Understanding Recreational Runners' Motives and Behavior to Support the Design of Running-Related Technology

UNDERSTANDING RECREATIONAL

RUNNERS'

MOTIVES AND BEHAVIOUR TO SUPPORT THE DESIGN OF

RUNNING-RELATED TECHNOLOGY

MARK JANSSEN

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SUMMARY

Running is one of the most popular recreational and unorganized leisure time sports. Running has great potential in promoting an active and healthy lifestyle due to its popularity, ease of practice, and potential health benefits. Despite these benefits, running also entails a significant challenge: running is known for its high drop-out rates. This drop-out is most noticeable among novice and inexperienced runners. Guidance for these runners might be favourable to support them in their running. Apps and sports watches can provide training schedules, connect runners in online communities, and allow runners to measure all kinds of running-related parameters. Although the enormous potential of apps and sports watches to support runners in monitoring training activities and provide motivational cues, there is still a significant group of people that drops out from running because of injuries or demotivation. Therefore, this doctoral research aims to understand the motives and behaviour of recreational runners to support the design of running-related technologies.

Two research questions were formulated:
1. *What are the motives and behaviour of recreational runners in relation to the usage of running-related technologies?*
2. *How can we design running-related technology that matches the motives and behaviour of recreational runners?*

To address our first research question, we conducted four large-sample survey-based studies, which provide empirical contributions in understanding the motives and behaviour of recreational runners in relation to the usage of running-related technologies.

Study 1 (Chapter 2) focused on the profile of runners who use running-related apps and sports watches. The analyses showed that 9 out of 10 event runners use at least one monitoring device, with more than half of the participants reporting that they use an app. Compared to app users, there were slightly more sports watch users (60.5%). Socio-demographic, sports-related behavioural and psychographic characteristics influenced the use of apps and sports watches. For example, apps were more likely to be used by younger, less experienced, and less involved runners. Older and more experienced runners with higher involvement are more likely to use sports watches. This group of runners is more often involved in sports clubs with professional guidance. While app-users, the novice, and inexperienced runners, run primarily individually without professional guidance and are more likely to drop out from running owing to personal reasons.

In the next study (Chapter 3), which built on study 1, a runner typology (based on motives and behaviour) was constructed. We investigated how different profiles of runners differ in their use of technology. Four types of runners were identified: casual individual runners, socially competitive runners, individual competitive runners, and devoted runners. The casual individual runners and socially competitive runners can be described as beginners and the most inexperienced runners. While we found the most app users among the casual individual runners. Among individual competitive runners and devoted runners, sports watches are used the most. These latter two types of runners are characterised by a high training volume and a performance-orientated motivation. This is in line with study 1, where apps users also tend to be younger and less experienced.

Chapter 4 (study 3) focused on the perceived reasons to quit running. Again based on a large-sample survey study, we found that runners, in general, perceive more individual reasons for quitting running rather than social reasons. Among the individual reasons, reasons like injuries and being tired of running are the most important reason to quit running. Less experienced runners were more likely to quit running and involved runners were less likely to perceive individual motives to stop running.

Chapter 5 (study 4) investigated how runners perceive their running environment and how this differs between runners. Results showed that all runners want their routes to be attractive and to have a restorative capacity. Less experienced runners find green, natural, and lively elements in their running environment more important than their more experienced counterparts.

The first section of four studies provided insights into the motives and behaviour of recreational runners in relation to the usage of running-related technologies (RQ1). We showed that recreational runners are a heterogeneous and diverse group in terms of their socio-demographics, behavioural, and motivational characteristics. These characteristics relate to the kind of running-related technology they use, how they use the data acquired by these technologies, how susceptible they are to quit running and how they experience their environment. Hence, different types of runners should be targeted differently when designing running-related technology. We argue that there is a mismatch between the runners' needs and interests and the existing running-related technology. Runners have a hard time keeping up with all the newly introduced technologies and finding the right products. While often, available products do not meet their needs for support and guidance while running. Therefore, in the second section consisting of four chapters, we explored how we can design running-related technology that matches the motives and behaviours of recreational runners (RQ2).

Study 5 (Chapter 6) analysed the design process during a sports and physical activity-related hackathon. In the field of sports, the design space is enormous and requires an

open and explorative approach. The study showed that spending more time envisioning and understanding societal and personal needs seems beneficial for the following design phases and eventually results in higher quality design outcomes. Next, in Chapter 7 (study 6), we used expert panels with experts from different fields to define their perception of how sport-related wearables should be designed. This study showed that the experts agreed that working together with experts from different domains to develop apps is essential. An interdisciplinary approach allows the knowledge of each field to be integrated, ensures that crucial factors relating to app use and engagement are considered, and guarantees a theoretical foundation.

We concluded from chapters 6 and 7 that understanding the societal and personal needs and combining knowledge of different domains is necessary. Therefore we combined in the last two studies these principles with the insights into the runners' motives and behaviours (Chapters 2–5). With two case studies, we developed two artefacts. The first design supports runners in their decision-making process for choosing an appropriate app (study 7). Our second design uses personalization and objective measures of training load to support and guide runners while training for their goals (study 8).

In study 7 (Chapter 8) we deployed a methodology to develop an online tool that supports the decision-making process to choose a smartphone application. We used a running-app case study to illustrate this method and made an artefact of the tool. First, we constructed and validated a screening instrument (Sport App Screening Tool) to assess app content quality. This served as input for building the tool and resulted in an online tool that relies on app content quality scores to match the users' needs with apps that score high in the screening instrument on those particular needs. Users can add new apps to the database via the screening instrument, making the tool self-supportive and future proof. A feedback loop allows users to give feedback on the recommended app and how well it meets their needs. This feedback is added to the database and used in future filtering and recommendations.

Study 8 in Chapter 9 is a case study in which we attempt to meet the runners' needs for support and guidance while running. We designed the Inspirun e-Coach app that uses personalisation and objective measures of training load to support and guide runners while training for their goals. Our algorithm uses perceived exertion, biofeedback, and GPS-data to calculate the runners' physical workload for the next training session. A 3-month user study showed that the automatic adaptation of training sessions to the runners' physical workload, stimulated the runners' goal perception, motivation, and experienced personalisation. With this algorithm, we made optimal use of the potential of app technology to support the large group of novice or less experienced runners and that by providing insight into our working mechanism.

In the last chapter (Chapter 10), we discuss the motives and behaviour of recreational runners regarding running-related technology and elaborate on why the potential of running-related technology is underexploited to support and guide runners. Finally, we reflect on how we can use this more profound understanding of recreational runners to design more personalised products and services. This requires involving the end-user in the design process. These insights can help other designers and engineers when developing running-related technology. Finally, we present educational implications and future work recommendations.

1

GENERAL INTRODUCTION

1. PHYSICAL (IN)ACTIVITY AND LEISURE-TIME SPORTS PARTICIPATION

In recent times, physical inactivity and sedentary behaviour have become major public health concerns [28,32,44,58,70,83,163]. The number of people with lifestyle-related health issues has increased, which has led to a decline in quality of life and the development of chronic diseases. Regular exercise (moderate to vigorous physical activity) has been observed to reduce risks of chronic diseases (e.g. cardiovascular and diabetes type 2) and all-cause mortality [88,155]. Likewise, regular physical activity is also associated with a high life expectancy [1,156] and healthy ageing [1,63]. Thereby, recent work suggested an association between sedentary behaviour and health problems, increasing mortality rates, and chronic diseases [12]. In general, the awareness concerning the importance of an active and healthy lifestyle within our society has notably increased [113,148] and is strengthened by global initiatives such as Exercise is Medicine, where physical activity has become an integral part of the prevention and treatment of numerous chronic diseases [14,113,144]. However, maintaining a healthy lifestyle and appropriate exercise level is challenging. Although guidelines on sufficient levels of physical activity are recommended worldwide [158], only half of the adult Dutch population truly complies with them [30].

Leisure-time sports activities can help maintain sufficient physical activity levels and are associated with positive benefits for physical and mental health and well-being [42,45,46,87,108,109,115]. In essence, sports participation has tremendous potential in promoting an active and healthy lifestyle. In the last few decades, there has been a rise in leisure time sports participation [127]. This trend evolved from participating in club-organised sports activities, formerly the most popular way for sports participation, towards more recreational and unorganised forms of leisure-time sports such as running, cycling, recreational walking, and fitness [16,70,126]. These leisure-time sports are described as easily accessible, flexible and, on-demand forms of sports participation, which contrast with the more traditional club-organised sports [16,17,20,44,78,126]. As regular exercise plays a crucial role in a healthy lifestyle [137], leisure-time sports can potentially stimulate more regular exercise and contribute to a healthy lifestyle and in turn to public health.

2. RECREATIONAL RUNNING

Running is one of the most popular recreational and unorganised leisure-time sports [59,68,121,124]. It has remarkable potential in promoting an active and healthy lifestyle by dint of its popularity and benefits.

2.1. Running: popularity and benefits

Over the last seven decades, running has drastically evolved as a sport. While nowadays it is characterised as a leisure-time sports that is practised everywhere and anytime, in the 1960s it was only practised in private track and field clubs. Back then, running or jogging in a park or along the street was considered unconventional [125]. After the 1970s, there was an exponential increase in runners: this so-called *first running wave* is characterised by a transition towards less structure and competition. People started running on the street and in parks, and thereby it became a way to enhance personal health [125]. According to Scheerder and colleagues [125] the *second running wave* emerged in the 1990–2000s and was supported by the fitness revolution. Events started booming, and as compared to the first wave, the focus was even more on health; runners were often not a member of any sports club, which indicates that they mostly trained without any instructor. At present, we are in the middle of the *third wave*. As a result of the experience economy, running is characterised with digitalisation, sharing online, fun, and the extensive use of smartphone applications (apps) [20]. Running has become one of the most popular leisure-time sports in the world in terms of participation [121,124]. Almost 10% of the total EU-28 population participates in running, which means that there are approximately 50 million running participants [124]. Furthermore, in the Netherlands, it is one of the most practised sports [68,166]. Among Dutch adults, 14.3% reported running as an activity they do weekly [166]. These figures are similar to data from other West-European countries [124] and the US [121]. During the COVID-19 pandemic, which had a negative impact on physical activity [34], running became even more popular [41].

Running garnered such immense popularity because of its numerous advantages. First, it can be practised by a diverse and heterogeneous group of people [19,35,73,125]. Running not only attracts various participants in terms of socio-demographic characteristics such as age, sex, and socio-economic status [60,151] but also in terms of motives (e.g. health, freedom, social experience, fun, and performance enhancement) [18,50] and experience (e.g. both novice and experienced runners). Second, runners gain an advantage from a number of health-related benefits, including enhanced musculoskeletal and cardiovascular health, better body composition, and better psychological state [17,52,57,67,72,104,114,128,131]. Thereby, running can be characterised by the simplicity of practice. In essence, people just need a pair of running shoes and suitable clothing to go out for a run. It is also known for its low threshold to start and is relatively inexpensive than other sports [44]. Whereas formerly running was mostly practised in private track and field clubs, in the last decades, because of its simplistic nature, more and more runners participate individually in informal groups, low-threshold exercise ('start to run') programmes or running events [19,125]. This group of individual runners has even become larger, the runners who used to train in sports clubs or small running-groups are now forced to running individually because of the measures in force during the COVID-19 pandemic, were running in groups was not allowed.

Participation in running events is deemed the 'new' carrier of the rising prominence of recreational running [60,124,151,154]. Finally, various studies have shown that the health benefits of running can be promoted and improved by the type of environment they run in. Running can be practised anywhere and anytime. Runners do not need a specific sports accommodation or infrastructure. Research reveals that a wide range of geographical running locations is used, for example, urban areas, parks, and natural settings [17,18,22,27,35,55,119,126,153]. Nevertheless, certain types of environments are more appreciated and used by runners. While some environments impede running, 'green' settings are most popular and furnish the most physiological and mental benefits [22,27,55]. Therefore, it not only matters that people participate in running but also where they run [13,64,85].

2.2. Running: risks and pitfalls

Notwithstanding its numerous benefits, running has a high drop-out rate. This high drop-out rate is often due to running-related injuries (RRI) [31] and motivational loss. This drop-out is the most noticeable among novice and inexperienced runners [66,75,150]. In the Netherlands, running is the third biggest cause of sports injuries – after field football and fitness – 14% of all injuries are caused by participating in running [136]. Research shows that between 20% and 80% of all runners get injured at a certain point [54,90], and for every 1,000 hours of running exposure, the incidence of RRI ranges between five and up to 30 injuries [10,54,82,90,150,164]. Novice runners, in general, face a significantly greater risk of injury per 1,000 h of running than experienced runners [89,150].

Although not all injuries directly lead to quitting running, getting injured also has other effects. For example, it is known that the fear of getting injured or staying injured is associated with motivational problems to sustain a physically active lifestyle [122]. In general, research [95] describes four main risk factors related to RRI: lack of running experience, previous injuries, competitive running, and running excessive distances. Most injuries, especially among novice runners, are related to training errors, particularly errors in thorough preparation, planning, and monitoring of training sessions [24,54,69], which often means that runners run very large distances. Thereby, it appears that runners with an irregular and unbalanced training schedule (including large differences in intensity, volume, and frequency) are more likely to drop-out [2 1,24,49,54,66,71,75,79,118,136,150]. In the traditional support structure, the trainers/ coaches in sports clubs provided guidance and support to runners. The former made sure that runners trained regularly and balanced, which in turn alleviate the risks of RRI. The shift to more individual running participation outside the sports club means that runners (especially novice) might not receive the guidance and support they require [23,25,150], which could potentially increase the risk of RRI. Consequently, increase drop-out rates. Some sort of guidance for novice and less experienced runners might be favourable to support them in their running [16].

3. RUNNING-RELATED TECHNOLOGIES

3.1. Technology in daily life

Technology has found a place in people's daily life. According to Müller's classification of digital technology [103], the Internet, (mobile) phones, and short text messages (i.e. generation 1 technologies) were first embedded in people's everyday life. Soon after that, 'generation 2 technologies' pervaded people's daily life, and the usage of apps, sports watches, smartwatches, and wearable trackers increased exponentially [40,47,84,98,157]. For example, in 2015, in the US, 82% of the adult population (18–49 years of age) owned a smartphone, whereas 15% of this population owned an activity tracker [21]. An average American smartphone has 22 apps downloaded in it, and 30% of them are sports-related including both active participation and media sports [22]. Approximately 20% of smartphone users utilise health-related apps [51], and about 3% of all available apps in the app stores are health-related apps capable of monitoring sports-related physical activities. [5]. A study in the Netherlands among smartphone users revealed that among the average 35 apps installed in a smartphone, half of them are used daily [40]. Besides gaming apps, physical activity-related apps that are capable of monitoring activities are the most popular [56]. This increasing use of technology to monitor activities and daily life is consistent with trends such as Quantified Self [139,140], which is typically described as the endeavour to keep track of maximum possible aspects of life using technological devices. These devices are designed to improve our quality of life by identifying and learning patterns in our everyday routine. Ultimately, these devices acquire an in-depth understanding of how different aspects influence our lives. Although the group of people who keep track of every possible aspect is relatively small, more people actually monitor certain aspects of their life, for example, their sports activities [140,147,159]. Recreational athletes use monitoring devices to keep track of their activities, share their achievements, get insight into their fitness, and other similar purposes. This popularity of monitoring sports activities has also been observed in running. Runners monitor their activities through different running-related technologies such as apps and sports watches [33,117].

3.2. Wearable and sensor technologies for runners

There is an extensive variety of available running-related products and services. These products have evolved over the past years as a result of technological development of sensors and wearable technology.

It started with the introduction of the digital sports watch in the late 70s/early 80s (i.e. Casio or Timex Ironman). At that time, it was revolutionary that 'technology' that could be worn (the first wearable) and display real-time running information: split times and actual time. A few years later, the sensor technology of measuring heart rate was introduced in wearable belts. These chest bands could be paired with a wrist computer (e.g. Polar Sport Tester PE3000). This 'watch' offered runners the possibility to view and analyse training data afterwards with the help of a computer. About two decades ago, the already existing GPS sensor technology evolved from heavy and oversized sensors to tiny and light integrable sensors. GPS-sensors could now be integrated into wearables, so the first GPS watch was released (i.e. Garmin forerunner 101) [86]. Prior to its release, foot pods were used to calculate the running speed on the basis of self-measured stride length. Subsequently, running speed, distance, running route, maps were the features that became the new standard for a GPS running watch. In 2008, the first running app, Runkeeper, was introduced and was followed by the release of similar apps. This completely changed the ease with which sporting activities were monitored. These apps converted the daily used smartphone (which people often already owned) into a sporting product. This evolution of running technology kept growing. More brands started to develop apps, and the apps became more accurate and incorporated interesting and innovative features using all kind of sensor technology. In addition, apps became social platforms and were integrated with other technological products such as watches. During the same period, the sports watch market witnessed an evolution as well. Following the same tendency, more and more features could be used to monitor the performance more accurately.

In the early 2010s, the first activity trackers and smartwatches, i.e. Nike fuel band and Sony Smartwatch, were released. This new segment of products was designed to wear throughout the day and not just during sports. Therefore, if we look at the current market, we can see a number of products and product categories. To fulfil the needs of the vast running population, the sporting goods industry has increased over the last decades [3,4,42,107,112,124], with an estimated size of 0.5% to 1.0% of all import and export trades [127]. There is a wide array of available running-related products and services. Running-related services include, among other, mass sports events [138], running clinics, and exercise tests. Running-related products include, among other, clothing, footwear, and monitoring devices. In recent years, the running market has witnessed an exponential increase in both availability and usage of technological related-running products and services, particularly apps and sports watches [40,47,84,98,157]. There is much more to come, especially if we look at the trends seen in sensor technology. Today sensors and algorithms can measure heart rate variability, oxygen saturation, breathing frequency, foot strike, blood pressure, UV, electrodermal, skin temperature, VO^2, and ECG. As these sensors become smaller, lighter, and more reliable, they will be integrated into new wearable products with more functionalities available to the public.

3.3. Apps and sports watches

Pobiruchin et al. [117] reported that about 75% of runners use wearable technology for training optimisation and distance recording. In the Netherlands, about 45% of runners use an app during training [40,76]. Clermont et al. [33] noted that tracking personalised training data were the primary reason for the use of technology among runners. They suggested that the biggest motivators were instant feedback (rewarding you for achieving targets) and insight into achievements (e.g. distance covered and average speed). For novice and less experienced runners, using smartphones to record running sessions has several advantages. As described earlier, smartphones are widely used and have found their place in everyday life [39,152]. Nine out of ten (87%) adults in the Netherlands reported that they own a smartphone (76% of the adult population in advanced economies) [142]. These smartphones allow people to collect data anywhere and anytime [48]. Apps are inexpensive (often free of charge), which makes them accessible for almost everyone. In recent years, a large number of sports apps have been developed for people in individual sports, and every day new apps are launched in the app stores [9]. Findings of previous research have revealed that approximately 45% to 75% of event runners use a running app [40,117]. For instance, Runkeeper, one of the most popular running-apps, has over 50 million users [120]. These running apps allow people to support sports participation through monitoring activities, setting goals, and comparing results to others. However, the question is whether the quality of currently available apps is sufficient to support recreational sports participants.

4. HUMAN–COMPUTER INTERACTION AND RUNNING

Not only the number of runners who use running-related technologies has increased, the development of new prototypes and systems has also received notable attention in the field of Human–Computer Interaction (HCI) research. As remarked earlier, we are currently in the middle of the third running wave, where running is characterised by digitalisation, online sharing, fun, and smart technologies [20]. The integration of technology is a frequently investigated topic in the HCI community [i.e.2,7,8,26,29,36,38,53,61,62,91–94,96,97,100,101,110,123,130,132,160,162]. The HCI community has recognised that interaction between humans and computers is driven by several unique perspectives. HCI researchers are focusing, for example, on how users use technology, the complexity of different interactions, and how this technology can support its users in their daily life. Multiple approaches are used to support, guide, and help users become better, fitter, happier, more motivated, and connected. In the case of running, researchers have developed various types of prototypes such as bracelets [96], shoes [77,149,160], running with drones [7,130], and we see numerous prototypes using mobile technology [8,36,91,93,111,141,160,162]. This mobile technology is also a topical theme in other fields of research. For example, in public health, a number of studies discuss mobile technology and applications through the lens of behaviour change [43,43,99,116,129,133,135,145,165]. The field of HCI acknowledges that the potential of technological support is present, and it can contribute to solving running-related problems including RRI and drop-out. However, researchers are confronted with substantial challenges while using these technological systems to prevent RRI or drop-out [74,161]. Several studies have focused on different aspects to improve running technique and thereby minimise the concomitant injuries [6,77,106,149]. Other researchers have focused more on running technology in relation to the social aspects of running [37,80,102,146] and the individual motivation of runners [15,81] to prevent drop-out from a motivational perspective.

4.1. Examples of running-related technologies

Maturity of any technology can be classified on the basis of its readiness level. The technology readiness level (TRL) ranges from 1 to 9 [65] (see table 1.1). Commercially available apps (such as Runkeeper, Runtastic, or Strava) and sports watches (such as Garmin or Polar sports watches) are products that are aligned with level 9 on the technology readiness scale.

The prototypes developed by HCI/design researchers are often in the development phase, commensurate with levels 4–6 of technology readiness. Therefore, they exhibit outstanding potential for future deployment. A few examples are discussed as follows. Aranki et al. [6] developed RunningCoach, a mobile health system that monitors and gives feedback on running cadence to optimise it and (possibly) minimise running injury. They used self-monitoring and tailoring (the user can change the feedback) as a persuasive feature in their system. Another example is Runmerge, an app developed by Kiss et al. [77], which enhances body awareness using visualisation of runners' steps to help them towards a better running experience. Authors found that enhanced proprioception (i.e. 'knowing your body') can be beneficial for everyday running training. Nylander and Tholander [106] developed Runright, an app-based system that provides real-time visual and audio feedback about the current running rhythm. Their non-interpretive visualisation led users to their interpretation of the feedback. Valsted et al. [149] developed Strive, a wearable that aims to assist runners in achieving rhythmic breathing, a breathing technique that potentially leads to discernibly improved running results and lower injury risk. The user's understanding of feedback patterns was assessed on the basis of self-monitoring.

Another key domain that is often researched is the social aspects of running. In this category, dialogue and social support features are common. For example, Timmerman [146] investigated how technology can support a group of runners. In line with that, Mueller et al. [102] introduced 'Jogging over a Distance', a system that allowed runners worldwide to run together using an audio-based social comparison feature and thus appraised how technology can support the social aspects of running. HeartLink [37], a system that broadcasts live biometric data to social networks and RUFUS [80], a system that enables runners to communicate with supporters using 'praise' during races also focus on the social aspects of running. A final category investigated quite often is the enhancement of the motivation of runners. For example, the e-coaching ecosystem [15] offers interactions between end-users and human trainers to enhance motivation and stimulate a healthy and active lifestyle. Again, social support features are at times used as part of persuasive technology. A human trainer is essential in this design. Runners are more engaged when professionals offer or supervise the training sessions, compared to a group of runners with self-made training sessions and no supervision. While most work related to motivation is focused on novice runners, Knaving et al. [81] proffered a framework and guidelines to design technology for experienced runners.

Table 1.1. *Technology Readiness Level (TRL), this table is an adaptation of [65]*

Phase	**TRL**	**Hardware/software**
Research	1	Basic principles observed and reported *Research begins to be translated into applied research and development*
	2	Technology concept or application formulated *Practical applications can be invented after basic principles are observed.*
	3	Characteristic proof of concept *Lab studies for physical validation of analytical predictions of individual elements of the technology*
Development	4	Laboratory validation of components *Basic technological components are integrated to verify they work together*
	5	Target environment validation of components *Higher fidelity of component integration testing in a simulated environment testing*
	6	System models in target environment *Prototypes demonstrating a significant technological readiness, are tested in a relevant environment*
Implementation	7	System prototype in operational environment *Functional prototypes demonstrating the completed system in its expected configuration are evaluated in an operational environment*
	8	Final system qualified through demonstration *Technologies are proven to work in their final form and under expected conditions through test and demonstration*
	9	Final system proven *Applications of technologies in their final form are proven through successful under all conditions*

5. RESEARCH QUESTIONS AND CONTRIBUTIONS

5.1. Research questions

Wearable technology has found its place in running practices. Widely available low-cost technology enables runners to monitor our health 24/7, gathering lots of data, acquire real-time feedback and receive guidance. Apps and sports watches provide standardised, 'one-size-fits-all' training schedules, challenge and motivate runners, connect runners in online communities, and allow runners to readily measure all sorts of running-related parameters. Despite the enormous potential of apps and sports watches to support runners in monitoring training activities and providing motivational cues, there is still a substantial proportion of the population that drops out from running because of injuries or demotivation. Becoming physically less active and more prone to health risks. This has given rise to a number of critical questions: (i) Who uses running-related technologies, and how do they use them? (ii) Does existing technology meet the expectations and needs of runners? (iii) If not, then why not? (iv) Do we overestimate the potential of wearable technologies for running and other sports?

Therefore, the overarching aim of this doctoral research is to understand motives and behaviour of recreational runners to support the design of running-related technologies.

To attain this aim, two research questions were formulated:

1. *What are the motives and behaviour of recreational runners in relation to the usage of running-related technologies?*
2. *How can we design running-related technology that matches the motives and behaviour of recreational runners?*

This dissertation consists of a general introduction (Chapter 1), followed by two sections (Chapters 2–9) and a general discussion (Chapter 10). The first section consists of four chapters (Chapters 2–5), which address the first research question. **Chapter 2** describes the characteristics of recreational runners participating in a half marathon in terms of socio-demographics, behavioural aspects, attitudes, interests, and opinions (AIOs). We investigate how these characteristics relate to the kind of technology (apps and sports watches) they use and created distinctive consumer profiles app and sports watch users.

