely disappear by being embedded into her sports clothing, or into her body) and are not felt by her body, communicating only via visual or audio feedback when a relevant event (or variation in data) occurs. This would increase the *physical comfort* pursued by several elite athletes. Finally, in order to enhance the *practical comfort* valued by some elites, design should take into account the body patterns and constraints that characterize each context of the athlete's "practical everyday life", allowing her, for example, to modify the location in which the device is worn depending on the types of activities in which her body is involved.

Second, wearables can be seen as extensions of the individual's identity, which is commonly communicated through the body as well as through its clothes and accessories (Twigg, 2009). This could entail a line of research that explores the aesthetics and social properties of the wearable PI device, and how they may ameliorate the *social comfort* stressed by some elites. To this aim, PI tools should be designed by taking into account the user's social context. As some of our participants highlighted, a device that is primarily designed for a specific situation may not fit between others. Design could look at self-shaping materials, rollable, foldable or flatable structures (Qatar et al., 2018), and interfaces capable to adapt themselves to the different social situations that the user may encounter, as well as at modular approaches to design, tailoring the device's aesthetics and functionalities to the changing context.

5.2 Metacognitive strategies

Our findings point out that the elite athletes we interviewed are able to user their trackers as an *enhancer* of their attention, or, when the training become particularly demanding or boring, as an *entertainer* that may distract them from the sports activity. In other words, they are aware of the importance of distraction, as a metacognitive strategy that may help them divert from an excess of perceived exertion. Brick et al. (2015) found that while involuntary distraction is associated with performance disruption and typically avoided by elites, active distraction serves to relax control over cognition, allowing relief from boredom and fatigue. Our study confirms these findings and suggests that self-tracking devices may play a role in supporting elite athletes in regulating their metacognitive strategies, such as attention and distraction. As the very same distraction that is valued in certain occasions (e.g., during a demanding workout) may lead to negative outcomes in others (e.g., in a race), it is important to design by keeping in mind the situatedness of the athlete's goals, which may vary depending on the situation and the specific activity with which she is engaged.

By contrast, the amateur athletes that we interviewed were not able to use their device for regulating attention and distraction, rather seeing it as a *regulator of performance* that may jeopardize their performances during races and long workouts. This may suggest that these athletes would benefit from being supported in developing the metacognitive strategies that the elites carry out during workouts and races.

5.2.1 Design for the ongoing performance

Suggesting that PI tools should support athletes' metacognitive strategies about attention and distraction means to pay attention to interactions with trackers used "in the course of action". These were rarely explored in PI research, which rather preferred to design interaction modalities that allow the user to review summaries of data after that they have been collected, as we have seen in the Background Section.

One opportunity for encouraging distraction during the sports activity is to provide "hypnotic" representations of data with the aim of shifting the focus from the ongoing performance to distractive thoughts. Visualizations, here, would resemble to "musical variations" that engage the athlete in a playful interaction. Another opportunity is to foresee diverse device's usage modalities, selecting different data to be displayed and different ways through which they are delivered depending on the athlete's internal status. When the device detects that the athlete's stress level is rising too much, for instance, it could proactively signal its presence calling for attention and suggesting to initiate a distractive strategy ("entertainment mode"). On the contrary, in situations where the athlete needs to being extremely focused on her current performance, or is engaged in sports sessions that are conceived as recreational moments, the device may turn into a "record-only/mute mode", or a "limited access mode". This modality would conceal those data connected with performance relieving the athlete from stress. Alternatively, it would selectively display only the information considered essential by the athlete: this could be made available to prevent her from continuously check her device and thus losing her concentration.

These design solutions, on the one hand, would support the elites in carrying out their strategies about attention and distraction; on the other hand, they would foster the amateurs not to exclusively use their PI device as a *regulator of performance*, but also as an *entertainer* that may relieve them from boredom and fatigue, or as an *enhancer* of their attention that may improve their performance. This may eventually encourage the amateurs to learn those metacognitive strategies that are mastered by the elites.

5.3 Changing behavior

The amateur athletes interviewed in our study express an interest in monitoring different parameters of their life for modifying a behavior that may impact on their sports performance. What really matters for them, however, may be not the change in behavior per se, but whether and how this would impact on their sports performance.