Chapter 3 continues the findings from Chapter 2 by creating a running typology. We segmented a heterogeneous group of runners (varying between 5k to 42.2k runners) into four types of runners based on their motives and interests towards running. For each of these types, we investigated how they use the available running-related technologies.

In **Chapter 4**, we focus on common reasons to quit running. This chapter shows which potential reasons to quit running are highly rated by recreational runners and relates these reasons to runners' characteristics to show which runners are most susceptible to quit running. In the final chapter of the first section (**Chapter 5**), running context is covered. Chapter 5 elucidates the role of running context; it delineates which environmental characteristics make a running environment attractive. In addition, to analyse whether different types of runners think differently of an attractive running environment, it relates the attractiveness of the running environment to characteristics of the runner. The first section ultimately concludes the first research question.

The second section consists of four chapters (Chapters 6–9), which address the second research question. Here, the insights from the first section are used to explore how we can design running-related technology that matches the motives and behaviours of recreational runners. First, **Chapter 6** presents an analysis of the design processes during a hackathon. During this hackathon, which focused on designing for sports and vitality, we monitored the design activities of the participating groups. In **Chapter 7**, we explore the expert perceptions of how sports-related technology should be like. Expert panels comprising participants with different areas of expertise were used to create supported view on how running-related technology should be designed. The following two chapters (8 and 9) show two different case studies where we designed running-related technology, using the insights of the previous six studies. **Chapter 8** describes a case study on how we could support runners in their decision-making process for choosing running-related technology. With an interdisciplinary team, we designed a decision-making tool that can help runners determine the most appropriate app. Thereby, we created three design principles that can be applied in future research. In **Chapter 9,** we discuss another case study. This case study is on how we can support runners in their training towards their running goals. We created an app that uses a personalised coaching approach with automatic adaptation of training schemes. The app stimulates goal perception, motivation and is personalised.

5.2. Contributions

This dissertation has three types of contributions: empirical, methodological, and artefact contributions. Chapters 2–5 (i.e. the first section) present empirical contributions. On the basis of large data samples, we provide meaningful insights into the motives and behaviour of recreational runners with regard to running-related technologies. Chapter 6 and 7 furnish insights into the design process and how running-related technologies should be designed. Chapter 8 has a methodological contribution; we propose design principles that can be used for the purpose designing in the field of sports. Finally, this dissertation has two artefact contributions that are discussed in Chapters 8 and 9. Chapter 8 describes a system that could support runners in the decision-making process for choosing running-related technology. Chapter 9 provides a system that can support runners in their training towards their running goals. It provides guidance for novice runners by personalizing their training sessions. In this chapter we also include a full detailed description of the working mechanism and algorithm.

5.3. Overview research questions and contributions

	Understanding recreational runners' motives and behaviour to support the design of running-related technology							
	What are the motives and behaviour of recreational runners?				How can we design running-related technology that matches the motives and behaviour of recreational runners?			
	Chapter 2	Chapter 3	Chapter 4	Chapter 5	Chapter 6	Chapter 7	Chapter 8	Chapter 9
Objective	What are the characteristics of event runners who use running-related apps and sports watches?	What are the different runner types—in terms of their attitudes, interests and opinions (AIOs) about running—and how do they differ in the technology they use?	What are the perceived reasons to quit running among event runners?	How do runners with different characteristics (AIOs) and years of running experience perceive their running environment on attractiveness and restorative capacity?	How does the design process of future designers look like during a Hackathon in the field of sports and vitality?	Which features are important for the effectiveness of physical activity–related apps for participation in individual, recreational sports?	How can we support runners in the decision-making process for choosing an appropriate app?	How can we support runners in their training toward their running goals?
Methods	Standardized online survey: Eindhoven Running Survey 2014 N = 2172 participants of the 21,1k run.	Standardized online survey: Eindhoven Running Survey 2016 N = 3723 participants of the 5k, 10k, 21,1k, 42,2k run.	Standardized online survey: Eindhoven Running Survey 2016 N = 898 participants of the 5k and 10k run.	Standardized online survey: Eindhoven Running Survey 2015 N = 2477 participants of the 21,1k run.	Interactive, qualitative study design. All steps in the design process were monitored using the Reflective Transformative Design framework.	Expert panels (N=11) using the nominal group technique.	Design study* with interdisciplinary team. Interviews with experts and user tests with different prototypes.	Design study* with interdisciplinary team. User tests with different beta prototypes Extented user test with final prototype.
Contribution	Empirical	Empirical	Empirical	Empirical	* used as input for the design studies	* used as input for the design studies	Methodological (design principles) Artefact (app-descision tool)	Artefact (Inspirun e-coach app)
Reference	Janssen, M., Scheerder, J., Thibaut, E., Brombacher, A., & Vos, S. (2017). Who uses running apps and sports watches? Determinants and consumer profiles of event runners' usage of running-related smartphone applications and sports watches. PLoS ONE, 1–17.	Janssen, M., Walravens, R., Thibaut, E., Scheerder, J., Brombacher, A., & Vos, S. Understanding Different Types of Recreational Runners and How They Use Running-Related Technology. Int. J. Environ. Res. Public Health 2020, 17, 2276.	Menheere, D., Janssen, M., Funk, M., van der Spek, E., Lallemand, C. & Vos, S. Runner's Perceptions of Reasons to Quit Running: Influence of Gender, Age and Running-Related Characteristics. Int. J. Environ. Res. Public Health 2020, 17, 6046.	Deelen, I., Janssen, M., Vos, S., Kamphuis, C., & Ettema, D. F. (2019). Attractive running environments for all? A cross-sectional study on physical environmental characteristics and runners' motives and attitudes, in relation to the experience of the running environment. BMC Public Health, 19(366).	Janssen, M., Heuvel, R. van den, Megens, C., Levy, P., & Vos, S. (2018). Analysis of the Design and Engineering-Process towards a First Prototype in the Field of Sports and Vitality. Proceedings, 2(6), 297.	Dallinga, J., Janssen, M., van der Werf, J., Walravens. R., Vos, S., & Deutekom, M. (2018). Analysis of the Features Important for the Effectiveness of Physical Activity–Related Apps for Recreational Sports: Expert Panel Approach. JMIR Mhealth Uhealth, 6(6), e143.	Janssen, M., Lallemand, C., Hoes, K. & Vos, S. (2020). "Which app to choose? An online tool that supports the decision-making process of recreational runners to choose an app". Design4Health, Amsterdam, 2020.	Janssen, M., Goudsmit, J., Lauwerijssen, C., Brombacher, A., Lallemand, C. & Vos, S. How Do Runners Experience Personalization of Their Training Scheme: The Inspirun E-Coach? Sensors 2020, 20, 4590.

Figure 1.1. *Overview research questions and contributions*

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1

SECTION 1

WHAT ARE THE **MOTIVES AND BEHAVIOUR** OF RECREATIONAL RUNNERS?

2

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*Chapter is written in American English

WHO USES RUNNING-RELATED TECHNOLOGY

This chapter focuses on the characteristics of recreational runners participating in a recreational running event (half marathon). The runners are described in terms of socio-demographics, behavioural aspects, and AIOs. We analyse how these characteristics relate to the kind of technology (apps and sports watches) they use. Distinctive consumer profiles for app and sports watch users are created.

1. ABSTRACT

Individual and unorganized sports with a health-related focus, such as recreational running, have grown extensively in the last decade. Consistent with this development, there has been an exponential increase in the availability and use of electronic monitoring devices such as smartphone applications (apps) and sports watches. These electronic devices could provide support and monitoring for unorganized runners, who have no access to professional trainers and coaches. The purpose of this paper is to gain insight into the characteristics of event runners who use running-related apps and sports watches. This knowledge is useful from research, design, and marketing perspectives to adequately address unorganized runners' needs, and to support them in healthy and sustainable running through personalized technology.

Data used in this study are drawn from the standardized online Eindhoven Running Survey 2014 (ERS14). In total, 2,172 participants in the Half Marathon Eindhoven 2014 completed the questionnaire (a response rate of 40.0 %). Binary logistic regressions were used to analyze the impact of socio-demographic variables, running-related variables, and psychographic characteristics on the use of running-related apps and sports watches. Next, consumer profiles were identified.

The results indicate that the use of monitoring devices is affected by socio-demographics as well as sports-related and psychographic variables, and this relationship depends on the type of monitoring device. Therefore, distinctive consumer profiles have been developed to provide a tool for designers and manufacturers of electronic running-related devices to better target (unorganized) runners' needs through personalized and differentiated approaches.

Apps are more likely to be used by younger, less experienced and involved runners. Hence, apps have the potential to target this group of novice, less trained, and unorganized runners. In contrast, sports watches are more likely to be used by a different group of runners, older and more experienced runners with higher involvement.

Although apps and sports watches may potentially promote and stimulate sports participation, these electronic devices do require a more differentiated approach to target specific needs of runners. Considerable efforts in terms of personalization and tailoring have to be made to develop the full potential of these electronic devices as drivers for healthy and sustainable sports participation.

2. INTRODUCTION

This paper focuses on event runners' usage of running-related smartphone applications (apps) and sports watches. Running is one of the most popular forms of sports participation in Western Europe. Currently, in the EU-28, there are approximately 50 million running participants. This is almost 10% of the total EU-28 population [44]. In the US, approximately 42 million people (of a total population of 323 million citizens) partake in running [42]. The running boom is consistent with a more general development toward more recreational, unorganized, and lighter forms of sports [44,46]. Some of the interesting qualities of running are its health-related focus, imposes hardly any restrictions on age, requires no specific infrastructure, and can be practiced independently of time and place [6,17]. Running attracts diverse participants in terms of socio-demographic characteristics such as age, sex, and socio-economic status [25,63], but also in terms of motives (e.g., health, freedom, social experience, fun, and performance enhancement) [7,20] and experience (e.g. both novice and experienced runners).

Moreover, there has been a shift from running in private track and field clubs to large numbers of people running individually or in small groups. The 'new' carrier of the growing popularity of recreational and unorganized running are running events [25,44,63,66]

Given the large number of running participants and the rise in heterogeneity, certain challenges need to be tackled. Personalized guidance and support is losing ground, often resulting in drop-out due to injuries or demotivation [8,9,61]. Substantial guidance is necessary to maintain sensible and sustainable sports participation among novice and less experienced runners [62,64].

In line with the progression toward more unorganized running, in recent years, there has been an exponential increase in the availability and use of sports and physical activity-related monitoring devices [12,18,28,33,68]. According to the intended usage, the two different groups of monitoring devices in sports can be classified as: (i) sports watches/wearable devices, which are specifically designed for sports; and (ii) apps specifically designed for sports [64]. These apps turn a smartphone, which can be seen as a non-specific sporting good, into a sport-related good [33].

In 2015 in the US, 82% of the adult population (18–49 years of age) owned a smartphone, whereas 15% of this population owned an activity tracker [48]. An average American smartphone carries 22 downloaded apps, and 30% of them are sports-related (including both active participation and media sports) [35]. Roughly 20% of smartphone users utilize health-related apps [21], and about 3% of all available apps in the app stores are health-related apps capable of monitoring sports related physical activities. [3].

The increase in user-friendly, low-cost, mainstream technology related to sports is consistent with more general trends such as mHealth [19] (i.e., the use of mobile computing and communication technologies in health care and public health) and Quantified Self [51] (i.e., self-monitoring health outcomes). Indeed, sports and physical activity-related monitoring devices have the potential to contribute to a healthier lifestyle and can become an important driver of behavioral change towards a healthier lifestyle [22]. As such, these electronic devices could also play a role in supporting and monitoring the large group of unorganized runners, who lack professional training and coaching.

Knowing who uses these types of technology is relevant to adequately address (unorganized) runners' needs, and to support them in healthy and sustainable running through personalized technology. This study aims to gain insight into the characteristics of (event) runners who use apps and sports watches. The determinants of event runners' usage of apps and sports watches are identified following a heterodox-based approach [13,14,46,55] with the incorporation of socio-demographic variables, running-related variables, and psychographic characteristics.

The scope of this paper is on the actual usage of apps and sports watches. However, studies dealing with the usage of sporting goods are scarce [38]. Yet, literature on sports participation and expenditures on sports is widely available (for an overview see e.g. [39,56,69]). Within this literature, most empirical studies have focused on the determining factors of overall sports expenditures [30,31,57,69]. Only a small number of studies have analyzed specific sports expenditure categories [55]. As a consequence, little is known about which determinants influence expenditures on wearable sports monitoring devices. However, given the supposed direct relationship between expenditure on sporting goods and usage of sporting goods, an overview is provided of empirical findings of consumer segmentation to detect relevant variables related to sports expenditure and usage. These studies have different theoretical perspectives (for an overview, see [15]).

Several socio-demographic (and socio-economic) variables have been found to be useful in explaining sports consumption behavior. First, the relationship between sporting goods expenditure and age are divergent. In some studies, the youngest groups have been found to spend more [29], while others found that age has a positive or U-shaped relationship with sporting goods expenditure [36]. Lera-López and Rapún-Gárate [30,31] did not find any significant relationship between the two factors. Second, men spend more money on sports than do women [29,52]. Finally, income [1,16,69,71] and education [1,30,31] are found to be positively related to sports expenditure. Groups with lower education levels seem to spend less on sporting goods, while people with a higher level of education are more likely to spend more money on sports. The results presented above indicate that demographic variables such as gender, age, income, and education are useful in order to understand sports consumption behavior.

Ohl and Taks [38] have stated that sports consumption behavior also depends on underlying motivations, such as behavioral variables (see also [58]). Sports-related variables, such as the training frequency and complexity of participation, can be considered as behavioral characteristics [47]. For example, Wicker et al. [70] covered the complexity of participation by performance level, expenditure, intensity of training, time of practice, event participation, years of practice, and organizational context (individual, group, or club). Similar sports-related variables have been used in previous research on triathlons [4,10] as well as in research by Scheerder et al. [46], who argue that these behavioral characteristics seem to be better predictors of sports consumption than demographic variables.

This finding also applies to running. For example, McGehee et al. [32] found that frequency of running, event participation and expenditure on running-related products and services increased in individuals with high levels of running involvement. Moreover, Ogles and Masters [37] found that different types of marathon runners are distinguishable not only by their demographic characteristics but also by their behavioral variables. The abovementioned results indicate that behavioral characteristics are useful in understanding consumer behavior.

Next to socio-demographic variables and behavioral characteristics, psychographic variables (the consumer's state of mind) determine sports participation and expenditure. These variables provide information about the attitudes, interests, and opinions (AIO's) that steer consumer behavior [47,50]. Examples used in the literature are the consumer's personality, lifestyle, values, attitudes, beliefs, motivations, and needs [5,10,11,23,27,58,60,67]. Although previous research has demonstrated that AIO's contribute significantly to explaining sports consumption [46], they are less easily obtained compared to the abovementioned socio-demographic, socio-economic, and sports-related variables (i.e. behavioral characteristics). Applied to running, Ogles and Masters [37] found that psychographics can be used to characterize different clusters of runners. Various studies [37,41,66] used similar motives (e.g. health, personal goal achievement, social aspects of running, addiction, competition, and ease of practice) to cluster runners. Although the design of the studies of Ogles and Masters [37], Rohme et al. [41], and Vos et al. [66] are all different, they conclude that adding psychographic variables enriches running profiles.

3. METHOD

3.1. Data

The research conducted was in line with the ethical principles of the Declaration of Helsinki and the American Psychological Association [2]. The privacy of all participants was guaranteed, and all data was anonymized before analysis. The data used in this study were drawn from the Eindhoven Running Survey 2014 (ERS14). This standardized online questionnaire was developed to collect information among event runners. The questions were based on the Leuven Running Survey 2009 [43] and adapted to event runners. The questionnaire consisted of four sections: (i) the use and interest in running-related apps and sports watches; (ii) socio-demographic characteristics (such as age, gender, and level of education); (iii) running characteristics (such as training frequency, organizational context, main sports, and event participation); and (iv) psychographic characteristics (such as motives and attitudes toward running). For this paper, a sub-dataset was constructed containing only those runners that participated in the Half Marathon Eindhoven 2014 (21.1k). This distance was selected because of the heterogeneity of the participants, including both experienced and less experienced runners. Data were collected in October 2014. Participants agreed upon registration to be contacted for research or other purposes. All participants that finished the race received an email with an introductory letter (mail text) and a web link to the online questionnaire. The introduction letter informed them about the purpose of the study and the anonymization of the data. In total, 2,172 participants completed the questionnaire (a response rate of 40.0%). The average age of the respondents in the dataset was 41.5 years, ranging from 16 years to 76 years old. Thirty percent of the participants were women, and more than four out of five (86.2%) participants were employed. The socio-demographic backgrounds of the respondents were comparable to other running samples in previous large-scale running studies in Western Europe (for an overview of these studies, see [44]).

3.2. Measurements

3.2.1. Dependent variables

The dependent variables in this study included: (i) the use of apps (binary coded as 1 yes / 0 no); and (ii) the use of sports watches (binary coded as 1 yes / 0 no). Respondents were asked to fill in their usage of apps and sports watches (defined as using one or more running-related app(s) / sports watch(es) in the last twelve months).

The respondents were also asked to give details about the specific brand and model they used.

3.2.2. Independent variables

In line with previous studies on sports expenditures [46,55], a so-called heterodox economic approach was used. Heterodox economic theory assumes that behavior not only depends on the income and the price of the good, but that variables such as subjective feelings and social interactions are more important in explaining human behavior (such as sports consumption). In line with this approach, the set of independent variables included three groups of variables: (i) socio-demographic variables; (ii) running-related variables; and (iii) psychographic characteristics.

The socio-demographic characteristics included gender, age, and level of education. The group of running-related characteristics consisted of variables that are directly related to running and which define the level of running involvement: training frequency (number of runs per week); organizational context (individually, with friends, colleagues and/or running groups or clubs); event participation (total number of running events participated in during last 12 months); and the most practiced sports (running/other sports) were questioned. Table 2.1 gives the descriptive statistics of the sample for the dependent and independent variables. To complete the heterodox approach, psychographic characteristics were operationalized, and scales were constructed. Respondents were asked to what extent they agreed with 19 items on a five-point Likert scale (ranging from 1 (totally disagree) to 5 (totally agree)). These items were based on previous research [37,41,66] and included in the Principal Component Analysis (PCA) with orthogonal Varimax Rotation (EVA=55.0%). From this PCA analysis, the items were grouped into four psychographic components, namely (i) running as a sport that is easy to practice (e.g. I can practice running anytime, anywhere), (ii) perceived advantages of running (e.g. Running gives me energy or running is good for my health), (iii) individual motives for quitting (e.g. I would quit running if I get injured or if my spare time decreases), and (iv) social motives for quitting (e.g. I would quit running if my trainer stops or if my running friends stop). Cronbach's Alpha scores were calculated for each component, and 5 items were removed to increase Cronbach's Alpha scores, resulting in a total of 14 items used for further analysis. Table 2.2 gives an overview of these components (i.e. scales), including average score (ranging from 1 to 5), Cronbach's Alpha's, and the number of items.

Table 2.1. *Overview, measurements, and descriptive statistics of the dependent and independent variables*

Variable	Measurement	n	%
App use	Yes	1,091	54.90
	No	897	45.10
Sports watch use	Yes	1,177	60.50
	No	768	29.50
Gender	Male	1,500	77.40
	Female	437	22.60
Age	≤ 35 year	712	37.10
	36-45 year	526	27.40
	≥ 46 year	679	35.40
Education	Lower or middle education	604	31.10
	Higher education	1,341	68.90
Training frequency	≤ 1x/week	536	26.90
	2x/week	859	43.10
	≥ 3x/week	599	30.00
Organizational Context	Individual	1,129	57.60
	Friends, colleagues, small groups	440	22.50
	Clubs	390	19.90
Main sport	Main sport	1,496	75.10
	Not as a main sport	497	24.90
Event participation	1x/year	449	22.50
	2-4x/year	980	49.10
	≥5x/year	565	28.30

Table 2.2. *Overview and descriptive statistics of the psychographic characteristics*

Attitudes toward running	Items	Cronbach's alpha	n	Mean	Standard Deviation
Running as a sport that is easy to practice	3	0.822	1,951	4.23	0.674
Perceived advantages of running	4	0.856	1,950	4.03	0.475
Individual motives for quitting	4	0.704	1,947	3.11	0.790
Social motives for quitting	3	0.925	1,944	1.61	0.708

3.3. Data analysis

First, descriptive statistics were collected to provide an overview of (i) the sample structure and (ii) the use of apps and sports watches. Second, chi-squared tests ($p<0.05$ was considered significant) with post hoc testing (through z-scores and adjusted p-values (Bonferroni-method)) were conducted to examine differences in the usage of apps and sports watches by the selected socio-demographic and running-related variables. For the psychographic characteristics, mean scores with standard deviation were calculated. Third, binary logistic regression analyses (method=enter) determinants of the use of apps and sports watches were identified. The independent variables were divided into three blocks: (i) socio-demographic variables; (ii) running-related variables; and (iii) psychographic characteristics. For both apps and sports watches, three models were estimated: (i) model 1 consists of socio-demographic variables only; (ii) model 2 consists of both socio-demographic variables and running-related variables; and (iii) model 3 consists of socio-demographic variables, running-related variables, and psychographic characteristics. Nagelkerke R^2 was used as a measure of goodness of fit. Values between 0.10 and 0.20 were considered as satisfactory [26]. The different models were tested for multicollinearity, outliers, and leverage points. No problems with the data were found concerning these aspects. Finally, the results of the full models were used to develop consumer profiles for the use of apps and sports watches. This approach was in line with the approach developed by Scheerder et al. [46] to identify sports apparel consumer profiles.

4. RESULTS

Results show that more than 8 out of 10 (86.2%) runners (n=1,995) used at least one monitoring device over the past 12 months. More than half of the participants (54.9%) reported the use of apps, while 60.5% used a sports watch; approximately 1 out of 4 participants used both apps and a sports watch (27.0%). The brand specific analysis revealed that the most popular app among runners is Runkeeper (50.8%), followed by Runtastic (16.0%), and Nike+ Running (11.1%). Garmin was found to be the most popular brand among users of sports watches (43.9%), whereas Polar (27.4%), TomTom, and Nike (both 7.4%) are used less.

The results of the bivariate analyses are presented in Tables 2.3 and 2.4. Significant differences ($p<0.01$ or $p<0.001$) for the use of apps were found for gender, age, training frequency, organizational context, main sport, and event participation. No significant difference in the use of apps was found for education ($p=0.087$). For the usage of sports watches, significant differences ($p<0.001$) were found for the variables age, training frequency, organizational context, main sports, and event participation. Gender and education were not significantly different ($p=0.703$ and $p=0.272$) for sports watch usage.

Table 2.3. *Results of chi-squared test with post hoc testing for event runners' usage of apps and sports watches for the socio-demographic variables and running-related characteristics, in percentages.*

		Use of Apps		**Use of Sports Watches**	
		%	p-value	%	p-value
Gender	Male	53.5	<0.001	60.7	=0.703
	Female	62.5		59.7	
Age	≤ 35 year	66.1[a]	<0.001 [a-c, b-c]	51.9[a]	<0.001 [a-b, a-c]
	36-45 year	63.4[b]		62.6[b]	
	≥ 46 year	38.4[c]		67.9[c]	
Education	Lower or middle education	52.5	=0.087	62.4	=0.272
	Higher education	56.7		59.7	
Training frequency	≤ 1x/week	64.1[a]	<0.001[a-c, b-c]	39.0[a]	<0.001[a-b, a-c, b-c]
	2x/week	57.8[b]		61.2[b]	
	≥ 3x/week	42.5[c]		78.5[c]	
Organizational Context	Individual	60.6[a]	<0.001[a-c, b-c]	55.2[a]	<0.001 [a-c, b-c]
	Friends, colleagues, small groups	56.6[b]		58.4[b]	
	Clubs	35.5[c]		76.6[c]	
Main sport	Main sport	50.9	<0.001	64.8	<0.001
	Not as a main sport	66.7		47.2	
Event participation	1x/year	65.5[a]	<0.001 [a-b, a-c, b-c]	44.4[a]	<0.001 [a-b, a-c, b-c]
	2-4x/year	57.5[b]		58.7[b]	
	≥5x/year	41.8[c]		76.2[c]	

Table 2.4. *Overview of mean scores (and standard deviation) for event runners' usage of apps and sports watches for the psychographic variables.*

Attitudes toward running	Use of Apps	Use of Sports Watches
Running as a sport that is easy to practice	4.26 (0.644)	4.25 (0.666)
Perceived advantages of running	4.00 (0.462)	4.09 (0.465)
Individual motives for quitting	3.23 (0.800)	3.06 (0.787)
Social motives for quitting	1.63 (0.712)	1.59 (0.692)

4.1. Running-related apps

Table 2.5 presents the results of the three binary logistic regression models for the use of apps. Model 1 shows that the use of apps is determined by age. Runners aged 46 years or older were less likely (OR=0.313, $p<0.001$) to use apps than younger runners (≤ 35 years). No effect was found for gender and education. The second model (Model 2) included both socio-demographic variables and running-related variables. Results show that age remains a determinant variable to predict usage. Older runners (46 years or older) were less likely (OR= 0.424, $p<0.001$) than people in their twenties or thirties to use an app. Running characteristic also significantly contribute to the use of apps. Significant effects were found for organizational context, event participation, and running as a main sport. Runners who run in a club are less likely (OR=0.584, $p<0.001$) to use an app than individual runners. Also, runners who more frequently participate in events (2-4 times a year: OR=0.757, $p<0.05$ / ≥5 times a year: OR=0.545, $p<0.001$) are less likely to use apps than those who run only in a single event each year. The 'main sport' variable also determines the usage of apps. Runners who do not consider running as their main sport are more likely to use apps (OR=1.434, $p<0.001$) than those who consider running as their most important (or only) sport. The training frequency has no significant contribution to the usage of apps.