This points out that PI systems that aim to produce a change in behavior (or offer functions addressed to this aim) should account for the specific practice in which they are inserted and for the situated goals for which they are used. Specific contexts, like the sports context, may superimpose overarching goals modifying how behavior change is appraised and pursued by the individuals. In the sports domain, in fact, behavior change seems more a means for better understanding the sports practice, rather than an end per se.

From this perspective, what the amateurs seek may be not simply a suggestion on how a given habit can be modified (e.g., how to reduce food intakes), but the exploration of the different correlations among data, as well as their idiosyncratic relations to the specificities of the athlete's body and ways of training (e.g. whether and how the loss of weight can improve the way they climb). In other words, they may need to gain the knowledge about "how to behave" that the elites already have, which allows them to ignore the behavior change features of their devices.

However, current trackers do not help the amateurs understand potentially interesting correlations, proposing the "behavior change functionalities" (i.e. the sleep, calories, steps monitoring functions) as separate features, which do not meaningfully intertwine with sports performance data. PI systems, therefore, need a greater integration of such functionalities into the situated goals of the user.

5.3.1 Design for reflection

As we have pointed out in the Background Section, PI systems are often employed to produce a change in behavior. Integrating the behavior change functionalities that PI devices offer into the athlete's situated goals, primarily means to design for self-reflection on behavior, in order to understand how to tune it to achieve her objectives. In fact, supporting the user in reaching her goals increases the need for self-reflection because the user is monitoring her behavior and finding associations between her current state and behavior (Halttu & Oinas-Kukkonen, 2017). As we have seen, reflection has been actively being examined in the PI research (Ayoby et al., 2012; Choe et al., 2017). Monitoring of lifestyle parameters, therefore, should be framed as a resource for knowing better the sports experience and experimenting different ways of behaving in order to achieve the knowledge about the sports practice that the elites already have.

To this aim, PI devices for sport may provide the amateurs with instruments to forecast the impacts of habit changes (such as more or less sleep) on the athlete's body (e.g., in terms of perceived exertion) and sports performance. We may think of interfaces that allow for the exploration of such impacts, where the users can vary certain variables and see how they will affect their sports practice in the future. For instance, the user could insert in the system specific values about hours spent in training, sleeping and dieting, representing a change in her current habits, and the system could foresee how it would likely better (or worsen) her performance, giving a percentage of probability that this would happen based on the historical data available (or data coming from "similar" athletes). This would give help in understanding consequences of behavior modifications on athlete's sports goals.

Alternatively, the system could prompt questions related to what happened in the data streams, encouraging the amateurs to reflect on specific data points and trends related to her behavior (e.g., Why is it more difficult for you to remain in the heart rate zone when you eat more than usual? Are there other factors that you should consider (e.g., you eat more in those days because you do more physical activity beyond sport?)). Encouraging athletes to actively comment peaks and anomalies, as well as changes in the data streams (probably due to even involuntary slightly changes in their lifestyle), would further foster reflection on how a variety of behaviors could impact their sports practices.

Another point is related to the meaningful insights that others' experience may represent for understanding one's own experience. Presenting "stories" of similar athletes (in which similarity may be computed on affinities in sports goals, ways of training, past history, body indexes, etc.) about how they adjusted their lifestyle to achieve their sports results may provide a further source for reflection. This could be achieved through crowdsourcing, by inviting elite athletes to share their sports experience and lifestyle changes in the form of "annotated data trends", in which they may report the evolution of their data about specific behaviors and how their modification influenced their sports performance: this may lead the amateurs to learn and develop the knowledge on "how to behave" owned by the elites.

7 CONCLUSION

In this article we extended our previous investigation on how athletes integrate PI tools into their sports practices. The amateur athletes involved in our study are moved by curiosity in the exploration of their data, use them to self-motivate, and rely on the accuracy of the parameters they monitor. Moreover, they intertwine the use of their device with behavior change attempts, which are addressed to improve their activity. The lack of knowledge about the relations that tie their habits to their sports performance, nevertheless, seem to undermine their opportunities for reaching their goals. The elite athletes we interviewed, instead, find in PI devices a comfortable tool to ease the management of their sports activities, do not need to be motivated by a technological support, and well know both “how to behave” and when the use of such support may yield detrimental effects, by distracting them from their ongoing activity. A key contribution of this study, then, is to highlight how diverse athletes differently use PI instruments in their sport practices.

We then discussed three themes emerged from the analysis of our findings. We highlighted that PI tools could be considered as extensions of the human body. Further, we pointed out that PI systems might be appropriated by their users, which may use them for goals that go beyond the designer’s intention, such as providing distraction in moments of boredom. The opportunity for better integrating the behavior change functionalities of PI devices into the user’s situated goals is another relevant theme we highlighted. This discussion represents the second contribution of this article.

Finally, we proposed three design implications, which suggest that PI should start considering the physicality of the device, explore new modalities for supporting the user’s contextual needs, and focus on reflection and goal support. A limitation of this research is that we did not implement such suggestions yet. However, more than providing verified design guidelines, we wanted to give researchers and designers some triggers for further reflections, grounded in the data we collected during the interviews. We consider these implications for design as “design hypotheses” (Hekler et al., 2013), which will require further assessments to prove their validity: they represent our third contribution.

REFERENCES

Alexander T. Adams, Elizabeth L. Murnane, Phil Adams, Michael Elfenbein, Pamara F. Chang, Shruti Sannon, Geri Gay, and Tanzeem Choudhury. 2018. Keppi: A Tangible User Interface for Self-Reporting Pain. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems (CHI '18)*. ACM, New York, NY, USA, Paper 502, 13 pages.

Aino Ahtinen, Pertti Huuskonen, and Jonna Häkkilä. 2010. Let's all get up and walk to the North Pole: design and evaluation of a mobile wellness application. In *Proceedings of the 6th Nordic Conference on Human-Computer Interaction: Extending Boundaries (NordiCHI '10)*. ACM, New York, NY, USA, 3-12.

Frank Bentley, Konrad Tollmar, Peter Stephenson, Laura Levy, Brian Jones, Scott Robertson, Ed Price, Richard Catrambone, and Jeff Wilson. 2013. Health Mashups: Presenting Statistical Patterns between Wellbeing Data and Context in Natural Language to Promote Behavior Change. *ACM Trans. Comput.-Hum. Interact.*, 20(5), Article 30

Glenn A. Bowen. 2008. Naturalistic inquiry and the saturation concept: A research note. *Qualitative Research* 8(1), 137-152.

Noel Brick, Tadhg MacIntyre, and Mark Campbell. 2015. Metacognitive processes in the self-regulation of performance in elite endurance runners. *Psychology of Sport and Exercise*, 19 (2015), 1-9.

Brink, H.I.L. (1993), Validity and Reliability in Qualitative Research, *Curationis*, 16(2): 35-38.

Federica Cena, Ilaria Lombardi, Amon Rapp, Federico Sarzotti. 2014. Self-monitoring of Emotions: a novel Personal Informatics Solution for an Enhanced Self-Reporting. In *Workshop Proceedings of the 22nd Conference on User Modeling, Adaptation and Personalization UMAP ‘14. CEUR Workshop Proceedings*, vol. 1181, Article 8.

Toby Edwards, Tania Spiteri, Ben Piggott, Joshua Bonhotal, Guy Gregory Haff, Christopher Joyce. (2018). *Monitoring and Managing Fatigue in Basketball. Sports*, 6(1), 19.

Eun Kyoung Choe, Nicole B. Lee, Bongshin Lee, Wanda Pratt, and Julie A. Kientz. 2014. Understanding quantified-selfers' practices in collecting and exploring personal data. In *Proceedings of the 32nd annual ACM conference on Human factors in computing systems (CHI '14).* ACM, New York, NY, USA, 1143-1152.

Eun Kyoung Choe, Bongshin Lee, Matthew Kay, Wanda Pratt, and Julie A. Kientz. 2015. SleepTight: low-burden, self-monitoring technology for capturing and reflecting on sleep behaviors. In *Proceedings of the 2015 ACM International Joint Conference on Pervasive and Ubiquitous Computing (UbiComp '15).* ACM, New York, NY, USA, 121-132.

Eun Kyoung Choe, Bongshin Lee, Haining Zhu, Nathalie Henry Riche, and Dominikus Baur. 2017. Understanding self-reflection: how people reflect on personal data through visual data exploration. In *Proceedings of the 11th EAI International Conference on Pervasive Computing Technologies for Healthcare (PervasiveHealth '17)*. ACM, New York, NY, USA, 173-182.