The full model (Model 3) shows that the three selected blocks of variables contribute to the explanation of the usage of apps. Age, organizational context, main sport, event participation, and individual motives for quitting running are associated with app usage. Runners aged 46 years or older were less likely (OR=0.449, $p<0.001$) to use apps than runners 35 years or younger. On the other hand, people whose main sport is not running are more likely (OR=1.402, $p<0.001$) to use apps. Club runners are less likely (OR=0.556, $p<0.001$) to use an app, as are runners who have participated in two or more events than those who run individually or participate in only one event per year. With regard to attitudes and motives toward running, runners who score higher on individual motives for quitting are more likely (OR=1.205, $p<0.001$) to use apps.

Table 2.5. *Results of the* ***binary logistic regression analysis*** *for event runners' usage of apps****,*** ***in odds ratios (****Exp (β)) with regards to the reference group (ref.)*

		Use of apps		
		Model 1	Model 2	Model 3
Constant		1.958***	2.522***	1.111
Gender	Male	Ref.	Ref.	Ref.
	Female	1.046	1.171	1.147
Age	≤ 35 year	Ref.	Ref.	Ref.
	36-45 year	0.908	1.090	1.123
	≥ 46 year	0.313***	0.424***	0.449***
Education	Lower or middle education	Ref.	Ref.	Ref.
	Higher education	0.964	0.884	0.860
Training frequency	≤ 1x/week		Ref.	Ref.
	2x/week		1.103	1.128
	≥ 3x/week		0.792	0.855
Organizational context	Individual		Ref.	Ref.
	Friends, colleagues, small groups		0.919	0.899
	Clubs		0.584***	0.556***
Main sport	Main sport		Ref.	Ref.
	Not as a main sport		1.434**	1.402*
Event participation	1x/year		Ref.	Ref.
	2-4x/year		0.757*	0.744*
	≥5x/year		0.545***	0.545***
Attitudes toward running	Running as a sport that is easy to practice			0.971
	Perceived advantages of running			1.071
	Individual motives for quitting			1.205**
	Social motives for quitting			1.050
Nagelkerke R^2		0.090	0.144	0.149

*=$p<0.05$; **= $p<0.01$; ***= $p<0.001$

Table 2.6. *Results of the* ***binary logistic regression analysis*** *for event runners' usage of sports watches****, in odds ratios (****Exp* (β)) *with regards to the reference group (ref.)*

		Use Sports Watches		
		Model 1	Model 2	Model 3
Constant		0.954	0.384***	0.133***
Gender	Male	Ref.	Ref.	Ref.
	Female	1.239	1.029	0.992
Age	≤ 35 year	Ref.	Ref.	Ref.
	36-45 year	1.593***	1.274	1.272
	≥ 46 year	1.125***	1.362*	1.365*
Education	Lower or middle education	Ref.	Ref.	Ref.
	Higher education	1.026	1.164	1.161
Training frequency	≤ 1x/week		Ref.	Ref.
	2x/week		1.868***	1.836***
	≥ 3x/week		3.745***	3.604***
Organizational context	Individual		Ref.	Ref.
	Friends, colleagues, small groups		1.021	1.067
	Clubs		1.538**	1.594**
Main sport	Main sport		Ref.	Ref.
	Not as a main sport		0.973	0.999
Event participation	1x/year		Ref.	Ref.
	2-4x/year		1.413**	1.368*
	≥5x/year		2.117***	2.005***
Attitudes toward running	Running as a sport that is easy to practice			0.987
	Perceived advantages of running			1.342*
	Individual motives for quitting			1.070
	Social motives for quitting			0.859
Nagelkerke R^2		0.029	0.154	0.161

*=p<0.05; **= p<0.01; ***= p<0.001

2

4.2. Sports watches

The results of the three binary logistic regression models for sports watches are shown in Table 6. Model 1 consists only of socio-demographic variables. Model 2 is a more extended model composed of socio-demographic variables and running-related variables. Model 3 is the most extended model, showing a heterodox set of variables: socio-demographic variables, running-related variables, and psychographic characteristics. In Model 1, in line with the results for the use of apps, only age has a significant contribution to the use of sports watches. However, in contrast with the use of apps, runners aged 46 years or older (OR=1.125, p<0.001) and runners between the ages of 36 and 45 years (OR=1.593, p<0.001) are more likely to use sports watches than event runners aged 35 years or younger. No significant effect was found between age and education.

In Model 2, age still determines the use of sports watches. Older runners (46 years or older) are more likely (OR=1.362, p<0.001) than people in their twenties or thirties to use an app. Regarding the running-related variables, the use of sports watches is related to organizational context, training frequency, and event participation. In contrast to the results found for the usage of apps, club runners are more likely (OR=1.538, p<0.001) to use sports watches than individual runners. In contrast to the usage of apps, event participation has a positive effect on the use of sports watches. Indeed, those who run two or more events a year are more likely to use sports watches than runners who partake in only one event a year (2-4 times a year: OR=1.413, p<0.01 / ≥5 times a year: OR=2.117, p<0.001). The training frequency also contributed to the usage of sports watches. Frequent runners (2 times or more a week) are more likely to use sports watches (2 times a week: OR=1.868, p<0.001 / ≥3 times a week: OR=3.745, p<0.001). While "main sport" is a determinant variable for the usage of apps, this variable does not contribute to the usage of sports watches.

In line with the results of the third binary regression model for the uses of apps, the three selected blocks of variables contribute to explain the usage of sports watches. The usage of sports watches is related to age, organizational context, event participation, training frequency, and perceived advantages of running. Runners aged 46 years or older are more likely (OR=1.365, p<0.05) to use sports watches than those aged 35 years or younger. The usage of sports watches is mainly determined by training frequency. Indeed, people who run twice a week (OR=1.836, p<0.001) and people who run three times or more a week (OR=3.604, p<0.001) are more likely to use a sports watch than those who run only once (or even less) per week. In contrast to the usage of apps, club runners (OR=1.594, p<0.01) and runners who participate in more than one event a year are more likely to use a sports watch (2-4 times a year:

OR=1.368, $p<0.05$ / ≥5 times a year: OR=2.005, $p<0.001$). Table 2.6 also reveals that runners who perceive advantages of running are more likely to use sports watches (OR=1.342, $p<0.05$).

4.3. Consumer profiles

On the basis of the results of the binary logistic regression models, it is possible to make estimations about the probability of the usage of apps and sports watches (see [46]). Table 2.7 shows, for example, that females aged 36- to 45-years-old, with lower or middle educational levels, running individually twice a week, with running not serving as their main sport, participating in a single event a year, and with a higher score on the psychographic variables “perceived advantages of runners”, “individual motives”, and “social motives for quitting” have a high (75%) probability of using an app. On the other hand, male runners, older than 46 years, with a higher education, who run 3 times or more a week in clubs, with running as their main sport, participation in 5 or more events a year, and have high scores on the psychographic variables “running as a sport that is easy to practice” and “perceived advantages of running” have a 10% probability of using an app. Some other examples of consumer profiles are listed in Table 2.7.

Table 2.7. *Probability of event runners' usage of apps and sports watches for different consumer profiles*

Socio-demographic			Running-Related				Psychographic				Probability	
Gender	Age	Education	Training frequency	Organizational Context	Main sport	Events	Ease practice	Perceived Advantage	Individual Quitting	Social Quitting	Usage of apps	Usage of sports watches
Male	46+ years	High	3x/w & more	Clubs	Yes	5x/y & more	High	High	Low	Low	0.10	0.76
Male	46+ years	High	3x/w & more	Clubs	Yes	5x/y & more	Low	High	High	Low	0.13	0.78
Male	46+ years	High	3x/w & more	Individual	Yes	2-4x/y	Low	High	High	Low	0.26	0.60
Male	36-45 years	High	2x/w	Small group	Yes	5x/y & more	High	High	Low	Low	0.38	0.51
Male	36-45 years	High	2x/w	Individual	Yes	2-4x/y	Low	High	High	Low	0.54	0.41
Female	36-45 years	High	1x/w & less	Small group	No	2-4x/y	Low	Low	High	High	0.59	0.21
Female	36-45 years	High	2x/w	Small group	No	2-4x/y	Low	Low	High	High	0.62	0.32
Male	36-45 years	High	2x/w	Individual	No	1x/y	High	High	Low	Low	0.64	0.32
Female	36-45 years	Low/mid	2x/w	Individual	No	1x/y	Low	High	High	High	0.75	0.28

5. DISCUSSION

The aim of this study was to gain insight into the characteristics of event runners who use apps and sports watches, and to identify the determinants factors of event runners' usage of apps and sports watches. Gaining insight into which runners use apps and sports watches is key to support runners in healthy and sustainable running (contributing to a decrease in drop-out rates in running) and to adequately address runners in their capacities as consumers. The literature showed that expenditures on wearable monitoring devices are rising in the sporting goods market. Monitoring devices have a considerable and growing share in the total expenditures on running [7,65]. The results in this paper confirm the use of monitoring devices in running; 86% of the participants in the selected half marathon had reportedly used at least one or two monitoring devices over the past 12 months. Results show that about 60% of the respondents use a sports watch. More than half of the respondents reported the use of apps (53.3%). When these results are combined, there is also a considerable group (27.0%) that use both apps and sports watches, while 14% of the event runners use no wearables at all. The brand-specific analysis reveals that the most popular app among runners is Runkeeper, followed by Runtastic and Nike+ Running. Statistics from different app stores are in line with these findings [3,21]. Garmin was found to be the most popular brand among users of sports watches, whereas Polar, TomTom, and Nike are used less.

The second purpose of this study was to identify the determining factors (i.e. socio-demographics, sports-related, and psychographic characteristics) of runners using these monitoring devices. From the findings of the bivariate analyses, significant results were found for gender, age, training frequency, organizational context, main sport, and event participation among app users. For sports watch users, significant differences were found for the variables age, training frequency, organizational context, main sport, and event participation.

Binary logistic regression analysis revealed that there was no consistent relationship between age and usage of apps or sports watches. Table 2.5 shows that the usage of apps is negatively related to age, which is, given the direct relationship between expenditure on sporting goods and usage of sporting goods, in line with findings from Lamb et al. [29]. Conversely, the usage of sports watches tends to be positively related to age, which is in line with the results of other studies [36,53]. These results indicate that the direction of the relationship between age and expenditure/usage of wearables depends on the type of monitoring device. Possible explanations can be found in smartphone usage in daily life. Younger adults are likely more often early adopters of new technologies [40], which can be a reason why older adults are less likely to use an app to monitor their running.

Male runners do not use monitoring devices more often than female runners. Results showed no significant differences in gender for both types of monitoring devices, while in other studies, gender is a determinant variable in sports expenditure [29,52]. A possible explanation can be found in the sample used in this study in which the distribution of male and female is skewed (resp. 77.4% and 22.6%).

No significant relationships were found between education and usage of monitoring devices. Other studies [1,30] find that groups with lower educational levels spend lower amounts of money on sporting goods, and on overall sports participation. However, the composition of the samples in these studies is different when compared to our study. For instance Lera-López and Rapún-Gárate [30] use a sample with sports participants in general, in contrast to our running specific sample. With regards to education, our sample was comparable to other running samples in previous large-scale running studies in Western Europe, being highly educated (for an overview of these studies, see [44]).

As observed in other studies [4,10,70], sports-related variables such as training frequency, organization context of running, running as a main sport, and event participation were used to indicate levels of involvement, which seems to be a determinant factor in expenditure on sporting goods. Results indicate that the variable "running as a main sport" has a significant effect on the usage of apps, but no relationships were found for sports watches. Runners for whom running is not their main sport are more likely to use apps. Training frequency and event participation are both positively related, while no significant relationship was found between the training frequency and app-usage, and significant negative relationships were found between app-usage and event participation. McGehee et al. [32] found that training frequency, event participation, and expenditure on running-related products and services increased in individuals with high levels of involvement. Additional results of the variables organizational context of running and running as a 'main sport' indicate that there are relationships between these variables and the probability to use monitoring devices, but the relationship depends on the type of device used. For instance, club runners are significantly more likely to use sports watches than individual runners, while club runners are less likely to use apps. A possible explanation can be the social influence in sports clubs. Previous studies have shown that social influence has a significant effect on consumption [24,49]. For example, the purchase of a sports watch by a fellow club member makes it more likely that another sports club member will purchase the same brand and model within a reasonable amount of time. Thus, the sports clubs and their members can often be seen as a more conservative and traditional sector [34]. Therefore, they are more likely to use a more traditional form of monitoring device, such as a sports watch.

The above results indicate that sports-related variables are predictors for the usage of monitoring devices [38,47,69]. It seems that beginners and less involved runners are more likely to use an app, while more experienced and higher involved runners are more likely to use a sports watch.

Psychographic variables (the consumer's state of mind) give information about AIO's guiding consumer behavior [47,50]. Examples used in research [5,10,11,23,27,59,60,67] are consumer's personality, lifestyle, values, attitudes, beliefs, motivations, and needs. These studies revealed a relation between psychographic variables and the amount of money and time that is spent on sports. In our study app-use is positively related to individual motives for quitting, which means that runners who score higher on this scale (i.e., more likely to stop running based on individual reasons) are more likely to use an app. This is in line with previous research [7], which found that runners who were more likely to quit running, are often novice runners who have less expenditure on sporting goods. Therefore, the use of an app would be more likely than a more expensive device such as a sports watch. One out of four motives contribute significantly to the probability to use a sports watch. In this case, the scale on perceived advantages of running is positively related.

Results indicate that socio-demographics, sport-related variables, and psychographic variables determine the use of apps and sports watches. This is in line with the findings of Ogles and Masters [37] and Scheerder et al. [46], who found that different types of runners were distinguishable not only by their demographic characteristics, but also by their behavioral and psychographic variables. Nevertheless, differences in the nature of the relationships between these variables are dependent on the type of monitoring device that is used.

Apps are more likely to be used by younger, less experienced and involved runners. Therefore, apps have the potential to target this group of novice and fragile runners, who run mostly individually without professional guidance, and are more likely to drop-out from running due to personal reasons. However, these apps require a more personalized and differentiated approaches to target these runners [64]. While more older and more experienced runners with higher involvement, are more likely to use sports watches. This group of runners are more likely involved in clubs with professional guidance. Therefore, they should be targeted differently than novice runners.

Like Scheerder et al. [46] did, the probability of using apps and sports watches for different consumer profiles was estimated on the basis of the results of the logistic regression models. We included all independent variables (both significant and not significant) to give designers and manufacturers of electronic running-related devices a complete view of all variables in these consumer profiles.

Some limitations and questions for further research can be highlighted. As stated in the literature review, income is sometimes found statistically positively related to the decision to take part in sports or not [54] and plays a significant role in the decision to spend money on sports and the amount of money that is spent. However, income was not included as a variable in this study. Next, this study does not allow for making empirically grounded statements for all runners. For this study, a sample of event runners was selected. This is an interesting target group because running events can be considered as a carrier of the growing popularity of recreational and unorganized running [45,63,66,70], although future research could consider different samples to fully reach all potentially different types of runners. In this sample, we only included runners of the half marathon (21.1k) because of the heterogeneity of the participants, including both experienced and less experienced runners. Thus, the results of this study are based on a Dutch sample. Furthermore, some methodological limitations concerning the dependent variables should be mentioned. First, we did not control for the intensity of the use of monitoring devices. Second, we did not consider the differences in the purchase price between apps and sports watches. As mentioned before, a smartphone is a non-specific sporting good that becomes a sporting good when a sports-related app is installed and used. Some app users may consider purchase of the smartphone, while others only count the download of the app. Moreover, the decision-making processes that lead to the use of monitoring devices were not included in this study. Challenges for future research concern further investigation of the popularity and reach of monitoring devices, the underlying motives to use either a sports watch or an app, and a broader focus on participants in 5-10k distance events and non-event runners. Future research should also consider replicating the study in different countries, because sports cultures and the consumption of sporting goods may vary.

6. CONCLUSIONS

In recent years, there has been an exponential increase in the availability and use of sports and health-related apps, activity trackers, and sports watches. The sporting goods industry has embraced technology in developing products that can motivate and coach people to become and remain active. The findings in this study provide a better understanding of runners' determinants of running-related apps and sports watch usage. From the results of the logistic regression models, it is possible to estimate the probability of using apps and sports watches for different runner profiles. The constructed consumer profiles provide a tool for designers and manufacturers of electronic running-related devices to better target runners through personalized and differentiated approaches. Segmentation considered socio-demographics, sports-related characteristics, and psychographic variables, which seem to have effectively differentiated between app users and sports watch users.

Apps are more likely to be used by younger, less experienced, and less involved unorganized runners. Hence, apps have the potential to target this group of novice and fragile runners. In contrast, sports watches are more likely to be used by a different group of runners, older and more experienced, organized runners with higher involvement. Although apps and sports watches may potentially promote and stimulate sports participation, these electronic devices do require a more differentiated approach to target specific needs of (unorganized) runners. Considerable efforts in terms of personalization and tailoring must be made to develop the full potential of these electronic devices as drivers for healthy and sustainable sports participation.

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DIFFERENT **TYPE** OF RUNNERS

In Chapter 2, we found that the use of apps and sports watches is affected by socio-demographic, sports-related behavioural, and psychographic characteristics, and that distinctive sets of characteristics relate to a specific type of monitoring device. In this chapter, we build on those findings and segment a heterogeneous group of runners (varying between 5k and 42.2k runners) into a typology of runners. This typology is constructed on the basis of motives and behaviours towards running. Eventually, four types of runners are created. For each of these running types, we provide insight into how they use running-related technology.

1. ABSTRACT

This study aims at helping professionals in the field of running and running-related (wearable) technology to address the needs of runners. It investigates the various runner types—in terms of their attitudes, interests, and opinions (AIOs) about running—and studies how they differ in the technology they use. Data used in this study are drawn from the standardized online Eindhoven Running Survey 2016 (ERS16). In total, 3723 participants completed the questionnaire. principal component analysis and cluster analysis were used to identify the different running types, crosstabs obtained insights into the use of technology between different typologies. Based on the runners AIOs four distinct runner types were identified: Casual Individual, Social Competitive, Individual Competitive, and Devoted Runners. Subsequently, we related these types to their use of technology. Our results showed a difference in the kinds of technology used by different runner types. The differentiation between type of runners can be used by health professionals, policy makers involved in public health, engineers, and trainer or coaches, to adapt their services to specific segments. In order to make use of the full potential of running-related systems to support runners to stay active, injury free and to contribute to a healthy lifestyle.

2. INTRODUCTION

Nowadays, public health is an important political goal for governments [10], since the number of people with lifestyle-related health problems has increased [24]. Fortunately being physically active contributes to a healthy life and decreases the risk of many chronic diseases [79]. Running is an example of an exercise activity that can contribute to a healthier life. Thereby, it is one of the most popular exercise activities in the world in terms of participation [59,62], and is practiced by a diverse and heterogeneous group of people [8,13,33,63]. The popularity of running, is related to the health-related benefits of running, (i.e. musculoskeletal and cardiovascular health, body composition, and psychological state) [23,30], but also other qualities like it hardly imposes any restrictions on age and it is easy to practice [7,20].

Unfortunately, running is also implicated in high drop-out rates due to running-related injuries and demotivation [9,21,25,29,35,40,45,75]. In line with these growing drop-out rates, in recent years, there has been an exponential increase in the availability and use of sports and physical activity-related monitoring devices such as mobile applications (apps), sports watches, and activity trackers, which claim to support runners [11,28,66,70]. This running-related technology has great potential, because it is affordable, accessible, has a large reach, and provide multi-function operation [17,48,80]. Although literature shows that technology is often not used for prolonged times; the user commitment is low [26,67,68]. Therefore, it is important to match the user's expectations toward technology and close the gap between runners expectations with technology and their actual experiences [16,33,77]. In order to understand the needs of runners effectively and adequately, AIOs of runners should be established and understood. Various researchers [52,58,81] already showed that AIOs are essential in understanding users. However, studies [11,42,56] exploring running-related technology have only focused on the relationship with demographic and running-related variables.

2.1. Running-related technology

Inspired by the Quantified Self movement, an increasing number of people are using technology to monitor themselves [4,50,71]. Pobiruchin et al. [56] showed that about 75% of runners used wearable technology for training optimization and distance recording, and provided insights into the large variety of wearable or smart technology that was used. A study by Janssen et al. [33] revealed that recreational runners differed significantly in what technology they used for their sport and that 60% used a sports watch, and more than half (53.3%) used dedicated apps. Clermont et al. [11] found that among runners, tracking personalized training data was the main reason for using technology, which suggested that the biggest motivators were instant feedback (rewarding you for achieving targets), and insight into achievements (e.g. distance covered, average speed). Not only the number of runners that use technology has increased, but also the development of running (and other sports) related systems has received significant attention in research. Although researchers face real challenges in using technological systems to prevent running injuries [34,82], there are several studies that focus on aspects to improve running technique and minimize injury [3,37,51,74]. Whereas, other researchers focus more on the role of running technology in relation to the social aspects of running [14,38,49,73], and the individual motivation of runners [6,39].

2.2. Different types of runners

Given the heterogeneity among runners, segmenting them into different groups in order to understand their AIOs is useful and appealing. Segmentation of consumers in sport has been documented extensively (e.g. [19,27,43,72]) with studies typically differentiating between consumers based on demographic factors. This traditional form of demographic segmentation has been used because researchers have applied the concept that gender and age could influence running preferences. The findings of Ogles and Masters [52] supported this notion, as age significantly differed among their groups. However, they also found that different types of marathon runners were distinguishable by not only their demographic characteristics, but also by their behavioural and psychographic variables. Other studies [22,58,78] have also used psychographic variables, including AIOs, to cluster runners.

Variables such as health, runner identity, personal goal achievement, the social aspects of running, running addiction, commitment, competition and ease of practice have been used to segment runners [22,33,54,55,58,64,78]. To better understand runners, for example, Parra-Camacho et al. [54,55] have segmented runners on commitment and reasons to partake in running. Rohm et al. [58] showed that the group they referred to as social competitors scored high on motives like competition and social reasons, while Vos et al. [78] found two groups of social runners: one group that scored highly on both social and competition motives, and a group they called 'Companion Runners', who scored highly on social motives and low on competition. A study by Forsberg [22] showed that runners with less running experience (≤ three years) focused more on AIOs related to health, whereas more experienced runners (≥ eight years) were more likely to run for 'the love of running' or for social reasons. Finally, all above mentioned studies [22,33,52,58,78] stressed the importance of AIOs in gaining valuable insights into the needs and requirements of runners. These AIOs provide an effective basis for the segmentation of runners and the creation of runner typologies.

2.3. Aim of the study

So, studies have found that running-related technology is widely used and gets significant attention in research. However, running-related technology has been using a 'one-size-fits-all' principle, and does not account for the motives, drivers or AIOs of a runner [16,33,76]. These insights suggest a need for a more differentiated approach that targets the distinct needs of specific runner types [17,33].

Several studies showed [22,33,52,58,78] that AIOs are important and able to give valuable insights into runners behaviour, to the best of our knowledge, no existing studies provide insights into the usage of running-related technology in relation to runner AIOs. This study is a follow-up study of previous research (Janssen et al. [33]) which gave a first insight into the characteristics of runners who use apps and sports watches and proposed an approach to estimate the probability that runners use running apps or sports watches. With the present study we create more in-depth insight into AIOs of runners. This study aims (i) to investigate how AIOs towards running combine into distinct runner profiles, and (ii) to unveil similarities and differences between these runner profiles in the use of running-related technology.

3. MATERIALS AND METHODS

3.1. Study design and respondents

In this study, an online questionnaire — the Eindhoven Running Survey 2016 (ERS16), see Appendix for the questionnaire — was used to collect data among participants of the Eindhoven Marathon running event. This event consisted of four different running distances (42.2 k, 21.1 k, 10 k, and 5 k). Survey questions were derived from a standardized questionnaire used in previous editions of this even (ERS2014 [33] and ERS2015 [18]).

After completion of the event, all registered participants (N = 18,261) received an email with an introductory letter and a web link to the online questionnaire. All participants agreed to be contacted for research purposes after registration. The introductory letter gave them information on the purpose of the study, allowed them to give informed consent, and guaranteed that their data would be processed anonymously. The research conducted was in line with the ethical principles of the Declaration of Helsinki and the American Psychological Association [2]. The privacy of all participants was guaranteed, and all data were anonymized before analysis. The Research Board of the Fontys School of Sport Studies was consulted prior to the initiation of this study, and approval for the study design was obtained.

A total of 3,727 participants fully completed the questionnaire (response rate of 20.4%), out of which 0.7% had participated in the Marathon, 54.4% in the half marathon, 16.5% in the 10k run, and 8.3% in the 5k. The average age of the respondents was 42.2 years, and their ages ranged between 18 years and 81 years old. Approximately one-third of the participants were women (33.4%), approximately nine out of ten participants were employed (89.9%), and 71.6% had received a higher education. The socio-demographic characteristics of the respondents were comparable to samples used in prior large-scale running studies conducted in western Europe [18,33,62].