James Clawson, Jessica A. Pater, Andrew D. Miller, Elizabeth D. Mynatt, and Lena Mamykina. 2015. No longer wearing: investigating the abandonment of personal health-tracking technologies on craigslist. In *Proceedings of the 2015 ACM International Joint Conference on Pervasive and Ubiquitous Computing (UbiComp '15).* ACM, New York, NY, USA, 647-658.

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 (CHI '08).* ACM, New York, NY, USA, 1797-1806.

Aaron J. Coutts and Stuart and Cormack. 2014. Monitoring the Training Response. In: *High-Performance Training for Sports*, David Joyce and Daniel Lewindon (Eds), Human Kinetics Publishers, Champaign USA, 71- 84.

Mihaly Csikszentmihalyi.1990. *Flow: The Psychology of Optimal Experience*. Harpers Perennial, New York.

Kevin Currell and Asker E. Jeukendrup. 2008. Validity, reliability and sensitivity of measures of sporting performance. *Sports* Med, 38(4), 297–316.

Lucy E. Dunne, Halley Profita, Clint Zeagler, James Clawson, Scott Gilliland, Ellen Yi-Luen Do, Jim Budd. 2014. The social comfort of wearable technology and gestural interaction. *Proceedings of the 36th Annual International Conference of the IEEE Engineering in Medicine and Biology Society* (EMBC), IEEE, Washington, DC, 4159-4162.

Daniel Epstein, Felicia Cordeiro, Elizabeth Bales, James Fogarty, and Sean Munson. 2014. Taming data complexity in lifelogs: exploring visual cuts of personal informatics data. In *Proceedings of the 2014 conference on Designing interactive systems (DIS '14)*. ACM, New York, NY, USA, 667-676.

Daniel A. Epstein, An Ping, James Fogarty, and Sean A. Munson. 2015a. A lived informatics model of personal informatics. In *Proceedings of the 2015 ACM International Joint Conference on Pervasive and Ubiquitous Computing (UbiComp '15)*. ACM, New York, NY, USA, 731-742.

Sharon L. Foster, Cambra Laverty-Finch, Daniel P. Gizzo, and Janay Osantowski. 1999. Practical issues in self-observation. *Psychological Assessment*, 11(4), 426-438.

Tobias Franke, Christian Pieringer, and Paul Lukowicz. 2011. How Should a Wearable Rowing Trainer Look Like? A User Study. In *Proceedings of the 2011 15th Annual International Symposium on Wearable Computers (ISWC '11)*. IEEE Computer Society, Washington, DC, USA, 15-18.

Thomas Fritz, Elaine M. Huang, Gail C. Murphy, and Thomas Zimmermann. 2014. Persuasive technology in the real world: a study of long-term use of activity sensing devices for fitness. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '14)*. ACM, New York, NY, USA, 487-496.

Jim Gemmell, Gordon Bell, and Roger Lueder. 2006. MyLifeBits: a personal database for everything. *Commun. ACM*, 49(1), 88-95.

Francine Gemperle, Chris Kasabach, John Stivoric, Malcolm Bauer, Richard Martin. 1998. In *Proceedings of the Second International Symposium on Design for wearability. Wearable Computers*, 1998, 116–122.

Barney G. Glaser and Anselm L. Strauss, 1967. *The Discovery of Grounded Theory: Strategies for Qualitative Research*. Chicago, IL, Aldine Publishing Company.

Rúben Gouveia, Evangelos Karapanos, and Marc Hassenzahl. 2015. How do we engage with activity trackers?: a longitudinal study of Habito. In *Proceedings of the 2015 ACM International Joint Conference on Pervasive and Ubiquitous Computing (UbiComp '15).* ACM, New York, NY, USA, 1305-1316.

Rúben Gouveia, Fábio Pereira, Evangelos Karapanos, Sean A. Munson, and Marc Hassenzahl. 2016. Exploring the design space of glanceable feedback for physical activity trackers. In *Proceedings of the 2016 ACM International Joint Conference on Pervasive and Ubiquitous Computing (UbiComp '16)*. ACM, New York, NY, USA, 144-155.

Rúben Gouveia, Evangelos Karapanos, and Marc Hassenzahl. 2018. Activity Tracking in vivo. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems (CHI '18)*. ACM, New York, NY, USA, Paper 362, 13 pages.

Shona L. Halson. 2014. Monitoring Training load to understand fatigue in athletes. *Sports Medicine*, 44(Supp. 2), 139-147.

Chris Harrison, Brian Y. Lim, Aubrey Shick, and Scott E. Hudson. 2009. Where to Locate Wearable Displays?: Reaction Time Performance of Visual Alerts from Tip to Toe. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '09)*. ACM, New York, NY, USA, 941-944.

Eric B. Hekler, Predrag Klasnja, Jon E. Froehlich, and Matthew P. Buman. 2013. Mind the theoretical gap: interpreting, using, and developing behavioral theory in HCI research. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '13)*.

ACM, New York, NY, USA, 3307-3316.

Maiken Hillerup Fogtmann, Kaj Grønbæk, and Martin Kofod Ludvigsen. 2011. Interaction technology for collective and psychomotor training in sports. In *Proceedings of the 8th International Conference on Advances in Computer Entertainment Technology (ACE '11)*, ACM, New York, NY, USA, Article 13, 8 pages.

Hiroshi Ishii, Craig Wisneski, Julian Orbanes, Ben Chun, and Joe Paradiso. 1999. PingPongPlus: design of an athletic-tangible interface for computer-supported cooperative play. In *Proceedings of the SIGCHI conference on Human Factors in Computing Systems (CHI '99)*. ACM, New York, 394-401.

Kirsi Halttu & Harri Oinas-Kukkonen. 2017. Persuading to Reflect: Role of Reflection and Insight in Persuasive Systems Design for Physical Health. *Human–Computer Interaction*, 32(5-6), 381-412.

Dize Hilviu and Amon Rapp. 2015. Narrating the quantified self. In *Adjunct Proceedings of the 2015 ACM International Joint Conference on Pervasive and Ubiquitous Computing and Proceedings of the 2015 ACM International Symposium on Wearable Computers (UbiComp/ISWC'15 Adjunct)*. ACM, New York, NY, USA, 1051-1056.

Victoria Hollis, Artie Konrad, and Steve Whittaker. 2015. Change of Heart: Emotion Tracking to Promote Behavior Change. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems (CHI '15)*. ACM, New York, NY, USA, 2643-2652.

Leah Hunter. 2014. Are wearables over? Fast Company Inc. (April 2014). Retrieved March 1, 2016 from http://www.fastcompany.com/3028879/most-innovative-companies/are-wearables-over.

IDTechEx, 2014. Wearable technology 2014-2024: Technologies, markets, forecasts e-textiles, wearable electronics, medical diagnostics, smart glasses, smart wristbands and more. (July 2014). Retrieved March 1, 2016 from https://www.idtechex.com/research/articles/wearable-technology-live-usa-2014-00007023.asp.

Roman Jakobson. 1960. Concluding statement: linguistics and poetics. In: Style in Language, Thomas A. Sebeok (Ed), Wiley, New York, 350–377.

Ravi Karkar, Jessica Schroeder, Daniel A. Epstein, Laura R. Pina, Jeffrey Scofield, James Fogarty, Julie A. Kientz, Sean A. Munson, Roger Vilardaga, and Jasmine Zia. 2017. TummyTrials: A Feasibility Study of Using Self-Experimentation to Detect Individualized Food Triggers. In Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems (CHI '17). ACM, New York, NY, USA, 6850-6863.

Daniel S. Kirschenbaum, Arnold M. Ordman, Andrew J. Tomarken, and Robert Holtzbauer. 1982. Effects of differential self-monitoring and level of mastery of sports performance: Brain power bowling. *Cognitive Therapy and Research*, 6(3), 335-342.

Kristina Knaving, Paweł Woźniak, Morten Fjeld, and Staffan Björk. 2015. Flow is Not Enough: Understanding the Needs of Advanced Amateur Runners to Design Motivation Technology. In Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems (CHI '15). ACM, New York, NY, USA, 2013-2022.

Felix Kosmalla, Florian Daiber, and Antonio Krüger. 2015. ClimbSense: Automatic Climbing Route Recognition using Wrist-worn Inertia Measurement Units. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems (CHI '15)*. ACM, New York, NY, USA, 2033-2042.