3.2. Questionnaire

The online questionnaire had three sections covering (i) AIOs on running, (ii) the use of running-associated technology, and (iii) socio-demographics and running habits. The first section of the questionnaire, containing 25 questions on running AIOs, were adopted from previous studies [33,52,58,78]. We asked the respondents the extent to which they agreed with the items, using a five-point Likert scale (ranging from 1 'totally disagree' to 5 'totally agree'). Items included assertions such as 'I can practice running anytime', 'running gives me energy', and 'I am proud to be a runner'. There were also items such as 'I would quit running if I got injured', and 'I would quit running if my trainer quits'. The present study included two additional items relating to competitiveness— 'running is a competitive sport', and 'running is a performance sport'—since we also wanted to gain insight into possible AIOs toward competitiveness in running. This section included a total of 27 scored items.

The second section of the questionnaire provided insights into the use of wearable technology by runners. First, they were asked whether they used technology while running, and if so, what they used most frequently (no use / use of app / use of sports watch). Then, the questionnaire progressed to items specific for non-users, app-users, or sports watch-users. Questions including, 'which data do you monitor while running (distance, time, speed, heart rate, other)', and 'what do you do with the monitored data (nothing, to review the session after a run, to monitor data over time, or to use the data to adapt future training)'. For non-users, the reasons for not using technology ('running with phone / watch is ignorant, too complex, no added value, no need to, does not fit my running-needs') were asked, with the responses recorded using the Likert scale.

The third and final section of the questionnaire covered socio-demographic characteristics — including gender (male / female), age, professional status (student / employed full / employed part / unemployed), and level of education (lower & middle / higher). The aspects that were covered regarding running habits included: the distance that was run (5 k, 10 k, 21.1 k, 42.2 k), most practiced sport (running / other sport), years of running experience (running < 1 year (novice runners) / 1–5 years (moderately experienced runners) / > 5 years (experienced runners), running distance (average distance per running session), running frequency (number of runs per week), event participation (number of running events participated in over the last year) and, running context (individual, with friends, colleagues and / or running groups, or clubs).

3.3. Analysis

3.3.1. Typology construction

To construct the typology, a sequence of analyses was performed (with all analyses conducted using SPSS 25.0). First, to reduce the 27 AIO items to components, a principal component analysis (PCA) with orthogonal Varimax Rotation was executed. In a PCA, one of the most commonly used criteria for solving the number of components aspect is the eigenvalue-one criterion [12,31]. We applied this approach, by including all components with an eigenvalue > 1.00. Thereby, the components were assessed on the content of the included items. Second, a reliability analysis was executed for all components, with Cronbach α scores > 0.700 considered acceptable, thereby all items were assessed and reconsidered if they substantively contributed to the component. Then, the average scores for the reliable items per component were calculated, resulting in average component scores. Finally, in order to create the typology, a K-means cluster analysis was performed using the constructed components.

The K-means cluster analysis technique was chosen because the data involved a high number of cases [65], and since it was the optimal method considering both within-cluster homogeneity and between-cluster heterogeneity [36]. This type of cluster analysis has been applied in previous segmentation studies [1,5,44,53,58]. Solutions between two to six clusters were checked and assessed on the basis of variability, heterogeneity, and distribution. Crosstabs, including chi-square with Bonferroni corrections, were used to check whether the clusters on the components were significantly different from each other.

3.3.2. Crosstabs

In order to obtain insights into the use of technology (including what data was monitored and use of monitored data) between different typologies, crosstabs, including chi-square tests with Bonferroni corrections, were used.

4. RESULTS

4.1. Runner profiles

4.1.1. Principal Component Analysis

The PCA (Eigenvalue > 1.00) resulted in six components, accounting for 61.73% of the variance. Five items scored PCA coefficients < 0.30 and also loaded on multiple components. Based on these PCA coefficients and item content, we decided that none of these five items suited any of the six components. Therefore, these five items were removed, the remaining 22 items were included in the next analysis. The six components, and some examples of the included items in them, are presented below:

- Perceived advantages of running (e.g., 'running gives me energy', or 'running is good for my health');
- Social motives for quitting (e.g., I would quit running 'if my trainer quit' or 'if my running friends quit');
- Identification with running (e.g., 'I am proud to be a runner', or 'I feel myself to be a real runner');
- Running is a sport that is easy to practice (e.g., 'I can practice running anytime, anywhere');
- Individual motives for quitting (e.g., I would quit running if 'I got injured', or if 'my spare time was decreased'); and
- Competitiveness in running (e.g. 'running is a competitive sport', or 'running is a performance sport').

The reliability analysis revealed that these six components scored Cronbach α values ranging from 0.697—0.935. One item of component 2 was removed, based on the content of that item (Cronbach α range then increased from 0.848—0.935). Component 6 consisted of just two items, as we only added two items on competitiveness to the existing questionnaire. Table 3.1 shows the six components, including their numbers of items, Cronbach α values, average scores, and standard deviations.

Table 3.1. *Components including the number of items, Cronbach α, average scores and standard deviations.*

Component	Attitudes toward running	Items	Cronbach α	N	Mean	SD
1	Perceived advantages of running	4	0.805	3666	4.35	0.479
2	Social motives for quitting	3	0.935	3700	1,65	0.731
3	Identification with running	5	0.787	3364	3.54	0.651
4	Running as a sport that is easy to practice	3	0.775	3709	4.24	0.625
5	Individual motives for quitting	4	0.716	3365	3.18	0.766
6	Competitiveness in running	2	0.697	3708	3.55	0.738

Table 3.2. *Mean scores with a standard deviation per type of runner, for all six components. Comparisons between types of runners via chi-square with Bonferroni-adjustment.*

Attitudes towards running	**Type I (N=886)**	**Type II (N=1008)**	**Type III (N=1012)**	**Type IV (N=821)**
Perceived advantages of running	4.12 (.48)*	4.18 (.41)*	4.64 (.39)**	4.43 (.44)**
Social motives for quitting	1.46 (.55)**	2.50 (.58)**	1.26 (.43)*	1.34 (.47)*
Identification with running	2.88 (.52)**	3.54 (.50)**	3.98 (.52)**	3.70 (.50)**
Running as a sport that is easy to practice	4.16 (.63)*	3.96 (.62)**	4.53 (.51)**	4.26 (.58)*
Individual motives for quitting	3.76 (.48)**	3.48 (.52)**	2.90 (.75)**	2.49 (.57)**
Competitiveness in running	3.12 (.64)**	3.70 (.51)**	4.25 (.45)**	2.98 (.54)**

** $p < 0.001$; * $p < 0.01$

4.1.2. Cluster analysis

K-means solutions for between two and six clusters were assessed. Clustering the dataset in four clusters proved to be the most suitable solution considering variability, heterogeneity, and runner distribution across the clusters. Solutions with two or three groups did not account for the heterogeneity of the runners over the clusters, while clustering in five or six groups resulted in highly unequal group distribution, including two very small groups, for which $N < 25$.

The results of the analysis show 886 Type I runners (23.8%), 1008 Type II runners (27.0%), 1012 Type III runners (27.2%), and 821 Type IV runners (22.0%). In Table 3.2, the results of the chi-square tests (with Bonferroni corrections) show that all four types differ significantly across all six components.

4.2. Characteristics of the typology

Based on their AIOs towards running, four types of runners were identified: (i) Casual Individual Runners (Type I), (ii) Social Competitive Runners (Type II), (iii) Individual Competitive Runners (Type III), and (iv) Devoted Runners (Type IV).

4.2.1. Type I—Casual Individual Runners

Compared to other types, Type I runners identified with running the least and were the most susceptible to quitting the sport for individual motives—and thus, they also scored low on competitiveness. Type I runners were classified as 'Casual Individual Runners', and the socio-demographics showed that this group consisted of relatively more females, runners < 35 years of age, higher educated runners, and students, compared with the other runner types. Considering the habits of the runners, analysis showed that this group comprised of relatively more 5 k and 10 k runners, more runners for whom running was not their main sport, more inexperienced runners, and more runners who trained less frequently, participated in fewer events than others, and ran more individually, compared to other runner types.

4.2.2. Type II—Social Competitive Runners

Type II runners were characterized as runners who were competitive and were the most susceptible to quitting in general, especially for social reasons. We referred to them as 'Social Competitive Runners', and this was not a group that stood out (scoring highest or lowest of all types), in terms of socio-demographics. Analysis on their running habits showed that the Type II runner group included relatively more 5 k and 10 k runners (as was noted for Type I, Casual Individual Runners). The Social Competitive Runners group scored relatively higher (compared to Individual Competitive Runners and Devoted Runners) for items such as runners for whom running was not their main sport, less experienced runners, runners who trained less frequently and who participated in fewer events than others, while Casual Individual Runners scored even higher on these items. On running context, Social Competitive Runners scored lowest of all on running individually, while showing the highest scores for running with friends, colleagues, small groups, and clubs.

4.2.3. Type III—Individual Competitive Runners

Type III runners were classified as 'Individual Competitive Runners' and were characterized by their competitiveness, and by the fact that they were not so susceptible to quitting (either as individuals or socially). In contrast to the previous group, they scored well on aspects such as the perceived advantages of running, and identification with running. The distribution of gender within this group differed the most, compared to other groups, with the highest proportion of male runners out of all four types. The group also had the most, lower and middle educated participants and the lowest numbers of students. With regard to running habits, Individual Competitive Runners scored high numbers for running as the main sport, long training distances, frequent training sessions, and participating in five or more events annually. While these running habits did not differ from Devoted Runners, Individual Competitive Runners ran more individually than either Devoted Runners or Social Competitive Runners.

4.2.4. Type IV—Devoted Runners

Similar to Type III runners, Type IVs scored highly on the perceived advantages of running and identification with running and had low susceptibility to quitting (either as individuals or socially) but were not as competitive as other types. We, therefore, named them as 'Devoted Runners', and they included the most runners older than 45, the most runners with low or middle education, and the most runners in part-time employment. This group scored highly on running as the main sport, long training distances, frequent training sessions, and five or more annual event participations similarly, to Type III Individual Competitive Runners. Devoted Runners are the most experienced runners, and—together with Social Competitive Runners—scored the highest numbers of club runners. Some background characteristics applicable to the running groups have been listed in Table 3.3.

Table 3.3. *Different independent variables related to the type of runners in percentages, tested with chi-square and Bonferroni-adjustment between type of runners.*

Variable	Measurement	Type of Runner				Mean
		Casual Individual Runner	**Social Competitive Runner**	**Individual Competitive Runner**	**Devoted Runner**	
Gender	Male	64.5 a	66.2 a,b	71.3 b	63.3 a	66.8
	Female	35.5 a	33.8 a,b	28.7 b	36.7 a	33.2
Age	≤ 35 year	38.6 a	29.7 b	24.0 c	15.3 d	27.1
	36-45 year	33.5 a	30.3 a	34.5 a	30.0 a	31.9
	≥ 46 year	27.0 a	40.0 b	41.5 b	54.7 c	41.0
Education	Lower or middle education	20.6 a	29.9 b	31.4 b	31.3 b	28.6
	Higher education	37.5 a	42.6 a	38.1 a	42.1 a	39.9
	University	41.9 a	27.5 b	30.6 b	26.6 b	31.5
Employment	Student	7.7 a	7.2 a	4.0 b	2.7 b	5.4
	Fulltime employed	73.5 a,b	69.4 b,c	77.1 a	67.0 c	71.8
	Parttime employed	16.1 a	18.5 a	14.1 a	23.8 b	18.0
	Unemployed	2.6 a	4.9 a,b	4.8 a,b	6.6 b	4.7
Distance Event	5k	13.2 a	11.0 a	3.7 b	5.1 b	7.9
	10k	19.7 a	17.3 a	13.1 b	16.0 a,b	16.2
	21.1k	50.9 a	55.8 a,b	58.0 b	52.8 a,b	55.1
	42.2k	16.1 a	15.9 a	25.2 b	26.1 b	20.9
Main sport	Running	50.9 a	72.4 b	82.8 c	85.6 c	73.5
	Other sport	49.1 a	27.6 b	17.2 c	14.4 c	26.5

Table 3.3. *Continued.*

Variable	Measurement	Type of Runner				Mean
		Casual Individual Runner	Social Competitive Runner	Individual Competitive Runner	Devoted Runner	
Experience	< 1 years	22.9 a	16.7 b	10.1 c	6.2 d	13.7
	1-5 years	44.3 a	40.9 a	40.9 a	34.7 b	40.5
	> 5 years	32.8 a	42.5 b	49.0 c	59.1 d	45.8
Training Distance	≤5k/ session	14.2 a	11.5 a	3.3 b	3.4 b	7.9
	6-10k/ session	48.3 a	42.0 b	33.8 c	35.4 c	39.6
	11-15k/ session	32.5 a	37.4 a	47.8 b	48.6 b	41.8
	≥16k/ session	5.0 a	9.1 b	15.1 c	12.6 c	10.7
Training frequency	≤ 1x/week	45.6 a	29.6 b	18.0 c	14.7 c	26.5
	2x/week	38.3 a	41.5 a	36.2 a	40.2 a	39.1
	≥ 3x/week	16.1 a	28.9 b	45.8 c	45.0 c	34.4
Event participation	1x/year	40.8 a	25.6 b	17.1 c	19.2 c	24.9
	2-4x/year	45.8 a	48.3 a	43.8 a	45.0 a	45.6
	≥5x/year	13.4 a	26.1 b	39.1 c	35.8 c	29.6
Running context	Individual	74.4 a	44.6 b	61.9 c	54.6 d	58.8
	Friends, colleagues, small groups	20.1 a	32.1 b	20.6 a	23.0 a	23.4
	Clubs	5.5 a	23.3 b	17.5 c	22.4 b	17.8

Chi-square with Bonferroni-adjustment, each subscript letter denotes a subset who do not differ significantly from each other at the .05 level

Table 3.4. *Usage of technology related to type of runners in percentages, tested with chi-square and Bonferroni-adjustment between type of runners.*

Variable	Measurement	Casual Individual Runner	Social Competitive Runner	Individual Competitive Runner	Devoted Runner	Mean
Technology usage	No use	14.1 a	15.5 a	6.7 b	12.2 a	12.1
	Use of app	41.1 a	26.7 b	25.3 b,c	20.7 c	28.4
	Use of Sports watch	44.8 a	57.8 b	68.0 c	67.1 c	59.5

Chi-square with Bonferroni-adjustment, each subscript letter denotes a subset who do not differ significantly from each other at the .05 level.

4.3. Use of apps and sports watches

Descriptive analysis revealed that, of the 3,727 runners, six out of ten used a sports watch (59.5%) and almost one third used an app (28.4%), with the remainder (12.1%) using neither. Next, data monitored and what runners do with the data were analyzed for app-users (n=1058), sports watch-users (n = 2218) and non-users (n = 451).

Almost all app-user monitor distance (98.2%,), time (96.6%) and speed (94.2%). A minority monitors heart rate (9.1%) or other parameters such as cadence or Kcal (5.4%). Eighty percent of the app-users (80.3%) use the data to review the session afterwards. Approximately 60% of all app-users (56.9%) also monitor data over time. One in ten app-users (11.7%), actually use the data to adapt their training, and 6.4% of the app-user do nothing with the monitored data.

Among the sports watch-users a similar tendency is shown, also most of the users monitor distance (96.0%), time (90.0%) and speed (85.5), and a small group of sports watch-users monitor other parameters (8.8%). For heart rate monitoring, however, there are differences between sports watch-users and app-users: seven out of ten sports watch-users (68.2%) monitor their heart rate. Again, a minority of sports watch-users (5.7%) indicate that they do not do anything with the monitored data. Almost 80% use the data to view the session afterwards (77.3%), 56.6% use the data to monitor overtime and 22.3% use the monitored data to adjust their workout.

For the group that did not use technology, the reasons not to use technology were asked. The four main reasons provided for not using technology while running were: (i) 'running with phone / watch is ignorant' (33.8% of the non-users), (ii) 'using technology has no benefit' (40.2%), (iii) 'there is no need to' (37.4%), and (iv) 'using technology does not fit my running needs' (24.1%).

4.4. Use of apps and sports watches in relation to the different type of runners

Crosstabs, including chi-square with Bonferroni correction, provided an insight into the differences in technology used by different types of runners (Table 3.4). The results revealed significant technology usage variations (only significant effects have been described). In relative terms, Casual Individual Runners were the keenest app-users (41.1%) and the smallest group of sports watch-users (44.8%), while the Social Competitive Runners included fewer app-users (26.7%) than the Casual Individual Runners (41.1%), approximately the same amount as the Individual Competitive Runners (25.3%) and more than the Devoted Runners (20.7%). Social Competitive Runners included more sports watch-users than the Casual Individual Runner group

(57.8% vs 44.8%), and less than either Individual Competitive Runners (68.0%) or Devoted Runners (67.1%). The lowest contribution of non-users (6.7%) was found among the Individual Competitive Runners, compared to the other types (12.2%, 14.1% and 15.5%), while they, and the Devoted Runners, had the highest uptake of sports watches (68.0% and 67.1%, respectively). Finally, the Devoted Runners group had the lowest number of app-users (20.7%), and in combination with the Individual Competitive Runners possessed the highest contribution of sports watch-users.

Table 3.5 gives insight in the comparison between the type of runner and the data they monitored with an app and what they do with this data. Among app-users, significant differences were found in the data they monitored, such as cadence and energy use (Kcal). Devoted Runners monitored ‘other data’ more than Casual Individual Runners (9.4% vs 3.0%). In terms of data usage, a difference was seen in the of use of monitoring data over time, as less Casual Individual Runners (53.6%) and Social Competitive Runners (54.3%) monitored their data over time, compared to Individual Competitive Runners (65.6%). No differences were found in relation to the other monitoring data items of ‘to review the session after a run’ or ‘used to adapt training’ in terms of monitoring distance, speed, and heart rate - there are significant differences between types of runners (table 3.6). For monitoring distance (92.3%) and speed (91.0%) Individual Competitive Runners scored the highest. Although both the Devoted (91.3% and 88.4%) and the Social Competitive Runners (88.0% and 87.3%) also make extensive use of this data for monitoring heart rate, the Social Competitive Runner scored lower than Individual Competitive Runners (65.2% vs 72.1%), with the Casual Individual Runner recording 68.8%. Looking into data usage, more differences were found. On ‘doing nothing with the data’ ($p = 0.059$), both Individual Competitive Runners (4.2%) and Devoted Runners (4.9%) scored lower than both Casual Individual Runners (6.8%) and Social Competitive Runners (7.4%). On both ‘monitoring data over time’ and ‘using the data to adapt training’, Individual Competitive Runners (65.3% and 29.7%, respectively) scored significantly higher than all other types (others all < 54.2% and < 22.0%, respectively). No differences were found in the data item ‘to review the session after a run’.

Regarding the four main reasons provided for not using technology, two showed significant differences between two types of runners. Among the Social Competitive Runners, the reason that ‘technology has no added value’ scored lower than it did for Devoted Runner (32.1% versus 51.5%), and the same applied to the reason that it ‘does not fit my running-needs’, where Social Competitive Runners scored 17.3% as opposed to 32% for Devoted Runners (see table 3.7).

Table 3.5. *App-users related to type of runners in percentages, tested with chi-square and Bonferroni-adjustment between type of runners.*

Variable	**Measurement**	**Casual Individual Runner**	**Social Competitive Runner**	**Individual Competitive Runner**	**Devoted Runner**	**Average**
What do you monitor?	Distance	98.9	98.5	98.4	95.9	98.2
	Time	97.8	97.0	96.5	93.5	96.6
	Speed	95.1	93.7	95.7	91.2	94.2
	Heart rate	9.9	10.0	7.0	8.8	9.1
	Other (like cadence, Kcal)	3.0 a	5.6 a,b	5.9 a,b	9.4 b	5.4
What do you do with the data?	Nothing	7.1	6.7	4.7	7.1	6.4
	To review the session after the run	81.0	79.9	82.0	76.5	80.3
	Monitoring data overtime	53.6 a	54.3 a	65.6 b	55.3 a,b	56.9
	Use data to adapt training	9.6	10.0	14.8	14.1	11.7

Chi-square with Bonferroni-adjustment, each subscript letter denotes a subset who do not differ significantly from each other at the .05 level.

3

Table 3.6. *Sports watch-users related to type of runners in percentages, tested with chi-square and Bonferroni-adjustment between type of runners.*

Variable	Measurement	Casual Individual Runner	Social Competitive Runner	Individual Competitive Runner	Devoted Runner	Average
What do you monitor?	Distance	87.4 a	88.0 a,b	92.3 b	91.3 a,b	90.0
	Time	96.5	95.2	96.2	96.4	96.0
	Speed[1]	85.9 a	87.3 a,b	91.0 b	88.4 a,b	85.5
	Heart rate	68.8 a,b	65.2 b	72.1 a	66.1 a,b	68.2
	Other (like cadence, Kcal)	8.6	6.7	10.6	8.9	8.8
What do you do with the data?	Nothing[2]	6.8 a	7.4 a	4.2 b	4.9 b	5.7
	To review the session after the run	77.1	78.2	75.7	78.6	77.3
	Monitoring data overtime	54.2 a	52.0 a	65.3 b	52.1 a	56.6
	Use data to adapt training***	20.4 a,b	15.1 b	9.7 c	22.0 a	22.3

Chi-square with Bonferroni-adjustment, each subscript letter denotes a subset who do not differ significantly from each other at the .05 level. [1]p=.051, [2]p=.059

Table 3.7. *No-users related to the type of runners in percentages, tested with chi-square and Bonferroni-adjustment between type of runners.*

Variable	Measurement	Casual Individual Runner	Social Competitive Runner	Individual Competitive Runner	Devoted Runner	Average
Reasons for not using technology	Running with phone/watch is ignorant	32.8	32.1	37.7	35.0	33.8
	No added value	45.6 a,b	32.1 b	32.4 a,b	51.5 a	40.2
	No need to	36.8	33.3	42.6	41.0	37.4
	Does not fit my running-needs	28.0 a,b	17.3 b	20.6 a,b	32.0 a	24.1

Chi-square with Bonferroni-adjustment, each subscript letter denotes a subset who do not differ significantly from each other at the .05 level

5. DISCUSSION

Running is one of the most popular exercise activities in the world [59,62], and is known for its many health benefits [23,30]. While on the other hand, running is also implicated in high drop-out rates due to running-related injuries and demotivation [9,21,25,29,35,45,75]. Running-related technology has great potential, to support runners in their exercise activities [48,80] and provide guidance in running injury-free and to keep motivated. Yet, literature shows that technology is often not used for prolonged times [26,67,68]. In order to make better use of the potential of running-related technology to support runners, more understanding of runners is necessary. Therefore, we constructed a typology of runners, based on their stated running AIOs, and analysed if the various types of runner, differed in the running-related technology they used.

Based on a sequence of statistics, four runner types were identified. The clusters met the criteria for relevant and valuable segments as stated by Kotler et al. [41]. They were measurable in terms of number of runners per segment, had significant volumes, and were differentiable, since they differed substantially from each other.

The constructed typology showed similarities with previous research. For example, Parra-Camacho et al. [55] segmented runners on reasons to partake in running. Their so called ‘individual hedonists’ are show similarities with both our Casual Individual Runners and Individual Competitive Runners, given the fact that all experiences running as an individual activity. Although we found two different individual types of runners. Which differ in how competitive they are and how strongly they identify themselves as runners.

In other research, our ‘Devoted Runners’ were comparable to those known as ‘devotees’, by Rohm et al. [58], ‘running enthusiasts’, by Ogles and Masters [52], and ‘enthusiast by Parra-Camacho et al. [55], and consisted of runners who identified strongly with running, and who were experienced, long-distance runners. Our ‘Individual Competitive Runners’ showed some similarities with both the ‘personal goal achievers’ and ‘personal accomplishers’, of [52], and with the ‘individual runner’ in Vos et al. [78]—although our type seemed to be more competitive, as opposed to the more health-focused types of Ogles & Masters (2013) and Vos et al. (2014).

The runner type that Rohm et al. [58] called ‘social competitors’—who were runners who scored highly on motives such as competition and social reasons—and the ‘competitive achievers’ from Ogles and Masters [52], were comparable to our ‘Social Competitive Runners’. These runners were characterized by AIOs related to competitiveness and social motives.

In contrast to Vos et al. [78], who found two groups of social runners, one group scoring high and one group scoring low on competition, we only found one group of social runners—this outcome could be due to the differences in the sample, as Vos et al. [78] investigated a women-only event. They argued that due to the more homogeneous nature of their sample, other types of runners were found.

Finally, our 'Casual Individual Runner', who was characterized by low identification with running, and for who running was not their main sport, had no equivalent in previous literature. To support the real existence of this runner type, we argue that, due to the evolution of running, and to running events being more and more accessible, people for whom running is not their main sport, or who do not identify themselves as runners, are attracted to participate in running events (whether more than once or not).

In conclusion, we managed to segment a heterogeneous group of runners into four smaller, homogeneous groups, thereby providing valuable with insights into the AIOs of the different groups in order to differentiate between runners and focus on the potential interests of types.

5.1. Use of running-related technology among runners

Research showed that technological devices are popular among runners [11,33,56]. This holds true for the current study, as 87.9% of the participants used a technological device—either an app or a sports watch—although we found a lower number of app-users among runners (28.4% in the current study, as opposed to > 50% in other studies), compared to both Clermont et al. [11] and Janssen et al. [33]. We argue that this lower number was due to the differences in the sample and the types of questions asked. As we included a broader range of runners, from beginners to very experienced, and from 5 k to full marathon runners. Our questionnaire also required respondents to identify their most frequently used technological device, whereas in Clermont et al. [11] and Janssen et al. [33], runners could choose multiple answers—giving respondents the option of answering that both a sports watch and an app were used (e.g. Garmin sports watch with compatible Garmin Connect app). This probably increased the number of answers of an app being used, whereas in the present study, the runners would be classified by their first choice, and be identified, in this example, as sports watch-users.