Felix Kosmalla, Frederik Wiehr, Florian Daiber, Antonio Krüger, and Markus Löchtefeld. 2016. ClimbAware: Investigating Perception and Acceptance of Wearables in Rock Climbing. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems (CHI '16).* ACM, New York, NY, USA, 1097-1108.

David J. Kooyman, Daniel A. James, and David D. Rowlands. 2013. A feedback system for the motor learning of skills in golf. *Procedia Engineering*, 60(0), 226 – 231.

Felix Kosmalla, Frederik Wiehr, Florian Daiber, Antonio Krüger, and Markus Löchtefeld. 2016. ClimbAware: Investigating Perception and Acceptance of Wearables in Rock Climbing. In Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems (CHI '16).

ACM, New York, NY, USA, 1097-1108.

Audra Landers. 2001. The value of training logs. *Olympic Coach* 11, (2011), 6-7 Colorado Springs, CO: Coaching USA.

Michael Lapinski, Eric Berkson, Thomas Gill, Mike Reinold, and Joseph A. Paradiso. 2009. A Distributed Wearable, Wireless Sensor System for Evaluating Professional Baseball Pitchers and Batters. In *Proceedings of the 2009 International Symposium on Wearable Computers (ISWC '09)*. IEEE Computer Society, Washington, DC, USA, 131-138.

Amanda Lazar, Christian Koehler, Joshua Tanenbaum, and David H. Nguyen. 2015. Why we use and abandon smart devices. In *Proceedings of the 2015 ACM International Joint Conference on Pervasive and Ubiquitous Computing (UbiComp '15).* ACM, New York, NY, USA, 635-646.

Dan Ledger, and Daniel McCaffrey. 2014. Inside wearables: How the science of human behavior change offers the secret to long-term engagement. *Endeavour Partners LLC 93*, (2014), 36-45.

Ian Li, Anind Dey, and Jodi Forlizzi. 2010. A stage-based model of personal informatics systems. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '10).* ACM, New York, NY, USA, 557-566.

Ian Li, Anind K. Dey, and Jodi Forlizzi. 2011. Understanding my data, myself: supporting self-reflection with ubicomp technologies. In *Proceedings of the 13th international conference on Ubiquitous computing (UbiComp '11)*. ACM, New York, NY, USA, 405-414.

Martin Ludvigsen, Maiken Hillerup Fogtmann, and Kaj Grønbæk. 2010. TacTowers: an interactive training equipment for elite athletes. *In Proceedings of the 8th ACM Conference on Designing Interactive Systems (DIS '10)*. ACM, New York, NY, USA, 412-415.

Teena Maddox 2014. Wearables have a dirty little secret: 50% of users lose interest. Tech Republic Inc. (February 2014). Retrieved March 1, 2016 from http://www.techrepublic.com/article/wearables-have-a-dirty-little-secret-most-people-lose-interest/.

Steve Mann. 2004. Continuous lifelong capture of personal experience with EyeTap. In

Proceedings of the the 1st ACM workshop on Continuous archival and retrieval of personal experiences (CARPE'04). ACM, New York, NY, USA, 1-21.

Bryan Marshall, Peter Cardon, Amit Poddar, and Renee Fontenot. 2013. Does Sample Size Matter in Qualitative Research? A Review of Qualitative Interviews in Is Research. *Journal of Computer Information Systems*, 54(1),11-22.

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 SIGCHI Conference on Human Factors in Computing Systems (CHI '14)*. ACM, New York, NY, USA, 2833-2842.

Kathleen M. MacQueen,, Eleanor McLellan-Lemal, Kelly Bartholow, and Bobby Milstein. 2008. Team-based Codebook Development: Structure, Process, and Agreement. In *Handbook for Team-Based Qualitative Research*, Greg Guest and Kathleen M. MacQueen (Eds.), AltaMira Press, Lanham, UK, 119-136.

Florian Michahelles and Bernt Schiele. 2005. Sensing and Monitoring Professional Skiers. IEEE Pervasive Computing, 4(3), 40-46.

Miles, M. B., & Huberman, A. M. (1994). Qualitative Data Analysis An Expanded Sourcebook. Thousand Oaks, CA Sage Publications.

Jere H. Mitchell, William Haskell, Peter Snell, Steven P. Van Camp. (2005). Task Force 8: Classification of sports. *Journal of the American College of* Cardiology, 45(8), 1364-1367.

Florian 'Floyd' Mueller, Darren Edge, Frank Vetere, Martin R. Gibbs, Stefan Agamanolis, Bert Bongers, and Jennifer G. Sheridan. 2011. Designing sports: a framework for exertion games. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '11).* ACM, New York, NY, USA, 2651-2660.

Florian 'Floyd' Mueller and Matthew Muirhead. 2015. Jogging with a Quadcopter. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems (CHI '15)*. ACM, New York, NY, USA, 2023-2032.

Dawn Nafus, Pete Denman, Lenitra Durham, Omar Florez, Lama Nachman, Saurav Sahay, Evan Savage, Sangita Sharma, Devon Strawn, and Rita H. Wouhaybi. 2016. As Simple as Possible but No Simpler: Creating Flexibility in Personal Informatics. In *Proceedings of the 2016 CHI Conference Extended Abstracts on Human Factors in Computing Systems (CHI EA '16).* ACM, New York, NY, USA, 1445-1452.

Rosemery O. Nelson, and Steven C. Hayes (1981). Theoretical explanations for reactivity in self-monitoring. *Behavior Modification,* 5(1), 3–14.

Emily J. Oliver, James Hardy, and David Markland. 2010. Identifying important practice behaviors for the development of high-level youth athletes: Exploring the perspectives of elite coaches. *Psychology of Sport and Exercise*, 11(6), 433–443.

Sebastiaan Pijnappel and Florian Mueller. 2013. 4 design themes for skateboarding. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '13)*. ACM, New York, NY, USA, 1271-1274.

Polit, D. F. & Beck, T.C. (2010). Generalization in Quantitative and Qualitative Research: Myths and Strategies. *International Journal of Nursing Studies*, 47(11), 1451–58.

Blaine A. Price, Ryan Kelly, Vikram Mehta, Ciaran McCormick, Hanad Ahmed, and Oliver Pearce. 2018. Feel My Pain: Design and Evaluation of Painpad, a Tangible Device for Supporting Inpatient Self-Logging of Pain. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems (CHI '18)*. ACM, New York, NY, USA, Paper 169, 13 pages.

Amon Rapp and Federica Cena. 2016. Personal Informatics for Everyday Life: How Users without Prior Self-Tracking Experience Engage with Personal Data. *International Journal of Human-Computer Studies* 94, 1-17.

Amon Rapp, Federica Cena, Judy Kay, Bob Kummerfeld, Frank Hopfgartner, Till Plumbaum, Jakob Eg Larsen, Daniel A. Epstein, and Rúben Gouveia. 2017. New frontiers of quantified self 3: exploring understudied categories of users. In *Proceedings of the 2017 ACM International Joint Conference on Pervasive and Ubiquitous Computing and Proceedings of the 2017 ACM*

International Symposium on Wearable Computers (UbiComp '17). ACM, New York, NY, 861-864.

Amon Rapp and Maurizio Tirassa. 2017. Know thyself: A Theory of the self for Personal Informatics. Human-Computer Interaction. *Human-Computer Interaction*, 32(5-6), 335-380.

Amon Rapp, Alessandro Marcengo, Luca Buriano, Giancarlo Ruffo, Mirko Lai, Federica Cena (2018). Designing a Personal Informatics System for Users without Experience in Self-tracking: A Case Study. *Behaviour & Information Technology*, 37(4), 335-366.

Amon Rapp and Lia Tirabeni (2018). Personal Informatics for Sport: Meaning, Body, and Social Relations in Amateur and Elite Athletes. *ACM Transactions on Computer-Human Interaction (TOCHI)*, 25(3), Article 16, 30 pages.

Hubert Ripoll, Yves Kerlirzin, Jean-François Stein, Bruno Reine (1995). Analysis of information processing, decision making, and visual strategies in complex problem solving sport situations. *Human Movement Science*, 14(3), 325–349.