We found that different runner types did differ in the kind of running-related technology they used. The Casual Individual Runner was the largest group of app-users; this group included younger, less experienced runners, and more recreational runners. Both Clermont et al [11] and Janssen et al. [33] found that this particular group of 'novice' and 'recreational' runners used apps more often—perhaps as their lower commitment to running made them inclined to prefer using lower-cost technology (apps) instead of the often more expensive sports watches. This concept was supported by other data, as it was found that more competitive and experienced runners (i.e. Individual Competitive and Devoted Runners) used sports watches more often, indicating that runners who identify themselves with running and were more involved in running, were likelier to spend more than the others.

When considering the data that was monitored with the devices, for both apps and sports watches, GPS-based data—time, distance, and speed—were used by almost every runner. One difference between app and sports watch-users was in their collection of heart rate data while running: among app-users the take-up rate for this data was < 10%, while considerably more (59.5%) sports watch-users collected heart rate data. The reason for this difference could be that app-users might need to buy another device (i.e. heart rate monitor) besides the smartphone, while sports watches are often equipped with a built-in heart rate monitor or are sold as a package including a heart rate monitor. Given that sports watch-users collected more objective training data, such as heart rate, we expected that they would use the data differently from app-users—and as expected, we found that twice as many sports watch-users (22.3%) used the collected data to adapt their training, compared to app-users (11.7%). We expected this difference to be greater, since heart rate can be a very useful measure according to which training can be adapted. However, we concluded that perhaps knowledge about heart rate, how to use heart rate information, and how to apply heart rate data was too complex for many runners.

With regards to the different type of runners, we found that Individual Competitive Runners who uses a sports watches to monitor heart rate more than Social Competitive Runners (72.1% vs 65.2%, respectively), and that this Individual Competitive Runner also has the highest number of runners that use this data to monitor training overtime (65.3%) and to adapt their training (29.7%). This finding is in line with the competitive nature of this type of runner. Although, this might also appeal to the Social Competitive Runner, given its similar competitive nature. We argue that the score on 'competitiveness in running' of the Individual Competitive Runner compared to the Social Competitive Runners (4.25 vs 3.70) illustrates this distinction. And that this competitiveness is reflected into more thoroughly monitoring the running performance and usage of this data to create the next training.

As mentioned previously, tracking personalized training data has been cited as the main reason to use technology [11], but there is a small non-user group. Their reasons, given in this study, were diverse, ranging from practicalities like 'running with a device is ignorant', to reasons that related to the way they wanted to be involved in running, such as 'not fitting their authentic running experience'. When considering the different type of runners, there were some differences. For instance, the reasons to not use running-related technology, 'it has no added value' and 'it does not fit my running experience' were given more by Devoted Runners than Social Competitive Runners. We speculate that the low scores on competitiveness might be related to lower interest in running with technology to monitor data. To the best of our knowledge, this particular group of non-users and their motives have not yet been studied, and it could be a significant topic for future research.

Based on our results, we argue that current running-related technology does not yet target specific segments or fails to target a specific segment. Our segmented approach might help professionals to differentiate between end-user types, and to design for a specific target group.

5.2. Limitations

Certain limitations can be highlighted. Firstly, the sample used in our study did not allow all runners to contribute. Instead, a sub-sample focusing on event runners was selected, and the running event participants were considered to be a representative selection of the broader recreational running community [61]. Future research could consider different runner samples, in an effort to ensure all potential runner types were represented. We included runners of all distances, ranging from the full marathon to the 5k city runs—and this could be seen as a limitation, given the large range of experiences. We believe that our sample paralleled the apparent heterogeneity of runners, insofar as their AIOs were the main typology focus, rather than the distances covered or runner experience. Certain methodological limitations concerning the dependent variables are mentioned below. Firstly, the intensity of device used and the reasons why a specific brand was used were not investigated when we asked runners to choose their most-used technological device. Focusing on the reasons why particular brands were used, and what features runners were looking for could be beneficial for future research. Secondly, we added only two items to measure AIOs on competitiveness in running, although they scored an acceptable Cronbach α of 0.697. Future research should consider replicating the current study with more items on this topic. We also believe that studying data from different countries would illustrate geographical variations in sports culture.

5.3. Implications

This study elaborated on a previous study [33] to better understand runners' AIOs and the usage of running-related technology. Our typology allows professionals working in the field of public health, sports, and engineering to better understand their target group. The differentiation between the different types of runners can be used to adapt services to specific segments based on AIOs. Policy makers involved in public health may use the typology to specifically target particular runners and match their policies to the needs of runners. Trainer, coaches, and physiotherapists, for example, could support runners to match running-related technology with their AIOs.

Finally, in the field of Human-Computer Interaction, personas are common use, to give insight into the values, needs, user-experience and interests of end-users (see e.g. [32,46,47]). This user-centered approach is an essential part of the design process, and a typology provides a solid basis to develop personas. Stragier and colleagues [69] advised that a segmented approach was preferable, in order to tailor app interfaces to user motivations; this segmented approach helps designers to differentiate between different end-users types, and their interests. This step is important, as many technological systems are still not reaching their target group of product users [15,47,57,60] and thereby the full potential of running-related system that support runners to stay active and healthy is reached yet.

6. CONCLUSIONS

Our study has shown that runner profiles based on AIOs can successfully differentiate wearable technology usage and gives more in-depth insight in the needs and interests of runners. These insights into runner AIOs could help professionals in the field of running and running technology to provide value to end-users. This, combined with the characteristics of the different runner types, should help to make use of the full potential of running-related system to support runners to stay active, injury free and contribute to a healthy lifestyle.

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PERCEIVED REASONS TO QUIT RUNNING

The previous chapter has shown that four types of runners can be distinguished on the basis of their motives and behaviour towards running. These types differ in how they use technology and which technology they opt for. Certain types of runners identify themselves with running and are not susceptible to quitting running, while other types are more likely to quit running for both social and individual reasons. In this chapter, we focus on the perceived reasons to quit running. This chapter shows which potential reasons to quit running are highly rated by recreational runners and relates these potential reasons to runners' characteristics to show which runners are the most susceptible to quit running.

1. ABSTRACT

Physical inactivity has become a major public health concern and, consequently, the awareness of striving for a healthy lifestyle has increased. As a result, the popularity of recreational sports, such as running, has increased. Running is known for its low threshold to start and its attractiveness for a heterogeneous group of people. Yet, one can still observe high drop-out rates among (novice) runners. To understand the reasons for drop-out as perceived by runners, we investigate potential reasons to quit running among short distance runners (5km and 10km) (n = 898). Data used in this study were drawn from the standardized online Eindhoven Running Survey 2016 (ERS16). Binary logistic regressions were used to investigate the relation between reasons to quit running and different variables like socio-demographic variables, running habits and attitudes, interests, and opinions (AIOs) on running. Our results indicate that, not only people of different gender and age show significant differences in perceived reasons to quit running, also running habits, (e.g., running context and frequency) and AIOs are related to perceived reasons to quit running too. With insights into these related variables, potential drop-out reasons could help health professionals in understanding and lowering drop-out rates among recreational runners.

2. INTRODUCTION

Physical inactivity has become a major public health concern as it is associated with the development of chronic diseases [31,51]. Consequently, the awareness and importance of striving for an active and healthy lifestyle within our society have increased [48]. This is notably reflected in the increased popularity of unorganized recreational sports such as running [20,23]. Running is known for its low threshold to start: it is relatively inexpensive and easy to practice [8] and is associated with many health benefits (i.e. musculoskeletal and cardiovascular health, body composition, and psychological state) [2,11,16,21,29,34,43,44] and is therefore a popular recreational sport. This popularity is especially apparent in the increasing number of commercial running events, and their growing number of participants. In terms of event participation, running is even one of the most popular recreational sports in the world [40,53]. Therefore, since the begin of the 21st century, we can speak of the second wave of running [40].

The growing number and diversity of specialized running events (e.g. ladies runs, colour runs, survival runs) are aligned with the development of the heterogeneous profile of 'the runner' over the years [30,38,50]. During the first wave of running starting in the 1960s, running used to be dominated by young males [3,41] as it was considered outrageous for women to engage in running [45]. It was not until almost 25 years later, the first Olympic marathon for women was introduced [40]. This partake of women in running continued to develop, where a strong growth is notably visible during the second wave of running, resulting in an almost equal distribution of men and women in recent years [19,40,50]. Similar to data of other Western countries [40], 11.3% of women and 13.2% of men within Dutch adults (i.e., the context of the present study), between the ages 20-79 years, expressed to run at least monthly in 2012 [19], also indicating the age diversity of running participants [40,52]. Besides some socio-demographic characteristics (i.e. gender and age) representing the heterogeneous population of runners, studies showed a variety in terms of motives to partake in running (e.g., health, social and competition elements, performance) [10,23,42]. Furthermore, one can also observe a broader range of different experienced runners (e.g., recreational, competitive) [5] but also running context (e.g., small groups, running partner, individually) [12,23,50]. This diverse profile of 'the runner' illustrates that running can appeal to many people (regardless of age, gender, motives, experience or running context) and illustrates the potential of making running even more accessible for an even larger group of people.

Despite the increasing popularity and the growing heterogeneity in runners, one can observe high drop-out rates due to running-related injuries and motivational loss, which is often noticeable among novice runners [15,25,49]. What type of runners are affected by running-related injuries and how this affects a potential drop-out, and how long this drop-out lasts, has been studied extensively in previous literature [9,15,25,35,49]. Although there is evidence on motivations to partake in running [10,30,32,33], reasons to quit running are rather unexplored.

Previous studies on reasons to start running, show the influence of the different type of characteristics. Indicating the influence of socio-demographic variables (i.e., gender and age), running habits (e.g., experience, frequency, relative performance) and in the runners' attitudes, interests, and opinions (AIOs). In a study of Hanson et al. (2015) women seem to be more motivated by AIOs on weight concern, self-esteem, affiliation and psychological coping compared to men and less by AIOs with regards to competition and goal achievement [13]. This is in line with a study by Deaner et al. (2011), indicating men reported higher levels of competitiveness compared to women [6]. Motivational differences in age were investigated by Ogles & Masters (2003), indicating young marathon participants (20-28 years) were more motivated by personal goal achievements, compared to older marathon runners (≥50 years). Furthermore, the older participants were more motivated by weight concerns, life meaning, health orientation and affiliation. Besides gender and age, running experience also impacts AIOs towards running. For example, Forsberg et al. (2015) showed that more experienced runners, those who run for more than eight years, were more likely to run for social motives and just ‘for the love of running’. Whereas lesser experienced runners, those who run up to three years were more health orientated.

Although motives for running can influence running drop-out [14,28,37], to the best of our knowledge, there is limited evidence about reasons to quit running. An important step toward expanding the evidence base is to understand the reasons for drop-out as perceived by runners. Hence, the scope of this paper is on the perceived reasons to quit running. Janssen et al. (2017, 2020) distinguish two groups of perceived reasons to quit running: individual (e.g., time management, injuries) and social (e.g., running partner/trainer quits) [23,24]. These reasons are covered by the items of the Leuven Running Survey 2009 [39] and adapted to event runners. Whether these are related to socio-demographic characteristics as gender and age, as they are for motives to running [6,13,30], or running-related characteristics is, however unknown.

With the present study, we aim to (i) gain insights in perceived reasons to quit running, and (ii) how this is affected by socio-demographics (i.e., gender and age) running habits, and AIOs on running.

3. MATERIALS AND METHODS

3.1. Study design and respondents

The data used in this study were drawn from the Eindhoven Running Survey 2016 (ERS2016). We collected data through an online standardized questionnaire among runners at the Eindhoven Marathon Running Event, which offered races at 5km, 10km, 21.1km and 42.2km. For this paper, a sub-dataset was drawn with only those runners that participated in the 5 km and 10 km. These distances were selected because of the heterogeneity of the participants, including both more experienced, less, and unexperienced runners. The items used in this questionnaire were directly derived from the standardized questionnaire from previous editions of this event (ERS2014 and ERS2015).

In total, 18,261 runners participated in this event, who agreed upon registration that they could be contacted for research purposes. After finishing the event, all runners received an email with an explanation of the study, informed consent, and our guarantee that their data would be processed anonymously. If they agreed upon participation in this study, they could click the link to the online questionnaire. The email contained all needed information and was in line with the ethical principles of the Declaration of Helsinki and the American Psychological Association. Thereby, the Research Board of the Fontys School of Sport Studies was consulted prior to initiation of this study, and approval for the study design was obtained.

Of the 18,261 runners, 3,727 runners completed the questionnaire (overall response rate of 20.4%) of which 7.9% in the 5 km and 16.2% in the 10 km run. Since this study focused on the 5 and 10km distances, the subset used here consists of 898 runners (603 who ran the 10km and 295 the 5km). The average age of the runners in the present study was 40.7 years, with the youngest runner at 18 years and the oldest 78 years old. 52.7% per cent of the participants were women (n = 474 runners). These socio-demographic backgrounds are comparable to other running samples in previous large-scale running studies in Western Europe [7,23,40].

3.2. Questionnaire

The online questionnaire consisted of three sections. The first section included attitudes, interests, and opinions (AIOs) on running, the second focused on socio-demographics and the last on running habits. The questionnaire is provided in the Supplementary Materials (File S1, questionnaire ERS2016), in which Figure 1 shows a flowchart of the questionnaire [24].

The first section of the questionnaire consists of items on running AIOs and was adopted from previous studies [7,23,24,50]. Runners were asked to rate the extent to which they agreed with the items, using a 5-point Likert scale (ranging from 1 = totally disagree, to 5 = totally agree). The second section of the questionnaire includes questions on sociodemographic characteristics. We asked for gender (male/female); age (years); professional status (student/unemployed/employed part-time/employed full-time); and level of education (lower and middle/higher/university). The third section covered running habits included running frequency (number of runs per week) years of running experience (<1 year: novice; 1–5 years: moderately experienced; >5 years: experienced); and preferred running context (individual/with friends/colleagues, small running groups/clubs).

3.3. Measurements

3.3.1. Creating scales of running AIOs

First, we created scales of the items on running AIOs by replicating the questionnaire used by Janssen et al. (2020). We ran reliability analyses for all scales. Items were assessed (Cronbach's Alpha's scores of >0.700 were considered acceptable) and reconsidered whether they substantively contributed to the component or not, and no changes were made. Finally, scales were constructed by calculating the average scores for the reliable items per component, resulting in average scale scores. Table 4.1 gives an overview of these components (i.e. scales), including the number of items, Cronbach's Alpha's, and average score (ranging from 1 to 5). Eventually, five AIO-scales were formed and used in this study:

- Perceived advantages of running (e.g., 'running gives me energy', or 'running is good for my health');
- Identification with running (e.g., 'I am proud to be a runner', or 'I feel myself to be a real runner');
- Running is a sport that is easy to practice (e.g., 'I can practice running anytime, anywhere');
- Social motives for quitting (e.g., I would quit running 'if my trainer quit' or 'if my running friends quit');
- Individual motives for quitting (e.g., I would quit running if 'I got injured', or if 'my spare time was decreased').

3.3.2. Dependent variables

In this study, we used two dependent variables: social motives for quitting and individual motives for quitting. As they do not follow a normal distribution, both scales were recoded into binary variables. All scores below the scale average (i.e. M = 1.79) were coded as '0 below' and all scores above the average were coded as '1 above'. In this way, we were able to interpret the data relative to the sample and able to see if there are variables that could explain why runners score lower or higher compared to their fellow runners.

3.3.3. Independent variables

As independent variables, we included three groups of variables: (i) socio-demographic variables; (ii) running habits; and (iii) running AIOs. The socio-demographic characteristics included gender, age, and level of education. The group of running habits consisted of variables that are directly related to running and which define the level of running involvement: years of running experience, training frequency, and running context. The three-remaining scale on running AIOs perceived advantages of running, identification with running and running as a sport that is easy to practice complete the list of independent variables. Table 4.2 gives the descriptive statistics of the sample for the dependent and independent variables.

Table 4.1. *Components including the number of items, Cronbach α, average scores and standard deviations.*

Scale	Attitudes toward running	Items	Cronbach α	N	Mean	SD
1	Perceived advantages of running	4	0.794	853	4.29	0.458
2	Identification with running	5	0.738	853	3.33	0.640
3	Running as a sport that is easy to practice	3	0.781	853	4.22	0.623
4	Social motives for quitting	3	0.941	853	1.79	0.722
5	Individual motives for quitting	4	0.712	853	3.33	0.784

Table 4.2. *Descriptive statistics of the sample, dependent and independent variables.*

Variable	Measurement	n	%
Individual Motives Binary	Below	399	46.8
	Above	454	53.2
Social Motives Binary	Below	390	45.7
	Above	463	54.3
Gender	Male	387	47.8
	Female	422	52.2
Age	≤ 35 year	261	32.1
	36-45 year	239	29.4
	≥ 46 year	313	38.5
Education	Lower or middle education	273	33.5
	Higher education	332	40.8
	University	209	25.7
Experience	< 1 years	248	29.2
	1-5 years	364	42.8
	> 5 years	238	28.0
Running frequency	≤ 1x/week	384	45.1
	2x/week	350	41.1
	≥ 3x/week	117	13.7
Running context	Individual	526	61.8
	Friends, colleagues, small groups	226	26.6
	Clubs	99	11.6

3.4. Analysis

All results were analyzed using SPSS 26.0 (IBM Corp., Armonk, NY, USA). First, descriptive statistics (i.e., mean scores, standard deviations, minimum and maximum values) were collected to provide an overview of the sample structure, and the items and variables used. Second, two binary logistic regression models (method = enter) were created with the two dependent variables: social motives for quitting and individual motives for quitting. As aforementioned, both scales were recoded into binary variables. Nagelkerke R^2 was used as a measure of goodness of fit. Values between 0.10 and 0.20 were considered as satisfactory and above 0.20 as very satisfactory [18,27]. The different models were tested for multicollinearity, outliers, and leverage points by calculating the variance inflation factors and influence statistics (Cook's). No problems with the data were found concerning these aspects.

4. RESULTS

4.1. Descriptive analysis

First, descriptive analysis shows that the social motives for quitting scores an average of 1.79 (SD = 0.72) on a 5-point Likert scale. From the 853 runners, 390 (45.7%) runners score below the group average, and the remaining 54.3% scores above and perceive relatively more social reasons to quit running. For the individual motives for quitting a mean of 3.33 (SD = 0.78) on a 5-point Likert scale was given. Here, of the 853 runners, 399 (46.8%) runners scored below this relative average, and the remaining 46.8% perceived relatively more individual reasons to quit running. In Table 4.3, the mean scores on the items that form both scales are presented. If we compare these items, it is clear to see that 'physical constraints or injuries' are the most important reason to quit running (M = 4.14 SD = 0.77), followed by item 6; 'tired of running' (M = 3.20; SD = 1.05). The items that are related to 'social motives to quit running', score the lowest (M = 1.82 or lower). Second, the results of the binary logistic regression are presented in Table 4.4. The binary logistic regression with social motives for quitting running as a dependent variable showed significant differences ($p < 0.05$, $p < 0.01$ or $p < 0.001$) for gender, experience with running, running context and on the AIOs towards running, viz. running as a sport that is easy to practice, perceived advantage of running and identification with running. The binary logistic regression with individual motives for quitting running as a dependent variable revealed significant differences for age, education level, experience with running, running frequency and one of the AIOs towards running, viz. identification with running.

Table 4.3. *Mean scores, standard deviations, minimum and maximum values of the items.*

Item No.	Item	Mean	SD	Min	Max
1	My running partners quit running[1]	1.82	0.85	1	5
2	My running group falls apart[1]	1.80	0.84	1	5
3	My trainer / coach is leaving[1]	1.76	0.80	1	5
4	Preference for another sport[2]	3.06	1.04	1	5
5	Reduction of leisure time[2]	2.95	1.05	1	5
6	Tired of running[2]	3.20	1.06	1	5
7	Physical constraints or injuries[2]	4.14	0.77	1	5

Superscript number indicate to which scale, the items belong to. Social reasons to quit running indicated with a 1, and individual reasons indicated with 2.

4.2. Binary logistic regression social reasons for quitting

In the model for 'social motives for quitting running', female runners were more likely (OR = 1.642; $p < 0.01$) to perceive social motives to quit running than male runners. No effect was found for age and education. With regards to the running habits, runners with more than 5 years of running experience, were less likely (OR = 0.610; $p < 0.05$) to perceive social motives to quit running compared to runners with less than 1 year of running experience. Thereby, runners who run with other runners are more likely to perceive social motives to quit running. Those who run with friends, colleagues and in small groups have an odds ratio of 3.352 ($p < 0.001$) and those who run in clubs have an odds ratio of 4.541 ($p < 0.01$), both compared to runners that participate individually. The third running habit; running frequency did not show significant differences. In the final set of independent variables, significant differences for all included AIOs towards running were found. Those who see running as a sport that is easy to practice (OR = 0.502; $p < 0.01$) and those who perceive advantages of running (OR = 0.314; $p < 0.01$) were less likely to perceive social motives to quit running, whereas runners who identify themselves with running (OR = 1.366; $p < 0.05$) were more likely to perceive social motives to quit running.

Table 4.4. *Results of the binary logistic regression, in odds ratios (Exp (β)) with regards to the reference group (ref.).*

		Social reasons (n=803)	**Individual reasons (n=803)**
Constant		646,050***	42,827***
Gender	Male	Ref.	Ref.
	Female	1.642**	1.234
Age	≤ 35 year	Ref.	Ref.
	36-45 year	1.018	0.777
	≥ 46 year	1.402	0.498***
Education	Lower or middle education	Ref.	Ref. ***
	Higher education	1.193	2.012***
	University	0.972	2.721***
Experience	< 1 years	Ref.	Ref.
	1-5 years	0.829	0.888
	> 5 years	0.610*	0.610*
Running frequency	≤ 1x/week	Ref.	Ref.
	2x/week	0.717	0.654*
	≥ 3x/week	0.734	0.799
Running context	Individual	Ref.***	Ref.
	Friends, colleagues, small groups	3.352***	1.203
	Clubs	4.541***	1.361
AIO toward running	Running as a sport that is easy to practice	0.502***	0.985
	Perceived advantages of running	0.314***	0.992
	Identification	1.366*	0.352***
Nagelkerke R^2		0.278	0.244

*=p<0.05; **= p<0.01; ***= p<0.001.

4.3. Binary logistic regression individual reasons for quitting

In the model for individual motives for quitting running, gender was not found to be associated with the individual motives, were the other socio-demographic variables was. Runners that were older (> 46 years) are less likely to perceive individual motives to quit running than younger runners (< 35 years) did (OR = 0.498; p < 0.001). Runners with higher education or who finished university, were more likely to quit running based on individual motives compared to runners with a lower of middle education (resp. OR = 2.012; $p < 0.001$ and OR = 2.721; $p < 0.001$). Similarly, to the model on social motives for quitting, runners with more than 5 years of running experience, were less likely (OR = 0.610; $p < 0.05$) to perceive individual motives to quit running compared to runners with less than 1 year of running experience. The running frequency was also found to be significant, those who run twice a week (OR = 0.654; $p < 0.05$) were less likely to perceive individual motives for quitting compared to runners who run once (or less) a week. Furthermore, runners who identify themselves with running (OR = 0,352; $p < 0.001$) were less to perceive individual motives to quit running. No significant differences were found for running context, and AIO-items running as a sport that is easy to practice and perceived advantages of running.

5. DISCUSSION

5.1. Main finding and discussion

The aim of this study was to gain insight among short-distance event runners into the perceived reasons to quit running, and to identify how these reasons are affected by socio-demographics (i.e., gender and age), running habits and AIOs on running. This is an important step toward expanding the evidence base to understand the reasons for dropout as perceived by runners. This is key to support runners in continued running and to address the barriers runners perceive adequately. The limitations of this study, such as the treatment of the data and its implications, are discussed at the end of the discussion section.

Our findings show that runners are more likely to perceive individual reasons to quit running than social reasons (Table 4.3). Physical constraints or injuries (item 7) is the most important reason to quit running, which is in line with previous studies [9,15,25,35,49], followed by being tired of running (item 6). Socials reasons to quit running because 'my trainer is leaving', or 'my buddy quits running' were less likely to be perceived as important. A possible explanation for this might be that a large group of the participants (approx. 60%) does not run in a social context but runs individually. This is in line with studies showing that running is an activity that is mostly practiced individually, outside the organized context of clubs [12,23,47]. For individual runners, individual reasons to quit running might be more applicable and easier to identify with, as compared to social reasons.

For individual reasons to quit running, significant differences were found for age, education level, experience with running, running frequency and one of the AIOs towards running; identification with running (Table 4.4). Furthermore, results showed that social reasons to quit running are significantly different depending on the gender, experience with running, running context and on the AIOs towards running; running as a sport that is easy to practice, perceived advantage of running and identification with running.

Compared to male runners, our results show that female runners perceive more social reasons to quit running. This result may be explained by the fact that women appear to attach greater value to social support [22,26,36]. A previous study by Vos et al. (2014), in which a typology of female runners was constructed, did show that women valued connectedness with others. This finding was also reported by Pridgeon & Grogan (2012), stating that loss of social support contributed to exercise dropout, especially among women. Another possible assumption would be that female runners, compared to male runners, run more often in a social context, and therefore experience social reasons to quit running more often. However, this explanation is not supported by a previous study (N = 3,727) on running typologies, which does not suggest that women are more likely to run in social contexts but often run in individual context as well [24]. Notably, in the present study, we did not find significant differences for individual reasons to quit running for gender. So, although female runners run in both social and individual contexts, social reasons to quit running are perceived more often by women than men.