John Rooksby, Mattias Rost, Alistair Morrison, and Matthew Chalmers Chalmers. 2014. Personal tracking as lived informatics. In *Proceedings of the 32nd annual ACM conference on Human factors in computing systems (CHI '14)*. ACM, New York, NY, 1163-1172.

Saldaña, J. (2015). The coding manual for qualitative researchers. Sage.

Anna E. Saw, Luana C. Main, and Paul B. Gastin. 2015a. Monitoring the athlete training response: subjective self-reported measures trump commonly used objective measures: a systematic review. *British Journal of Sports Medicine*, 50(5), 1-13.

Anna E. Saw, Luana C. Main, and Paul B. Gastin. 2015b. Monitoring Athletes Through Self-Report: Factors Influencing Implementation. *Journal of Sports Science and* Medicine, 14(1), 137-146.

Segen's Medical Dictionary. 2011. Endurance Sport. Retrieved November 25, 2016 from http://medical-dictionary.thefreedictionary.com/Endurance+Sport

Andy Stamm, David V. Thiel, B. Burkett, and Daniel A. James. 2011. Towards determining absolute velocity of freestyle swimming using 3-axis accelerometers. *Procedia Engineering*

13(0), 120-125.

Anselm L. Strauss and Juliet M. Corbin. 1990. Grounded theory research: Procedures, canons, and evaluative criteria. *Qualitative Sociology*, 13(1), 3–21.

Dag Svanæs. 2013. Interaction design for and with the lived body: Some implications of merleau-ponty's phenomenology. *ACM Trans. Comput.-Hum. Interact.*, 20(1), Article 8, 30 pages.

Christian Swann, Aidan P. Moran, and David Piggott. 2015. Defining elite athletes: issues in the study of expert performance in sport psychology. *Psychology of Sport and Exercise*, 16(Part 1), 3-14.

Kristie-Lee Taylor, Dale W. Chapman, John B. Cronin, Micheal J. Newton, and Nicholas Gill. 2012. Fatigue monitoring in high performance sport: A survey of current trends. *Journal of Australian Strength and Conditioning 20*, 1 (2012),12-23.

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 (CHI '15)*. ACM, New York, NY, USA, 2913-2922.

Robin Thorpe, Greg Atkinson, Barry Drust, Warren Gregson (2017). Monitoring Fatigue Status in Elite Team Sport Athletes: Implications for Practice. *International Journal of Sports Physiology and Performance*, 12(2), S227-S234.

Tammy Toscos, Anne Faber, Shunying An, and Mona Praful Gandhi. 2006. Chick clique: persuasive technology to motivate teenage girls to exercise. In *CHI '06 Extended Abstracts on Human Factors in Computing Systems (CHI EA '06).* ACM, New York, NY, USA, 1873-1878.

Julia Twigg. 2009. *Clothing, identity and the embodiment of age. In J. Powell and T. Gilbert (eds) Aging and Identity: A Postmodern Dialogue*. New York, NY: Nova Science Publishers.

Brett Wakefield, Carman Neustaedter, and Serena Hillman. 2014. The informatics needs of amateur endurance athletic coaches. In *CHI '14 Extended Abstracts on Human Factors in Computing Systems (CHI EA '14).* ACM, New York, NY, USA, 2287-2292.

Wouter Walmink, Danielle Wilde, and Florian 'Floyd' Mueller. 2014. Displaying heart rate data on a bicycle helmet to support social exertion experiences. In *Proceedings of the 8th International Conference on Tangible, Embedded and Embodied Interaction (TEI '14).* ACM, New York, NY, USA, 97-104.

Rayoung Yang, Eunice Shin, Mark W. Newman, and Mark S. Ackerman. 2015. When fitness trackers don't 'fit': end-user difficulties in the assessment of personal tracking device accuracy. In *Proceedings of the 2015 ACM International Joint Conference on Pervasive and Ubiquitous Computing (UbiComp '15)*. ACM, New York, NY, USA, 623-634.

Bo Zhou, Harald Koerger, Markus Wirth, Constantin Zwick, Christine Martindale, Heber Cruz, Bjoern Eskofier, and Paul Lukowicz. 2016. Smart soccer shoe: monitoring foot-ball interaction with shoe integrated textile pressure sensor matrix. In *Proceedings of the 2016 ACM International Symposium on Wearable Computers (ISWC '16)*. ACM, New York, NY, 64-71.