Runners aged above 45 years, perceive fewer individual reasons to quit running as compared to younger runners below 35 years. This result might hint at the idea of people feeling more in control of their own time when ageing, as compared to having difficulties in seeking a way to incorporate running in their daily lives [17,22,26]. This might also be related to the fact that people over 45 are in a less exploratory phase of their lives, and thus do not perceive reasons to seek for different types of sports to practice [17]. Another explanation might be that these ‘older’ runners are more experienced and therefore, more aware of their bodies and potential injuries [25,46]. This is in line with a previous study, indicating that the most experienced runners included most runners being older than 45 [24]. What is notable is that there is no significant difference found for social reasons to quit running for age, indicating that reasons to quit from a social perspective are not dependent on age.

Our results suggest that runners who have a higher education or university degree perceive more individual reasons to quit running compared to runners with a low or middle educational degree. Runners with a university degree perceive these reasons about three times as much, and runners with a higher education twice as much. This is not the case for social reasons to quit running. The reason for this might be that runners with a higher or university degree have more trouble in finding a good work-life-sports balance, and thus have more trouble in prioritizing running on a day-to-day basis.

Running experience influenced both social and individual reasons to quit negatively, where runners who run for more than 5 years perceive less (social and individual) reasons to quit as compared to runners running for less than a year. We can hypothesize that runners who already have been running for more than 5 years have already been able to overcome obstacles and barriers (e.g., injuries or motivational loss) throughout the years and kept pursuing running [25,46]. While on the other hand, participants running for less than a year might have a lower self-efficacy, i.e. confidence in one's ability to overcome potential obstacles [1]. Another possible explanation is that experienced runners might feel more competent, and therefore are less afraid of getting injured or being dependent on external factors like a coach or a running group. A previous study, for instance, indicated that the more experienced runners (>7 years) were more likely to run "for the love of running" [10], which might indicate that regardless of some obstacles, their love for running helps them overcome these.

When looking at running frequency, the results suggest that runners who run twice a week perceive fewer individual reasons to quit running as compared to runners who run once a week or less. Notably, this is not the case for social reasons to quit running, nor for runners who run three times a week or more. Although these runners who run twice a week have a higher time investment compared to runners who run once a week or less, they might be able to better incorporate this activity in their schedule on a weekly basis [37]. For those running ≤ 1 per week, the involvement into running is lower, as compared to runners who dedicate to run twice a week. These 'occasional' runners might perceive more reasons to quit since they have not been able to commit to the sport that often on a training basis yet [24,37]. Additionally, a lower running frequency might also affect the feeling of competence or experience, which in turn might increase the fear of getting injured [25].

Although runners in our sample generally experienced more individual reasons to quit running, the running context positively influenced social reasons to quit running. Runners who run in a running group perceive more than three times as many social reasons to quit running compared to runners who run individual, and runners running at a running club more than four times as much. It might seem obvious that when one runs individually, fewer social reasons to quit can be observed. Interestingly though, individual runners do not perceive more individual reasons to quit running, as compared to social runners. Individual reasons to quit running might thus not be dependent on the running context but on other variables (e.g. age, running experience, running frequency) as stated in earlier studies [6,13,30].

Runners who do not think of running as a sport that is easy to practice, and do not perceive many advantages of running, perceive more social reasons to quit running. Instead of these advantages of running, these runners might value and need other AIOs (e.g., social support) to go running and therefore, experience more social reasons to quit running [36].

When one identifies as being a runner, our results indicate that this affects both social and individual reasons to quit running. Runners who identify themselves as a runner perceive more social reasons to quit running. This might indicate that runners who run in a social context (e.g. club or running group), identify themselves as being a 'real' runner and therefore might also depend more on their fellow runners (as a community) and social support. When for example a fellow runner quits, this might act as a trigger to quit running [36]. Contrary to this, runners who identify as being a runner perceive fewer individual reasons to quit running. A possible explanation might be that these are less likely to get tired of running or running is their main sport. This is in line with previous studies indicating that runners who identify strongly with running are the more experienced, long-distance runners [7,24], hinting they might have been able to overcome these possible reasons to quit previously.

Based on our results, we argue that although we see significant differences related to gender in social reasons to quit running and significant ones related to age in individual reasons to quit running, these should not be considered conclusive. Our results showed that running characteristics (e.g. running experience, context, frequency, running AIOs) also influence one's perceived reasons to quit running. We thus contribute to knowledge on running dropouts by drawing a more accurate picture of the situation.

5.2. Limitations

Our studies entail some limitations. As part of our sampling strategy, we selected a subset of the dataset and included runners who participated in the 5km and 10km distances of the running event. Through this, we purposively focused on novice and less experienced runners, who are more likely to drop-out. Although these runners might not be representative of all runners who perceive reasons to quit running, participants of large running events have been considered a representative selection of the broader recreational running community in previous studies [4,24].

In this study, we investigated runners' perceived reasons to quit running. By asking perceived reasons, this study relies on self-reported data and the perception of the participants. We do not know if these reasons would be an actual reason to quit running. However, knowing more about the perception of runners might indicate possible solutions or interventions to lower drop-out rates.

Finally, some methodological limitations related to the dependent variables should be mentioned. As aforementioned, we had to recode our two dependent variables into binary variables because both scales were not normally distributed. We thus lost some information about individual differences. Yet, we were able to interpret the data relativity to the sample. Second, we used 7 items to construct the 2 independent variables. Next to these seven possible reasons to quit running, there are other reasons why runners may quit running. Here we decided to build further on previous studies and hence could benefit from items which have an acceptable internal consistency.

6. CONCLUSIONS

Our survey study shows that although gender and age have shown significant differences in perceived reasons to quit running, these should not be considered conclusive. Our findings implicate that running characteristics (e.g. running experience, context, frequency, running AIOs) also influence one's perceived reasons to quit running. These insights could help policymakers to understand novice runners and their perceived reasons for a potential drop-out. This insight can be used to match public health policies to the motives and barriers of novice runners. Sports professionals (e.g., trainers and, coaches) could use this insight to lower drop-out rates among novice runners and eliminate potential perceived reasons to quit running.

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5

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PERCEIVED **RUNNING** ENVIRONMENT

The previous chapter furnished insights into potential drop-out reasons. Runners are more likely to perceive individual reasons to quit running than social reasons. Less experienced runners were more likely to quit running, and runners who identify themselves with running were less likely to perceive individual motives to quit running. In this final chapter of the first section of this dissertation, the running behaviour of recreational runners is put into context. We investigate which environmental characteristics render a running environment attractive and relate the attractiveness of running environments to characteristics of different runners.

1. ABSTRACT

Running has become one of the most popular sports and has proven benefits for public health. Policy makers are increasingly aware that attractively designed public spaces may promote running. However, little is known about what makes a running environment attractive and restorative for runners and to what extent this depends on characteristics of the runner. This study aims to investigate 1) to what extent intrapersonal characteristics (i.e. motives and attitudes) and perceived environmental characteristics (e.g. quality of the running surface, greenness of the route, feelings of safety and hinderance by other road users) are associated with the perceived attractiveness and restorative capacity of the running environment and 2) to what extent the number of years of running experience modify these associations.

Cross-sectional data were collected through the online Eindhoven Running Survey 2015 (ERS15) among half marathon runners (N = 2,477; response rate 26.6%). Linear regression analyses were performed for two outcomes separately (i.e. perceived attractiveness and perceived restorative capacity of the running environment) to investigate their relations with motives and attitudes, perceived environmental characteristics and interactions between perceived environmental characteristics and number of years of running experience. Perceived environmental characteristics, including green and lively routes and a comfortable running surface were more important for runners' evaluation of the attractiveness and restorative capacity of the running environment than runners' motives and attitudes. In contrast to experienced runners, perceived hinder from unleashed dogs and pedestrians positively impacted the attractiveness and restorative capacity for less experienced runners.

Perceived environmental characteristics were important determinants of the attractiveness and restorative capacity of the running environment for both novice and experienced runners. However, green and lively elements in the running environment, and hinderances by cars were more important for less experienced runners. In order to keep novice runners involved in running it is recommended to design and provide good access to attractive, green, and lively spaces, with separate lanes for other road users.

2. BACKGROUND

Increasing participation in sport and physical activity is an important health policy objective [15,22,76]. Sports participation is associated with positive benefits for physical and mental health and well-being [21,23]. In particular, positive effects have been found for running as an integral part of an active and healthy lifestyle [53,67,69,74]. In recent decades, running has rapidly become more popular and has become more accessible to many people. In the Netherlands, running is one of the most practiced sports [39]. Among Dutch adults between the ages of 20-79 years, 13.2% of men and 11.3% women reported running at least once a month in 2012 [39,71]. These figures are similar to data from other Western countries [63]. Running has increasingly become a 'lifestyle sport', with runners focusing on improving their health, wellbeing and image [68]. Currently, more and more runners participate individually, in informal groups, in running events or in low-threshold exercise ('start to run') programmes instead of in traditional sports clubs focusing on competition [11,64]. The growing popularity of recreational running can be understood in light of the individualization of sports participation, which shows an increased popularity of informal and types of sports activities that are flexible in time and space (in so called 'light' sports settings), which have increased more rapidly than sports participation in traditional organized sports clubs (or 'heavy' sports settings) [8,10,22,45,65].

The increased popularity of running individually or in informal groups has also led to a greater variety of geographical locations used, including public spaces such as parks and natural environments [7,8,14,16,20,58,65]. Various studies showed that some environments may facilitate and strengthen the health benefits of running, whereas other environments hinder running. Thus, it matters where (e.g. at what geographical location, indoors or outdoors or at which running surface) an individual runs [6,31,46]. Policy makers also increasingly recognize the built environment as an important factor that may contribute to active living environments by designing cities that encourage people to be more physically active [28,52,61]. For example, municipalities develop attractive urban running trails and routes [8,73].

However, little is known about what environmental characteristics make a running environment attractive and restorative by runners and to what extent this experience depends on the personal characteristics of the runner. What makes a public space an attractive environment for specific types of runners, one that invites people to run and keep running? Understanding this is important for several reasons. First, attractive environments may promote participation in sport and physical activity, including running [24,52][29]. This is important as running contributes to a more physically active and healthy population [53,67,69,74]. Furthermore, the positive health effects of attractive environments for sports participants have been well documented. Exercising in nature or green environments, also referred to as 'green exercise', has been associated with greater physical and mental health benefits, including lower blood pressure, stress reduction, and with improving mood, self-esteem, perceived health and wellbeing [3,13,30,48,56,57]. In addition, the restorative capacity of the environment increases wellbeing and contributes to the adherence of healthy behaviours such as running. Finally, attractively designed public spaces contribute to pleasurable and liveable urban environments and can have benefits beyond health, such as the environmental sustainability and economic vitality of cities and regions [61,62]. Therefore, designing attractive and restorative environments increases the positive experiences of users. Providing more insight into the experiences of runners may help policy makers make informed choices with regard to designing public spaces and helps professionals gain attention for healthy urban living.

To understand the factors that determine how the running environment is experienced, this study applies a socio-ecological framework, which is frequently used in studies on physical activity [60] and sports participation [37,44]. According to the socio-ecological approach, there are multiple influences on specific health behaviours, including factors on the intrapersonal, interpersonal, and environmental level. All influences on health behaviours potentially interact across these different levels [60]. In this paper, we particularly focus on the interplay between intrapersonal and environmental characteristics and how these relate to the experience of the running environment.

Intrapersonal factors, such as motivation, the reasons why a person participates in sport, have an important impact on persistence in sports participation and the frequency of participation [55,70]. Research on running has shown that the majority of the European running population runs because of health goals, such as getting fit (54%) or losing weight (40%). Other motives are having fun (22%) and/or relieving stress (21%) [63]. However, runners are a very heterogeneous group [11,16,42,64,75]. For example, runners can differ regarding their motivations related to health, competitiveness and sociality [42,75], and their meanings may be experienced both negatively and positively [16]. Furthermore, the level of competitiveness and experience in running can explain differences between types of runners. Running increasingly loses its competitive image and most runners now belong to a group of recreational 'casual' runners who are unattached to a running club. For them, "'completing' is much more preferred than 'competing'" [12]. However, more dedicated and 'serious' competitive runners have different motives and preferences, such as a strong desire for a healthy lifestyle [67]. In addition, differences in running motives and attitudes may be related to runners' years of experience in running. For example, Forsberg [27] found that runners with three or fewer years of running experience focused more on health reasons, whereas runners who were running for eight or more years more were frequently running for 'the love of it' or for social reasons. It is likely that different types of runners also differ in their requirements regarding the running environment and therefore perceive the attractiveness or restorative capacity of the environment differently.

In addition to intrapersonal factors, the influence of the physical environment on health and healthy lifestyles including physical activity has been studied extensively in the public health and physical activity domains [28,47,49,59]. Objectively measured environmental factors, such as street design, land use mix, street connectivity, access to and availability of facilities, such as shops and recreational or sports facilities, proximity of green spaces, population density and socioeconomic status of the neighbourhood are associated with different types and intensities of physical activity [29,38,41,50,54] and sports participation [20,37,43]. In addition, perceptions of the physical environment, including perceived safety and attractiveness, are related to sports participation [4,43]. However, less is known about the environmental correlates of running. Although running significantly differs from walking regarding pace, intensity, bodily experience and spatial reach, studies found indications that recreational walking and running may have similar environmental correlates, because recreational walkers and runners use the same public spaces [24]. Perceived characteristics of the physical environment associated with recreational walking include perceived safety, aesthetics, quality of the walking infrastructure and attractiveness of the environment (e.g. presence of cafes and other people and quiet and green areas) [5,25,40,59]. An indication of the importance of the physical environment for encouraging running was provided by Titze et al. [72]. This study showed that women who perceived themselves as less healthy and who lived in an unattractive neighbourhood were more likely to quit running. Factors including an attractive neighbourhood and social support were likely to play a key role in encouraging running [72].

While many studies found evidence for the importance of objective characteristics of the physical environment for physical activity and sports participation, fewer focused on how the physical environmental characteristics affects how the running environment is experienced, and how this differs for different types of runners [16,34]. Since 'the mobility turn' in the social sciences, more attention has been paid to so called embodied experiences. For example, Cresswell [17] introduced a more holistic view of mobility, wherein the complex interplay between movement, experience and representation (or meaning) is central, instead of the perception of mobility as a 'getting from A to B'. Running can therefore be seen as an interaction between the body, senses and the environment, and the experiences of the body are lived through the senses.

Touching, smelling, feeling, hearing and seeing allows runners to run safely, choose and recognize terrain, adapt pace and take other runners and road users into account [1,16,36]. These experiences of runners can be positive and negative, pleasurable and painful [2] and are therefore likely to influence running behaviour (e.g. distance, pace and frequency), choices for specific surfaces or running environments, as well as the perseverance of running.

Studies showed that various running surfaces or terrains are experienced differently by different runners and impact whether the running environment is evaluated as attractive [1,8,16,24,35]. For example, bark running tracks, (i.e. informal running facilities in the public space consisting of paths with soft surfaces), have been shown to be highly valued because of injury prevention. These running facilities were experienced as attractive by unorganized recreational 'light' runners, can reach runners at different levels and showed potential to stimulate people to start running [9]. In addition, Bodin and Hartig [6] found that runners prefer green environments over urban settings as they offer more fascination and help escape from daily hassles.

Furthermore, we expect that novice or inexperienced runners may differ from experienced runners with regard to their running motives and attitudes, and their preferences in terms of running distance, interactions with other road users or the running surface [8,24]. We expect, for example, that the presence of other road users, such as cars, cyclists, and unleashed dogs, may affect whether novice runners experience their running environment as attractive, whereas experienced runners know how to address this and are less affected. Greater insight into the experiences of different groups of runners is important to understand how novice runners may be better encouraged and facilitated to keep active and involved in sport [34].

This study aims to investigate 1) to what extent characteristics on the intrapersonal level (i.e. motives and attitudes towards running) and the physical environmental level (i.e. perceived constraints by other road users, feelings of safety and quality and characteristics of the running surface and routes) are associated with the perceived attractiveness and perceived restorative capacity of the running environment and 2) to what extent the number of years of running experience modify the association between perceived environmental characteristics and attractiveness and restorative capacity of the running environment.

3. METHODS

3.1. Study design and respondents

For this cross-sectional study, the Eindhoven Running Survey 2015 (ERS15) was used to collect data among participants of the Eindhoven Marathon running event in October 2015. The survey questions were based on the Eindhoven Running Survey 2014 (ERS14), used in previous studies [42,66,75]. For the current study, a sub-dataset containing only those runners who participated in the Half Marathon Eindhoven 2015 (21.1k) was used. Consistent with Janssen et al [42], half marathon runners were selected because of the heterogeneous characteristics of this group of participants, which included both highly experienced and less experienced runners. At registration for the event, all participants agreed that they could be approached for an online questionnaire after the event. After finishing the half marathon, all registered participants (N = 9,314) received an email with an introductory letter and a web link to the online questionnaire. The introduction letter informed them about the purpose of the study and the guarantee that the data would be processed anonymously and in accordance with the ethical principles of the Declaration of Helsinki. After clicking on the link to the questionnaire, respondents were given the choice to end or to continue with the questionnaire. They also were given the opportunity to declare that they do not want to be approached more often. The questionnaire started with a similar announcement about the purpose of the study and privacy. After the announcement, the respondents again had to confirm that they wanted to start the questionnaire. None of the questions were required to fill in. In total, 2,477 participants fully completed the questionnaire (response rate of 26.6%). The socio-demographic background of the respondents was comparable to other samples in previous large-scale running studies in Western Europe [63].

3.2. Measures

Consistent with the socio-ecological approach, the online questionnaire consisted of blocks with questions representing socio-demographic and running-related characteristics, motives, and attitudes towards running, and characteristics of the running environment.

3.2.1. Outcome variables: perceived attractiveness and restorative capacity of the running environment

Two dependent variables were analysed: perceived attractiveness of the running environment and perceived restorative capacity of the running environment. Both variables were measured with a single item and scored on a five-point Likert scale ranging from 1 (totally disagree) to 5 (totally agree). Respondents were asked to rate the following two statements: 'the environment through which my running route passes is attractive' and 'the environment through which my running route passes is relaxing'. This approach of measuring attractiveness and restorative capacity of the environment in single-item measures is consistent with previous research on this and related topics, including satisfaction, wellbeing, preferences for places and experience of place qualities [24,26,32].

3.2.2. Intrapersonal characteristics: motives and attitudes, and number of years of running experience

The first set of independent variables included intrapersonal characteristics, namely motives and attitudes towards running. In total, 25 items on motives and attitudes towards running were measured (based on Janssen et al (2017) [42]). On a five-point Likert scale ranging from 1 (totally disagree) to 5 (totally agree), runners were asked to rate the extent to which they agreed with statements. All items were included in a principal component analysis (PCA) with orthogonal varimax rotation (EVA = 59.1%). As a result, the following five psychographic components were formed: 1) bodily and mental advantages of running (e.g. running gives me energy or running is good for my health), 2) identification with running (e.g. I am proud to be a runner or I feel myself a real runner), 3) practical advantages of running (e.g. I can practise running anytime, anywhere), 4) individual motives for quitting (e.g. I would quit running if I get injured or if my spare time would decrease) and 5) social motives for quitting (e.g. I would quit running if my trainer quits or if my running friends quit). Table 5.1 shows the components including the number of items, Cronbach's alphas, average scores, and standard deviations. We included number of years of running experience as a moderator in the analyses and we distinguished between running <1 year (novice runners), 1-5 years (moderate experienced runners) and >5 years (experienced runners).

Table 5.1. *Internal consistencies on motives and attitudes toward running (N = 2,477)*

Motives and attitudes toward running	Items	Cronbach's alpha
Bodily and perceived advantages of running	4	0.862
Identification with running	8	0.796
Practical advantages of running	5	0.753
Individual motives for quitting	5	0.688
Social motives for quitting	3	0.912

3.3. Perceived environmental characteristics

The second set of independent variables included perceived environmental characteristics (based on Ettema [24]). Respondents were asked to indicate on a five-point Likert scale ranging from 1 (totally disagree) to 5 (totally agree), to what extent they agreed with 10 statements on constraining/negative and encouraging/positive environmental features. Constraining items included interactions with pedestrians, cyclists, cars, and unleashed dogs (e.g. I am hindered by unleashed dogs on my running route) and experiences with (verbal) harassment or threats and poor street lighting. Encouraging items included a comfortable running surface and a lively and mostly green running route.

3.4. Potential confounders

We controlled our analyses for sociodemographic and running-related characteristics. Socio-demographics included age, sex, and education. Education was classified into three levels based on the self-reported highest level of completed education (lower, middle, or higher education). Running-related characteristics included number of years of running experience: running <1 year (novice runners), 1-5 years (moderate experienced runners) and >5 years (experienced runners); distance monitoring of the running route (yes/no); use of monitoring devices (watch yes/no, app yes/no) and organizational running context (individual, friends/small group, or athletics club). Monitoring variables were included as confounders because the use of apps and watches have been frequently used by less experienced runners and have been associated with being more physically active and feeling and behaving healthier and may therefore influence the motives and attitudes of runners [18,19]. In addition, monitoring devices, particularly those with a GPS feature, are one of the most frequently used functions of monitoring devices by runners [42,75] and may act as a proxy for awareness of the running environment, as runners may choose specific running routes based on their devices.

3.5. Statistical analyses

All analyses were conducted in SPSS 24.0. Descriptive statistics on respondents' socio-demographic, running related, motivational, and perceived environmental characteristics were examined. Chi-squares and analyses of variance (ANOVA) were conducted to test for significant differences regarding these characteristics between respondents with different years of running experience (i.e. <1, 1-5 or >5 years). Subsequently, two linear regression analyses (Enter method) were performed for perceived attractiveness (outcome variable 1) and perceived restorative capacity of the running environment (outcome variable 2) to investigate their relationships with potential confounders, motives and attitudes, and perceived environmental characteristics (model 1). To test whether the association of perceived environmental characteristics with the outcomes differed between novice and experienced runners, interactions between perceived environmental characteristics and number of years of running experience were included (model 2).

4. RESULTS

4.1. Descriptive results and differences between runners with different years of running experience

Most respondents had 1 to 5 years of running experience (44.9%), 42.0% was experienced (> 5 years) and 13.1% was relatively inexperienced (novice) and started running less than one year ago (Table 5.2). Novice runners were younger (58.0% was younger than 35 years old) and more frequently engaged individually in running (71.9%). They scored significantly lower on bodily and mental advantages of running (M = 4.3; SD = 0.5) compared to experienced runners (M = 4.4; SD = 0.5) and on identification with running (M = 3.5; SD = 0.5) than the average of the sample (M = 3.8; SD = 0.5). Novice runners more frequently had individual quitting motives (M = 3.2; SD = 0.7) than the average (M = 2.9; SD = 0.7) and particularly compared to more experienced runners (M = 2.7; SD = 0.7). The average score on attractiveness (M = 4.0; SD = 0.9) and restorative capacity (M = 4.0; 0.8) suggests that runners are quite satisfied with their running environment, although these scores differed significantly for runners with less and more experience.

Table 5.2. *Descriptive statistics of respondents with different years of running experience*

	Total (N = 2,477)	**Novice runners (< 1 y) (N = 324; 13.1%)**	**Moderate experienced runners (1-5 y) (N = 1112; 44.9%)**	**Experienced runners (> 5 y) (N = 1041; 42,0%)**	**P-values**
Age (%)					<0.001
≤ 35 year	32.3	58.0	39.3	16.8	
36-45 year	32.5	28.4	37.6	28.3	
≥ 46 year	35.2	13.6	23.1	54.9	
Female (%)	32.5	28.7	39.0	26.8	<0.001
Education (%)					0.841
Lower or middle	29.6	28.4	30.0	29.4	
Higher	70.4	71.6	70.0	70.6	
Monitoring of distance (%)					<0.001
Yes	57.3	70.4	62.7	47.6	
No	42.7	29.6	36.3	52.4	
Monitoring via sports watch (%)					<0.001
Yes	53.0	28.7	51.7	62.0	
No	47.0	71.3	48.3	38.0	
Monitoring via app (%)					<0.001
Yes	34.7	59.9	39.8	21.3	
No	65.3	40.1	60.2	78.7	
Organizational running setting (%)					<0.001
Individual	56.6	71.9	58.1	50.2	
Friends, colleagues, small group	32.1	23.1	22.3	24.1	
Athletics club	20.3	5.0	19.6	25.7	
Motives and attitudes, *mean (SD)*					
Bodily and mental advantages of running	4.4 (0.5)	4.3 (0.5)	4.4 (0.5)	4.4 (0.5)	<0.001
Identification with running	3.8 (0.5)	3.5 (0.5)	3.8 (0.5)	3.8 (0.5)	<0.001
Practical advantages of running	4.1 (0.5)	4.1 (0.5)	4.1 (0.5)	4.1 (0.5)	0.708
Individual motives for quitting	2.9 (0.7)	3.2 (0.7)	2.9 (0.7)	2.7 (0.7)	<0.001
Social motives for quitting	1.6 (0.7)	1.6 (0.8)	1.7 (0.7)	1.6 (0.7)	0.064

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***Table 5.2**. Continued.*

	Total (N = 2,477)	Novice runners (< 1 y) (N = 324; 13.1%)	Moderate experienced runners (1-5 y) (N = 1112; 44.9%)	Experienced runners (> 5 y) (N = 1041; 42,0%)	P-values
Experiences of the running environment, *mean (SD)*					
Hinderance by pedestrians	1.7 (0.7)	1.7 (0.7)	1.7 (0.7)	1.7 (0.7)	0.169
Hinderance by cyclists/mopeds	2.0 (1.0)	2.0 (1.0)	2.2 (1.0)	2.0 (1.0)	0.403
Hinderance by cars	2.1 (1.0)	2.0 (1.0)	2.1 (1.0)	2.0 (1.0)	0.044
Hinderance by unleashed dogs	2.2 (1.1)	1.9 (1.0)	2.2 (1.0)	2.3 (1.1)	<0.001
Hinderance through remarks	1.5 (0.7)	1.5 (0.8)	1.6 (0.7)	1.5 (0.7)	0.41
Hinderance through threats	1.5 (0.7)	1.5 (0.7)	1.5 (0.7)	1.5 (0.6)	0.171
Hinderance through poor lighting	2.6 (1.2)	2.7 (1.2)	2.7 (1.2)	2.5 (1.2)	<0.001
Comfortable surface	3.6 (0.9)	3.7 (0.9)	3.6 (1.0)	3.6 (0.9)	0.099
Lively route	4.0 (0.8)	4.0 (0.8)	3.9 (0.8)	4.0 (0.8)	0.175
Green route	3.6 (0.9)	3.6 (0.9)	3.5 (0.9)	3.6 (0.9)	0.238
Score on attractiveness and restorative capacity (outcome variables), *mean (SD)*					
Attractiveness	4.0 (0.9)	4.0 (0.9)	3.9 (0.9)	4.1 (0.9)	<0.001
Restorative capacity	3.9 (0.8)	3.9 (0.8)	3.9 (0.9)	4.0 (0.8)	<0.001

4.2. Associations with attractiveness of the running environment

Table 5.3 shows the results of the regression analyses on perceived attractiveness of the running environment (adjusted R2 = 0.509 in model 2). Runners who valued running highly because of the perceived bodily and mental advantages (β = 0.037 p < 0.05) or practical advantages (β = 0.043; p < 0.05), perceived their running environment as more attractive. Those who perceived hinderance by pedestrians (β = -0.049; p < 0.01) or cars (β = -0.038; p < 0.05) perceived the running environment as less attractive. Poor lighting (β = 0.037; p < 0.05), a comfortable running surface (β = 0.17; p < 0.001) and running in a lively (β = 0.33; p < 0.001) or mostly green route (β = 0.434; p < 0.001) were associated with a more attractive running environment. Hinderance by unleashed dogs was negatively associated with perceived attractiveness (β = -0.287; p < 0.05) but was positively associated for novice runners. A lively route was positively associated with perceived attractiveness among novice runners but not among more experienced runners. A comfortable running surface was important for the perceived attractiveness of the running environment among moderately experienced runners but less for novice or experienced runners.

Table 5.3. *Linear regression on perceived attractiveness of the running environment (N = 2,477)*

	Model 1 (confounders, motives, and attitudes, perceived environmental characteristics)		**Model 2 (model 1 + perceived environmental – number of years of running experience interactions)**	
	St. Beta (p)	SE	St. Beta (p)	SE
Constant[1]	0.574*	0.253	1.314	0.744
Confounders				
Age (ref = ≥ 46 year)				
≤ 35 year	-0.016	0.032	-0.016	0.032
36-45 year	-0.04*	0.029	-0.042*	0.029
Male (female = ref)	-0.016	0.025	-0.015	0.025
Education (higher = ref)				
Lower or middle	-0.011	0.026	-0.011	0.026
Years of running experience (> 5 y = ref)				
< 1 y	0.009	0.039	-0.112	0.294
1-5 y	-0.025	0.026	-0.1	0.178
Distance monitoring y/n (ref = no)	0.001	0.028	-0.001	0.028
Watch use (ref = no)	0.012	0.039	0.014	0.039
App use (ref = no)	0.014	0.045	0.013	0.045
Organizational context (athletics club = ref)				
Individual	0.050*	0.034	0.052*	0.034
Friends, colleagues, small group	0.011	0.036	0.013	0.036
Intrapersonal characteristics: motivations and attitudes				
Bodily and mental advantages of running	0.037*	0.031	0.039*	0.031
Identification with running	-0.015	0.027	-0.019	0.027
Practical advantages of running	0.043*	0.027	0.043*	0.027
Individual motives for quitting	-0.015	0.018	-0.016	0.018
Social motives for quitting	-0.003	0.019	-0.002	0.019

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Table 5.3. *Continued.*

	Model 1 (confounders, motives, and attitudes, perceived environmental characteristics)		**Model 2 (model 1 + perceived environmental – number of years of running experience interactions)**	
	St. Beta (p)	SE	St. Beta (p)	SE
Perceived environmental characteristics				
Hinderance by pedestrians	-0.049**	0.021	-0.089	0.158
Hinderance by cyclists/mopeds	-0.006	0.015	0.03	0.119
Hinderance by cars	-0.038*	0.014	0.046	0.112
Hinderance by unleashed dogs	0.011	0.012	-0.287*	0.097
Hinderance through remarks	-0.001	0.022	0.153	0.172
Hinderance through threats	-0.031	0.025	-0.068	0.191
Hinderance through poor lighting	0.037*	0.01	0.126	0.078
Comfortable surface	0.17***	0.013	-0.103	0.101
Lively route	0.33***	0.013	0.161	0.104
Lively route	0.434***	0.014	0.606***	0.113
Interactions perceived environment characteristics * years of running experience (ref = > 5 y running experience)				
Pedestrians * < 1 y running experience			0.003	0.064
Pedestrians * 1-5 y running experience			0.048	0.044
Cyclists/mopeds * < 1 y running experience			-0.029	0.048
Cyclists/mopeds * 1-5 y running experience			-0.007	0.033
Cars * < 1 y running experience			-0.041	0.045
Cars * 1-5 y running experience			-0.058	0.031
Unleashed dogs * < 1 y running experience			0.269*	0.041
Unleashed dogs * 1-5 y running experience			0.061	0.025
Remarks * < 1 y running experience			-0.123	0.067
Remarks * 1-5 y running experience			-0.047	0.050
Threats * < 1 y running experience			-0.009	0.077
Threats * 1-5 y running experience			0.056	0.053
Poor lighting * < 1 y running experience			-0.053	0.032
Poor lighting * 1-5 y running experience			-0.05	0.021
Comfortable surface * < 1 y running experience			0.177	0.042
Comfortable surface * 1-5 y running experience			0.209**	0.027
Lively route * < 1 y running experience			0.236*	0.042
Lively route * 1-5 y running experience			-0.034	0.029
Green route * < 1 y running experience			-0.173	0.046
Green route * 1-5 y running experience			-0.078	0.031

Table 5.3. *Continued.*

	Model 1 (confounders, motives, and attitudes, perceived environmental characteristics)	**Model 2 (model 1 + perceived environmental – number of years of running experience interactions)**
	St. Beta (p) SE	St. Beta (p) SE
Model fit		
Adjusted R^2	0.509	0.509
SE	0.5607	0.5605

[1]Constant: Unstandardized Beta instead of Standardized Beta.
*Significance < 0.05; **Significance < 0.01; ***Significance < 0.001.

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Table 5.4. *Linear regression on perceived restorative capacity of the running environment (N = 2,477)*

	Model 1 (confounders, motives, and attitudes, perceived environmental characteristics)		**Model 2 (model 1 + perceived environmental – number of years of running experience interactions)**	
	St. Beta (p)	SE	St. Beta (p)	SE
Constant[1]	0.258	0.237	-0.139	0.696
Confounders				
Age (ref = ≥ 46 year)				
≤ 35 year	-0.01	0.03	-0.008	0.03
36-45 year	-0.031*	0.027	-0.031*	0.027
Male (female = ref)	-0.002	0.024	-0.002	0.024
Education (higher = ref)				
Lower or middle	0.014	0.024	0.014	0.024
Years of running experience (> 5 y = ref)				
< 1 y	0.015	0.037	0.112	0.275
1-5 y	0.01	0.025	-0.023	0.166
Distance monitoring y/n (ref = no)	0.011	0.026	0.009	0.026
Watch use (ref = no)	0.025	0.037	0.029	0.037
App use (ref = no)	0.047#	0.042	0.049*	0.042
Organizational context (athletics club = ref)				
Individual	-0.016	0.032	-0.013	0.032
Friends, colleagues, small group	-0.008	0.034	-0.008	0.034
Intrapersonal characteristics: motivations and attitudes				
Bodily and mental advantages of running	0.041*	0.029	0.041*	0.029
Identification with running	0.017	0.025	0.015	0.025
Practical advantages of running	0.015	0.025	0.018	0.025
Individual motives for quitting	-0.022	0.017	-0.02	0.017
Social motives for quitting	0.008	0.018	0.007	0.018
Perceived environmental characteristics				
Hinderance by pedestrians	-0.025	0.019	-0.231	0.148
Hinderance by cyclists/mopeds	0.008	0.014	0.148	0.112
Hinderance by cars	-0.040**	0.013	0.304*	0.105
Hinderance by unleashed dogs	0.012	0.011	-0.077	0.091
Hinderance through remarks	-0.007	0.021	0.161	0.161
Hinderance through threats	-0.015	0.023	-0.167	0.179
Hinderance through poor lighting	0.016	0.009	0.023	0.073
Comfortable surface	0.037**	0.012	-0.086	0.094
Lively route	0.128***	0.013	0.127	0.097
Lively route	0.686***	0.013	0.808***	0.105

Table 5.4. *Continued.*

	Model 1 (confounders, motives, and attitudes, perceived environmental characteristics)		**Model 2 (model 1 + perceived environmental – number of years of running experience interactions)**	
	St. Beta (p)	SE	St. Beta (p)	SE
Interactions perceived environment characteristics * years of running experience (ref = > 5 y running experience)				
Pedestrians * < 1 y running experience			0.017	0.06
Pedestrians * 1-5 y running experience			0.24**	0.041
Cyclists/mopeds * < 1 y running experience			-0.044	0.045
Cyclists/mopeds * 1-5 y running experience			-0.111	0.031
Cars * < 1 y running experience			-0.205*	0.043
Cars * 1-5 y running experience			-0.192**	0.029
Unleashed dogs * < 1 y running experience			0.046	0.038
Unleashed dogs * 1-5 y running experience			0.058	0.024
Remarks * < 1 y running experience			-0.155	0.063
Remarks * 1-5 y running experience			-0.031	0.047
Threats * < 1 y running experience			0.136	0.072
Threats * 1-5 y running experience			0.034	0.05
Poor lighting * < 1 y running experience			-0.027	0.03
Poor lighting * 1-5 y running experience			0.022	0.02
Comfortable surface * < 1 y running experience			0.099	0.039
Comfortable surface * 1-5 y running experience			0.071	0.025
Lively route * < 1 y running experience			0.076	0.039
Lively route * 1-5 y running experience			-0.10	0.027
Green route * < 1 y running experience			-0.187	0.043
Green route * 1-5 y running experience			0.04	0.029
Model fit				
Adjusted R^2	0.599		0.602	
SE	0.5261		0.5244	

[1]Constant: Unstandardized Beta instead of Standardized Beta.

*Significance < 0.05; **Significance < 0.01; ***Significance < 0.001.

4.3. Associations with restorative capacity of the running environment

Table 5.4 shows the results of the regression analyses on the restorative capacity of the running environment. Runners who valued running highly because of perceived bodily and mental advantages ($\beta = 0.041$; $p < 0.05$) found their running environment more restorative. Green ($\beta = 0.686$; $p < 0.001$) and lively ($\beta = 0.128$; $p < 0.001$) running routes and a comfortable surface ($\beta = 0.037$; $p < 0.01$) were positively associated with restorative capacity. Hinderance by cars was negatively associated with restorative capacity ($\beta = -0.040$; $p < 0.01$); however, this was more so for novice and moderately experienced runners than experienced runners. Hinderance by pedestrians was positively associated with a restorative running environment among moderately experienced runners.

5. DISCUSSION

5.1. Main findings and discussion

In this study, we investigated how perceived attractiveness and restorative capacity of the running environment can be explained by intrapersonal characteristics and perceptions of the environment and to what extent these associations differed for novice runners and more experienced runners. Our primary finding was that perceived environmental characteristics, particularly green and lively running routes and a comfortable running surface, enhanced runners' evaluation of the attractiveness and restorative capacity of the running environment, more so than intrapersonal factors such as runners' motives and attitudes. Perceived environmental characteristics were important to all runners and only a few differences between novice and experienced runners were found. Surprisingly, hinderance from unleashed dogs and pedestrians positively impacted the attractiveness or restorative capacity for less experienced runners.

With regard to intrapersonal characteristics, (i.e. runners' motives and attitudes), our results showed that the level of perceived bodily and mental advantages of running and the practical advantages of running positively impacted the attractiveness and restorative capacity of the running environment. Bodily and mentally experienced advantages from running practice, such as through the positive effects of running on health, stamina, or mental relaxation, may increase the motivation and positive attitudes towards running (and the frequency of running). In addition, the practical advantages of running refer to the flexible and autonomous characteristic of running. Running can be practiced anytime, everywhere and fits easily in busy life schedules compared to other types of sports and is therefore highly valued [8,12,64]. This flexible and autonomous characteristic of running stimulates runners to go outside, explore new routes and environments and create favourite, attractive and relaxing running routes. However, previous positive experiences and evaluations of the attractive and relaxing environment may also stimulate motives and attitudes to go for a run. Regardless of the direction and causality of the associations found, our results show that the perceived advantages and the autonomous and flexible characteristics of running, are more important determinants of perceiving the environment as attractive and restorative, than motives and attitudes such as running identity and social motivation.

Characteristics at the environmental level that were positively associated with both the attractiveness and restorative capacity of the running environment included a comfortable running surface and a lively and (mostly) green environment. These results reflect findings from previous studies showing the importance of the running surface for the enjoyment of running (e.g. soft/grass or bark running tracks are more comfortable and injury-preventive but require you to work harder; hard/stiff and flat roads are faster but have higher risk for injuries) [1,8,16,35]. The importance of running in a lively and green environment corresponds to previous findings showing positive physical and mental health benefits of these types of environments [3,13,30,48,56,57]. In addition, our results correspond with findings in the context of recreational walking, suggesting that people actively choose routes because of the presence of green space, which makes walking routes more attractive and relaxed [48,51]. Furthermore, hinderance by pedestrians and cars were negatively associated with attractiveness. Similar results were also found in the study of Ettema [24] among novice runners who took part in a 'start to run' programme. Hinderance by cars was also negatively associated with restorative capacity. Because the number of years of running experience modified this association, showing that experienced runners who were hindered by cars evaluated the restorative capacity more positively than less experienced runners, it may be that more experienced runners choose to use different parts of the public space than less experienced runners. More experienced runners may prefer roads that they value because it allows them to run faster (and not because they prefer to encounter traffic). They also may run longer distances than less experienced runners, which allow them to run outside or longer outside crowded urbanized areas. The positive association we found for poor lighting on attractiveness of the running environment may also be related to the preferences for more attractive running paths and routes, for example in parks and natural areas, which are more poorly lit than public roads in urban areas.

Some associations of environmental characteristics with perceived attractiveness and restorative capacity of the running environment differed for novice and experienced runners. For example, we found that hinderance by dogs was positively associated with perceived attractiveness of the running environment for novice runners (i.e. those involved in running for less than one year) and negatively for more experienced runners. In addition, hinderance by pedestrians was positively associated with a restorative environment among moderate experienced runners (i.e. those with one to five years of running experience). These findings indicate that less experienced runners likely perceive different environments as more attractive or restorative. They may run in parks, forests, and natural areas. Green spaces, however, attract other recreational users, such as pedestrians and dog-owners, as well. Although unleashed dogs [24] and pedestrians [16] may be a well-known constraint of runners, these constraints likely do not affect their perceived attractiveness and restorative capacity of the environment to a great extent. In addition, both a comfortable running surface and hinderance from pedestrians were positively associated with attractive and restorative capacity, respectively, among moderately experienced runners. Additionally, less experienced runners who were constrained by cars evaluated their running environment as less restorative than more experienced runners. These findings indicate that more experienced runners may choose different running environments or perceive environments differently than less experienced runners. More experienced runners may have fixed routines regarding their running routes and running locations, which are based on unconscious choices [33]. They may have chosen their running routes based on the running surface (e.g. asphalt, paved paths, pavements, unpaved paths in parks or forests, tartan, or a combination between them). In addition, more experienced and serious athletes are likely more focused on their training results regarding running distance, pace and achievements and may be more motivated to run and/or are less distracted by cars and less attractive routes. They may also vary their running environments to keep the running experience more attractive for themselves. Novice runners may need an attractive running route with lively and natural elements to encourage them more than experienced runners to regularly go for a run.

5.2. Strengths and limitations of this study and future directions

Strengths of this study are that we collected data on different levels as described by socio-ecological models [60], which allowed us to investigate intrapersonal and perceived environmental characteristics of different types of runners. Our data on motives and attitudes and perceptions of the environment are based on existing literature.

This study also has some limitations. First, the Eindhoven Running Survey 2015 (ERS15) lacked geographical data on running locations, which would have allowed us to link objective Geographical Information Software (GIS)-data (on for instance running environments) to the survey data. It would be interesting to also link objective environmental characteristics of the running environment to perceived attractiveness and restorative capacity. A potential bias that may have occurred, and we could not control for because of the missing of geographical data, is an overrepresentation of respondents living in areas with similar urbanity levels (e.g. highly urbanized or rural). Such an overrepresentation could potentially have influenced the results regarding perceived attractiveness and restorative capacity of specific running environments. Furthermore, the group of novice runners (in terms of number of years of running experience) in our sample was able to complete at least one-half marathon within one year of training, which indicates a moderate level of fitness. However, we believe this has not led to a bias of the results toward more experienced runners.

Future research should focus on interrelationships between perceived environmental characteristics and objective environmental characteristics. For example, GPS-based location data on running routes, running locations, and running intensity and physical activity in general could be used. In addition, from a health perspective, it is interesting to apply a longitudinal research design and follow less experienced runners for a longer time period of for instance several years to investigate running adherence and quitting patterns. To what extent do characteristics of the running environment and perceptions thereof play a role herein? How do motives and attitudes change when runners become more experienced and how is this related to their experience of the running environment?

6. CONCLUSIONS

Running has become one of the most popular and practised sports, and it is a well-known phenomenon in the urban streetscape, public parks, and natural areas. Both scholars and policy makers increasingly have become aware that an attractively designed public space may stimulate sports participation including running. We found that perceived environmental characteristics, particularly green and lively running routes, and a comfortable running surface, enhanced runners' evaluation of the attractiveness and restorative capacity of the running environment. Perceived environmental characteristics were important to all runners, and more so than intrapersonal factors such as runners' motives and attitudes. However, green and lively running routes, a comfortable running surface and hinderance by cars were more important to less experienced runners.

Our findings indicate that the built environment is particularly important for encouraging less experienced runners. To stimulate novice runners to stay involved in running, policy makers should prioritize the attention for public space as the environment with the greatest potential for stimulating healthy lifestyles. It is recommended to design attractive, green, and lively spaces with separate lanes for runners and other road users. For example, governments could facilitate running routes, connecting parks and natural areas through green (or bark) running tracks and provide good access upon this green infrastructure on the neighbourhood level.

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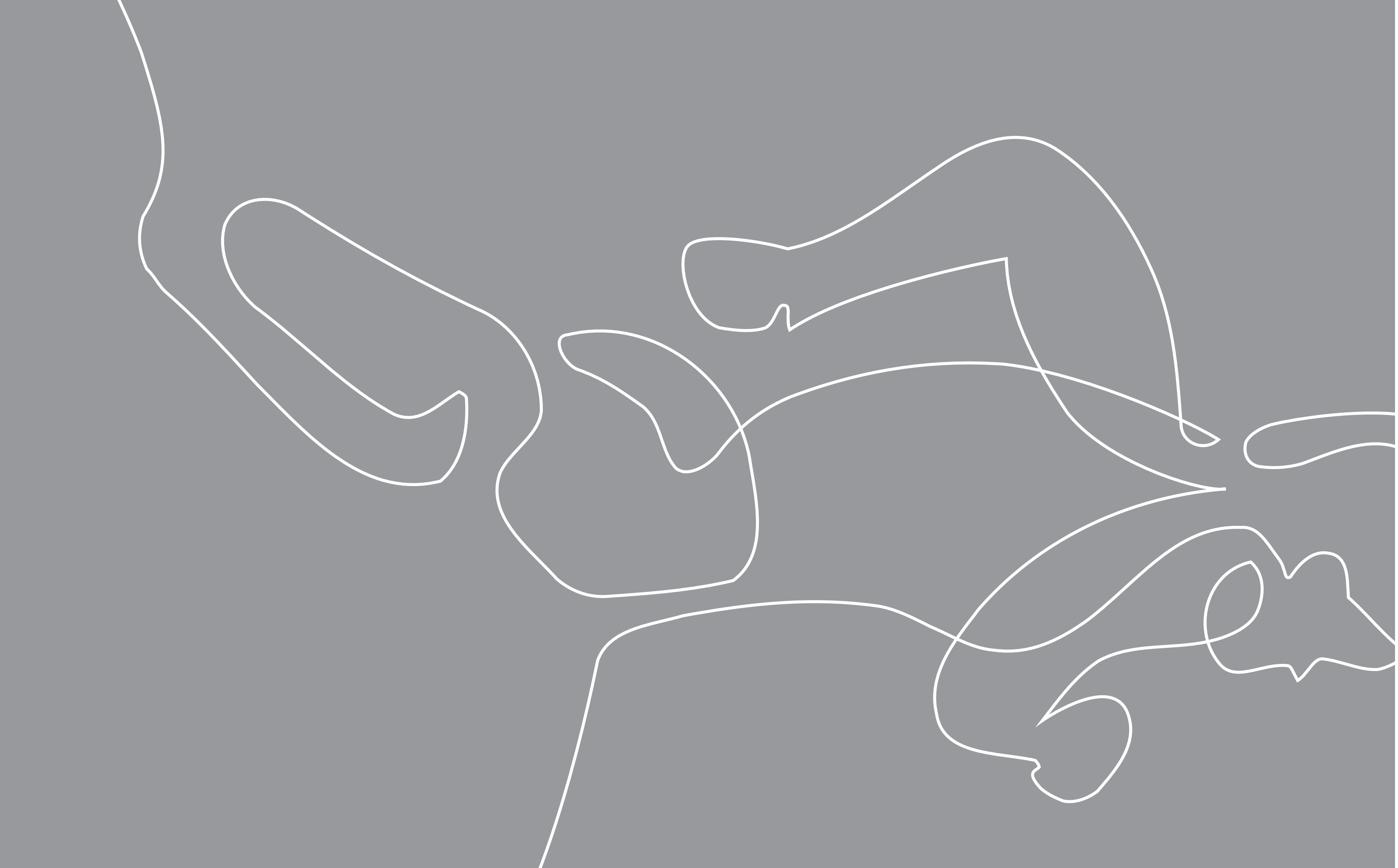
CONCLUSION OF SECTION 1 AND INPUT FOR SECTION 2

The objective of Section 1 was to understand the motives and behaviour of recreational runners in relation to running-related technologies. This section demonstrated that recreational runners are a heterogeneous and diverse group in terms of their socio-demographics, behavioural, and motivational characteristics. The runner' characteristics are related to their use of running-related technology and how they use the data acquired from the same. These characteristics also determine their perceived motives to quit running and how they experience their running environment.

Apps and sports watches are the most used forms of running-related technologies. Apps are most used by inexperienced runners who identify themselves the least with running and are the most susceptible to quit running for individual motives (e.g. injuries, demotivation, and lack of time). Runners who use apps, do not use objective measures of training load (such as heart rate) in combination with the app; they rather monitor speed, time, distance, and routes (GPS data). In contrast, sports watch users more often use heart rate as a measure of training load and thereby monitoring parameters such as cadence, speed, time, distance, and running routes. All runners want their routes to be attractive and to have a restorative capacity, although green and lively elements in the running environment were more important for runners with less running experience compared to their more experienced counterparts. These experienced runners are the most represented by sports watch users, which can characterise more experienced runners with higher involvement in running. As compared to app users, they are more often seen in sports clubs with professional guidance. Compared to sports watches, apps are more accessible, easily scalable, and because they are already extensively used by inexperienced runners, they can have tremendous potential to support this group of runners.

It remains unclear why is their potential still unexploited. The most used apps do not fulfil this potential to support and guide runners. Hence, there appears to be a gap between the runners' needs and interests and the available running-related technologies. Therefore, in the next section, we investigate how we can design running-related technology for recreational runners. First, it is defined how a design process looks like when developing sports-related prototypes, and what the expert perception is on how sport-related technology should be designed. Second, it shows a prototype to narrow down the proposed gap. On the one hand, to make runners aware of already existing running-related technologies, a prototype should support runners in their decision-making process for choosing an appropriate app. On the other hand, to fulfil the potential to support and guide runners, a prototype should use personalisation and objective measures of training load to support and guide runners while training for their goals.

SECTION 2



HOW CAN WE **DESIGN RUNNING-RELATED TECHNOLOGY** THAT MATCHES THE MOTIVES AND BEHAVIOUR OF RUNNERS?

6

This chapter is an exact reproduction of the paper published as:

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Author contributions: Conceptualisation, MJ and SV; methodology, MJ, CM, and SV; formal analysis, MJ, investigation, MJ and SV; writing – original draft preparation, MJ; writing – review and editing, MJ, RH, CM, PL and SV.

ANALYSIS OF THE DESIGN PROCESS

**In section 2, we focus on how to design running-related technology for recreational runners.
This chapter provides detailed insight into the design process for prospective engineers and designers during a sports and vitality hackathon. The Reflective Transformative Design process framework was used to monitor, categorise, and describe the various activities throughout the design process.**

1. ABSTRACT

The scope of technology has expanded towards areas such as sports and vitality, offering significant challenges for engineering designers. However, only little is known about the underlying design and engineering processes used within these fields. Therefore, this paper aims to get an in-depth understanding of these type of processes. During a three-day design competition (Hackathon), three groups of engineers were challenged to develop experience-able prototypes in the field of sports and vitality. Their process was monitored based on the Reflective Transformative Design process (RTD-process) framework, describing the various activities part of the design process. Groups had to keep track of their activities, and six group reflection-sessions were held. Results show that all groups used an open and explorative approach, they frequently swapped between activities, making them able to reflect on their actions. While spending more time on envisioning and creating a clear vision seem to relate to the quality of the design concept.

2. INTRODUCTION

The scope of engineering design has expanded towards areas like sports, physical activity, and vitality. There are several arguments for this. First, there is a growing awareness to tackle physical inactivity and sedentary behaviour, which is a major public health concern [1]. Second, there is an increasing attention for health lifestyles and vitality. Nowadays, people can choose their own way of being involved in sports, compatible with their own individual lifestyle and consistent with their own interests [6]. When incorporating these characteristics, sports can play a determined role towards vitality and contribute to a healthier lifestyle. Third, recent developments in low-cost sensor technologies have opened new markets and possibilities [8]. Fourth, the sports participation sector has become a significant economic sector [7]. For example, in recent years there has been an exponential increase in the availability and use of sports and physical activity-related monitoring devices [3,4].

It is obvious that technology creates new opportunities for the field of sports and vitality, but also offers significant challenges for engineering designers. For instance, Wilson and colleague's [9] found that in product design multiple iterations were used within and between different design phases, where in the sports design only iterations within each design phases were used, and rarely between design phases. Thereby, the design space in this field is enormous, and requires a distinctive approach and envisioning of societal and personal needs. Amongst others, the target group is extremely heterogeneous in terms of physical abilities, training load responses, motivational drivers and attitudes [3,8], and it aims to create behaviour changes in patterns that are deeply rooted in daily life [5]. Therefore, this paper aims to unravel these processes used by future engineering designers towards a first prototype in the field of sports and vitality.

2.1. Reflective Transformative Design process

The Reflective Transformative Design process framework (RTDP), introduced by Hummels and Frens [2] is an open framework for designing, but can also be used as a framework to describe and analyse design processes. Its structure, by nature open and flexible, based on activities and the links between them, provides an open yet structured way to analyse any design process. The RTDP is: *"a design process, particularly aimed to support the design of disruptive innovative and/or intelligent systems, products, and services"* [2] (p.147). The model consists of five circles (figure 6.1). The middle circle 'decisions' can be seen as a process of taking decisions based on information of the other four circles. The remaining four circles can be seen as strategies to generate or gather information. '*Envisioning*' is information gathering to create a designer's vision. It is used to give direction to the design process. Like every circle, in the beginning, this vision is small, based on little information and must develop during the process. *Exploring & validating* is used to gather information by validating the design decisions through experience-able prototypes. For example, testing a concept by experts, or validating a simple prototype in real life. The circle of *thinking* consists of analyzing and abstracting to create a framework or model. *Making* is the last strategy, creating experience-able prototypes and producing experiential information. Hummels and Frens [2] stated that "*Design making enables the designer to use her intuition and through making the designer can open up new solution spaces that go beyond imagination"* [2] (p. 161). Given the connections and relatedness between all circles and activities, it is recommended to swap frequently from one to the other circle. Through swapping, engineers are forced to incorporating different kinds of information to feed the design decisions. This enables the engineers to reflect on the activities in and during action. In this paper, we analyse the design and research processes of future design engineers towards vitality and sports focused prototypes through the RTDP model.

3. MATERIALS AND METHODS

3.1. Hackathon design challenge

During a three-day Hackathon, three groups of future engineering designers (n=14) were challenged to rapidly prototype practical ideas. The focus was to design for sports and vitality, with specific attention to health-related aspects such as increasing (sports) active behaviour, reducing sedentary behaviour, and reducing stress. Participants joined a topic that interested them. The outcome of hackathon should be a pitch of their concept to the audience and jury, including a working prototype. The research conducted was in line with the ethical principles of the Declaration of Helsinki and the Institutional Research Board. The privacy of all participants was guaranteed, and all data was anonymized before analysis.

An interactive, qualitative study design was chosen for this study. A protocol of the RTDP framework [2] was used to map the engineering design process. Each group had the responsibility to keep track of all activities conducted. Sticky notes in different colours (representing different members) were used to write down information of each activity and placed on an overview cardboard. For each activity, the following questions were answered: (i) What was the activity? (ii) How was the activity performed? (iii) Did group members work alone or with others? (iv) At what time they started and what was the duration of the activity? Next, a minimum of six short sessions (10 minutes) on fixed moments (11 am and 6 pm, each day) were conducted. These moments stimulated reflection on their activities, but also gave the moderator the opportunity to validate the information on the sticky-notes with the participants.

3.2. Measurements and analysis

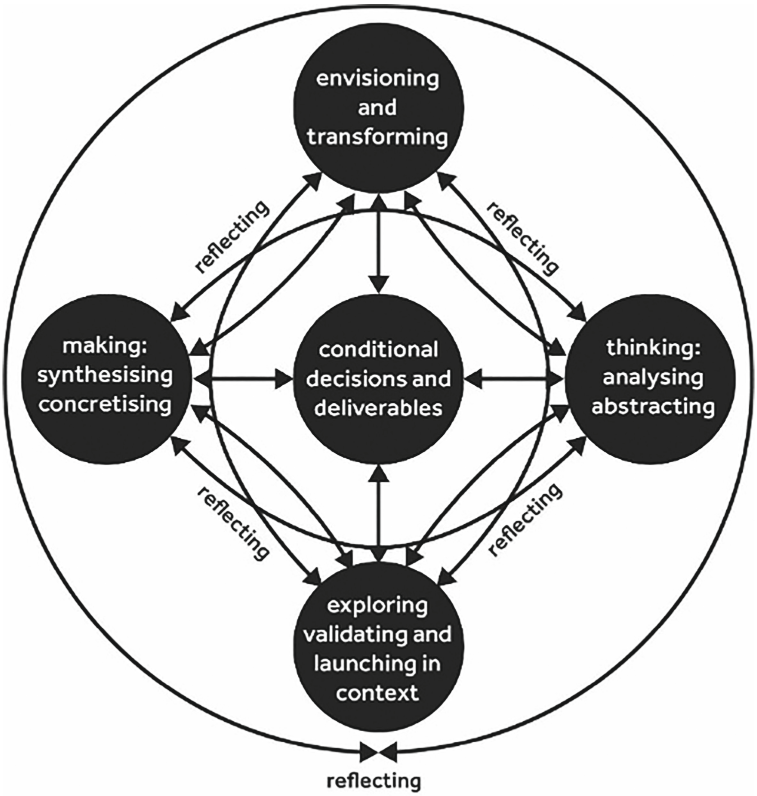

Figure 6.1. *The Reflective Transformative Design process [2]*

The following measurements of the design process were calculated based on the information on the sticky-notes: total number of activities, total time spent on the activity, average time per activity, percentage of the number of activities per strategy and percentage of the time spent per strategy. Next to the process, also the outcome of the hackathon was measured. Seven experts formed a jury and had to score, via a multi-item list, the pitches, and the prototypes. Each jury member was forced to rank the groups. In this paper, the rankings of the jury members were summed. If a jury member ranked the group first, 1 point was given. Second place agreed with 2 points, and last place 3 points. The group with the least points won the competition. Spearman's Rho was used to correlate the design process measurements to the jury scores.

4. RESULTS

4.1. Design process

First, some general results are described. Next, we will focus on differences between the groups (for an overview see table 6.1). Results reveal differences, between groups and group members, in the total time spent on the concepts. For instance, some participants spent around 2000 minutes, while others spent only 1155 minutes. Also, the contribution of four information gathering/generating strategies is not equally distributed. The future engineering designers spent only between 3,6% and 7,6% of their time on *envisioning*. Moreover, this approach is mostly used on the first day, and rarely during the second and final day. While information generating by *making* is by far the most used strategy, every group spent the most of their time (between 54,5% and 61,2%) on activities related to *making*. Analyses also show differences between groups, group 1 and group 3 did spend about the same total time (4125 minutes and 4155 minutes), where group 2 spent only 3210 minutes. Thereby the analyses show that different patterns on the different strategies are visible. Group 1 and 3 showed a similar pattern, spending the least time on *envisioning*, followed by *thinking* and *exploring & validating*. They spend the most time on *making*. Group 2 also spent the least time on *envisioning* but did a lot more *thinking* compared to the other groups, and less *exploring & validating*. Group 3 spent 7,6% of their total time on *envisioning* (315 minutes). Group 1 and 2 spent half the time (150 minutes) and only 3,6% and 4,7% of the total time on *envisioning*. All groups swapped between strategies, only the strategy of *envisioning* (and to some extent *thinking*) was not incorporated, resulting in alternated use of activities only related to *exploring & validating* and *making*, instead of using all four strategies frequently and alternated.

Table 6.1. *Overview of all measurements of the design process for the different groups (G1, G2, G3)*

	Number of activities			Total Time (minutes) of activities			Average Time (minutes) per activity			Percentage (%) of total number of activities on activity			Percentage (%) of total time spent on activity		
Group	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Envisioning	2	3	3	150	150	315	75	50	105	3	9	7	4	5	8
Thinking	14	7	7	660	780	615	47	111	88	23	21	17	16	24	15
Exploring & Validating	19	6	14	975	315	960	51	53	69	31	18	34	24	10	23
Making	26	18	17	2340	1965	2265	90	109	133	43	53	42	57	61	55
Total	61	34	41	4125	3210	4155	66	94	101	100	100	100	100	100	100

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4.2. Outcome hackathon: concepts

The first group pitched their concept called 'Ambi' a system in the form of a 'Tamachoti' that warns when you are too long inactive or when the air quality decreases. The second group developed 'Freshlook' a system with a stress ball that stimulates you to go for a walk when you sit too long. The third group choose to design a system that detected positive and negative changes in an office environment, changes were made visible by ripples in the water in combination with 'AMP' a workshop that should make participants aware of the risks of stress via an interactive puppet.

4.3. Outcome hackathon: jury scores

Based on the rankings of the seven jury members. Group 3 won this hackathon based on their concept 'AMP' (9 points). The jury praised this concept because it provides an actual solution for a societal problem and was realistic in terms of practical feasibility. Group 2 (15 points) and Group 1 (18 points) completed the ranking.

4.4. Relation: design process and outcome

To relate the measurements of the design process to the jury ranking, correlations (Spearman's Rho) were executed. The number of different activities, as well as total time spent on the concepts, seems not related to the jury ranking. Secondly, average time spent per activity did correlate to jury ranking, the longer the time spent per activity, the higher the ranking of the jury. Group 3 spent almost twice the time on envisioning compared to group 1 and 2, using a higher percentage of the total time on creating a vision and scope of the concept. Thereby they compensated this time in the making-related activities and came up with a relatively simple, working 3d model. Ranked correlations showed that spending more time on envisioning did relate to a better ranking. While spending more or less time on the other strategies did not relate to a better ranking.

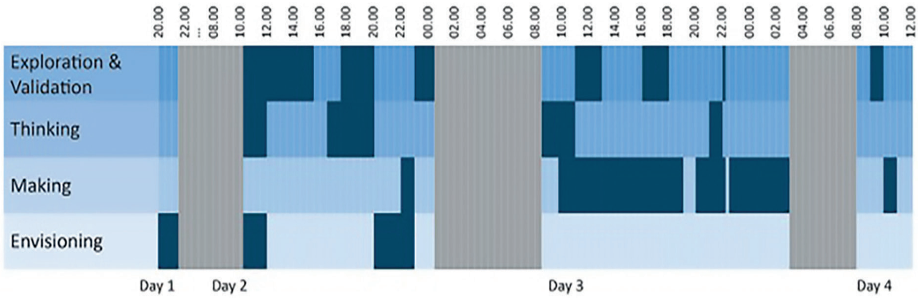

Figure 6.2. *Visualisation of the design process including different strategies, activities, and time per activity of group 3 during the three-day Hackathon.*

5. DISCUSSION

This paper focused on unravelling the design process used by future engineering designers towards a first prototype in the field of sports and vitality. It seems that the winning concept spent more time on envisioning, but also envisioned more thoroughly. Resulting in a concept that provides an actual solution for a societal problem and is realistic in terms of practical feasibility. A possible explanation can be found in characteristics of designing in the field of sports and vitality. In this field, the design space is enormous, requiring a distinctive approach. Hence, the envisioning of societal and personal needs is key. Therefore, spending more time on envisioning and understanding societal and personal needs more thoroughly may have resulted in a better concept. A possible reason why group 3 (master students only) did a more thoroughly envisioning could be related to their prior experience with the RTDP and user-involvement. A limitation of this study is that we included both bachelor and master students. The concepts of the groups were mainly focused on vitality related topics. This is a general trend in the Netherlands where recreational sports are more and more connected to being active and living healthy, including issues like sedentary behaviour, stress, burn-out, etc.

Vos et al. [8] stated that to understand the societal and personal needs and, the associated crossovers between different professions require a multidisciplinary approach. This is key for the design and provision of products and services targeting mass sports participation. Since the groups were unidisciplinary, these crossovers did not happen and therefore possibly there was even more to gain in terms of envisioning.

Analyses showed that groups did swap between strategies, only the strategy of envisioning and thinking were rarely incorporated. In line with Wilson and colleagues [9], we also found that groups rarely iterated between different phases in the design process, for example none of the groups did go back to envisioning (including their design brief or design rationale) after the first full day of designing (e.g. figure 6.2).

In future research, it can be interesting to monitor (i) the actual methodology the groups used to gather or generate information within the four circles of the RTDP. This will provide not only insight into the quantity of the activities but also the quality, (ii) and to monitor the decisions, to get more insight into which information is used and is decisive. Finally, in future research the design and engineering processes will be monitored over longer periods of time, taking away the time-pressure of the hackathon and to see if there will be changes in quantity and quality of envisioning. Thereby multidisciplinary teams will be formed with different expertise to facilitate crossovers during the envisioning.

6. CONCLUSIONS

Technology has created new opportunities for the field of sports and vitality, but also offers significant challenges like the enormous design space in this field and a distinctive approach and envisioning of societal and personal needs for engineering designers [3,8]. This study functioned as a first exploration and has given an insight into how engineering designers use design methods within the field of sports and vitality. It seems that time spent on envisioning, but also envisioning more thoroughly affected the outcome. This finding provides an interesting starting point to further investigate engineering design in the field of sports and vitality.

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*Chapter is written in American English

EXPERT VIEWS ON RUNNING-RELATED TECHNOLOGY DESIGN

The previous chapter described how future designers and engineers should design for sports and vitality. They can use an open and explorative approach with attention to both societal and personal needs and create a clear vision that is beneficial for the quality of the design concept. In this chapter, we used expert panels with participants with different areas of expertise to create a supported view on how they think running-related technologies should be designed.

1. ABSTRACT

A large number of people participate in individual or unorganized sports on a recreational level. Furthermore, many participants drop out because of injury or lowered motivation. Potentially, physical activity–related apps could motivate people during sport participation and help them to follow and maintain a healthy active lifestyle. It remains unclear what the quality of running, cycling, and walking apps is and how it can be assessed. Quality of these apps was defined as having a positive influence on participation in recreational sports. This information will show which features need to be assessed when rating physical activity–related app quality.

The aim of this study was to identify expert perception on which features are important for the effectiveness of physical activity–related apps for participation in individual, recreational sports.

Data were gathered via an expert panel approach using the nominal group technique. Two expert panels were organized to identify and rank app features relevant for sport participation. Experts were researchers or professionals in the field of industrial design and information technology (technology expert panel) and in the field of behavior change, health, and human movement sciences who had affinity with physical activity–related apps (health science expert panel). Of the 24 experts who were approached, 11 (46%) agreed to participate. Each panel session consisted of three consultation rounds. The 10 most important features per expert were collected. We calculated the frequency of the top 10 features and the mean importance score per feature (0-100). The sessions were taped and transcribed verbatim; a thematic analysis was conducted on the qualitative data.

In the technology expert panel, applied feedback and feedforward (91.3) and fun (91.3) were found most important (scale 0-100). Together with flexibility and look and feel, these features were mentioned most often (all n=4 [number of experts]; importance scores=41.3 and 43.8, respectively). The experts in the health science expert panels a and b found instructional feedback (95.0), motivating, or challenging (95.0), peer rating and use (92.0), motivating feedback (91.3), and monitoring or statistics (91.0) most important. Most often ranked features were monitoring or statistics, motivating feedback, works good technically, tailoring starting point, fun, usability anticipating or context awareness, and privacy (all n=3-4 [number of experts]; importance scores=16.7-95.0). The qualitative analysis resulted in four overarching themes: (1) combination behavior change, technical, and design features needed; (2) extended feedback and tailoring is advised; (3) theoretical or evidence base as standard; and (4) entry requirements related to app use.

The results show that a variety of features, including design, technical, and behavior change, are considered important for the effectiveness of physical activity–related apps by experts from different fields of expertise. These insights may assist in the development of an improved app rating scale.

2. INTRODUCTION

2.1. Recreational sport participation

Starting with and maintaining physical activity (PA) is a challenge for many citizens. We see that in the United States and Europe, physical inactivity and sedentary behavior are increasing, causing health-related problems such as decreased quality of life and increase in health care costs [5]. Potentially, participation in sports can contribute to a more healthy lifestyle [7,22,23,26,37]. However, participation rates are also quite low, with 59% of European citizens exercising or playing a sport less than once a week [13]. In the Netherlands, the situation is slightly more positive, with 44% of Dutch citizens participating in sports less than once a week or never [42]. Of the citizens that participate in recreational sports in the United States and Europe, a large number of people participate in individual or unorganized sports (e.g., running and cycling) [6,30,34,35,41]. In the Netherlands, the participation in recreational individual sports such as running, cycling, walking, and fitness is increasing as well [42]. A large part of these participants are beginners or less experienced. These individual sports are often practiced in lighter nonclub-organized settings (leisure time sport participation that allows for a flexible experience) or individually op. In the latter, there exist no or limited support and guidance of a trainer or coach. Therefore, these individual athletes are at risk of injuries or loss of motivation and hence dropping out and therefore decreasing PA [21]. Substantial guidance is necessary to prevent injuries and to stay motivated to participate in sports, especially among beginner and less experienced participants [44,45].

2.2. Potential of physical activity–related apps

Potentially PA–related apps could motivate these people during sport participation and help them to follow and maintain a healthy and active lifestyle. Mobile health (mHealth)–related apps are popular; in 2016, the app stores displayed 105,000 (Google Play) and 126,000 (Apple Play Store) mHealth-related apps in health and fitness and medical categories [31]. In recent years, a large number of PA–related apps have been developed for people in individual sports, and every day, new apps are being launched in the app stores [3,9]. Previous research shows that approximately 50% to 75% of (event) runners use a running app[9,21]. Cycling and walking apps are gaining in popularity as well. For instance, Strava (an app for running and cycling) has millions of users and the number of users increases each month [39,47]. In contrast to the published data available on the use of running and cycling apps, little is known about the use of walking apps. These running, cycling, or walking apps provide possibilities to support people in participation in exercise and sports (such as monitoring activities, setting goals, and comparing your results to others) [11,15]. However, the question is whether the quality of currently available apps is sufficient to support recreational sport participants. An analysis of the quality of apps and knowledge about which app features matter the most is necessary to determine whether apps have added value.

2.3. Assessment of physical activity–related apps

The quality of PA–related apps has been evaluated in various manners in previous research. Some studies have examined if and how many behavior change techniques (BCT's) are applied in current health– or PA–related apps by using an app taxonomy of Abraham and Michie [1,4,11,12,25]. Results showed that only a small amount of BCT's (mean number of 3.7-8 BCT's) are applied in PA or healthy nutrition apps [4,11,12]. Content analyses of apps also showed that the evidence base of currently available health and fitness apps is limited [8,19,46]. A recent study evaluated if and how gamification was used in health and fitness apps [34]. They showed that gamification features were often used in popular apps; however, low adherence to professional guidelines or industry standard for gaming was found [24]. Other app rating scales have been developed as well, such as the Mobile App Rating Scale (MARS) and an app rating scale for exercise apps [17,38]. The MARS was developed for classifying and assessing the quality of mHealth apps [38]. In general, moderate quality scores were found for mental health and wellbeing apps and weight management apps [2,38]. The app rating scale for exercise apps developed by Guo et al (2017) was based on exercise prescriptions developed by the American College of Sports Medicine (ACSM) for aerobic exercise, strength and resistance, and flexibility [17]. On the basis of this scale, low scores (maximum 35 out of 70 points) were found for the tested exercise apps [17]. Another method to evaluate the quality of PA–related apps is by assessing technical features or design. The mHealth taxonomy of Olla and Shimskey examines features such as data management, user interface, and device type [27]. The MARS evaluated technical features as well, such as having an app community and containing data protection using a password [38]. However, these technical features were not included in the quality score of the app.

In summary, a variety of app features have been examined in current app rating scales, including design, technical, and behavior change features. In some of these rating scales (e.g., MARS and taxonomy of Abraham and Michie) [1,38], all app features are considered evenly important, whereas the rating scale developed by Guo et al applied a weighting to the items [17]. The time allocated to different components (aerobic exercise, strength and resistance, and flexibility) of a standard exercise program for health and fitness (ACSM guidelines) was used to weigh the items [17].

2.4. Problem statement

This study is innovative in two ways: the incorporation of experts' opinions (instead of based on literature or theories on behavior change) and the assessment of the importance of features (instead of only the presence of features). It remains unclear how the quality of running, cycling, and walking apps, defined as having a positive influence on participation in recreational sports, can be assessed. We do not know if some app features may be more important than others for participation in recreational sports and if a weighing should be applied. In addition, there is currently no PA–related app rating scale that scores design, technical, and behavior features. Currently available app rating scales are based on literature or theories on behavior change but do not take into account the opinion of experts regarding the importance of app features. In this study, experts were defined as researchers or professionals in the field of behavior change, psychology, health, and human movement sciences, as well as industrial designers and information technologists. Their knowledge of and experience with design and evaluation of PA–related apps is deemed to be very valuable. The obtained additional information regarding the rating of features can be used in the development of an improved PA–related app check list.

2.5. Objective

Therefore, the aim was to identify expert perception on which features are important for the effectiveness of PA–related apps for participation in individual, recreational sports.

3. METHODS

3.1. Design

The data were gathered via an expert panel approach in which the nominal group technique (NGT) was used [10]. Two expert panels were organized to identify and rank app features relevant for effectiveness of PA–related apps for participation in individual, recreational sports. This NGT was chosen for this study as it provides the possibility to identify problems and gain more insight in a topic by quantifying opinions of participants in a democratic way [20,43]. In addition, the NGT includes a structured group process and can be used to generate and rank ideas for group discussion, to reach consensus, and to engage group members to solve a problem [10]. The NGT was proven evenly effective as other methods in terms of accuracy, idea selection, and satisfaction with the process, such as face-to-face meetings, Delphi method, and interactive groups [14,16]. Moreover, a previous study showed that it was an effective and efficient tool to generate ideas and to develop consensus in a group of experts [18]. Small and rather homogeneous groups are preferred in using NGT [40].

3.2. Participants

A total of 12 experts for each panel (24 experts in total) were recruited and approached, taking into account dropout, among others, because of time constraints. Convenience sampling was used to recruit the experts. These experts were selected based on their experience, expertise, and perception concerning PA–related apps [39]. All experts needed to have a Master's degree. Two types of experts were selected for these two panels. Inclusion criteria for the first group (technology expert panel) included scientific background in information and communication technology (ICT), service design, industrial design, or research through design (or other comparable fields). Inclusion criteria for the second group (health science expert panel) included (1) Scientific background in behavioral, psychological, health, or human movement sciences (or other comparable fields) or professional experience in these domains and (2) Research or professional experience (at least 3 years) with PA–related apps. This way, knowledge and expertise from different disciplines was collected. This study was part of a larger research project called "An app for everyone?!" The aim of this project was to determine which (popular) sport app fits which type of user or professional based on their goals and wishes. If the selected experts were already involved as partner in this research project, they were excluded. All experts signed an informed consent before participating in the expert panels.

Of the 24 approached experts, 11 (46%) were able to attend the expert panel sessions. Four experts were included in the first session and seven in the second group session. Due to time restrictions, the other 13 experts were not available on the scheduled sessions. Still, we were able to include all relevant expertise in the panels.

Table 7.1 presents the characteristics of the experts who participated in the panels. For the NGT, the health science expert panel was divided into two subgroups (a group of three [health science expert panel A] and a group of four experts [health science expert panel B]), to make sure that all experts had enough time to express their thoughts and that there was enough time for discussion [40].

3.3. Procedure

First, the selected experts were contacted via email to participate in the NGT. All experts who agreed to participate received an email with additional information about the purpose and procedure of the study. The first expert panel (technology expert

Table 7.1. *Expert characteristics*

Characteristics	Technology expert panel	Health science expert panel A	Health science expert panel B
Sex			
Male	4	2	0
Female	0	1	4
Expertise			
Behavior change	0	1	2
Human movement sciences (injury prevention or monitoring)	0	1	1
Health sciences	0	1	0
Persuasive technology	0	0	1
ICT[a] service design	2	0	0
Industrial design	2	0	0
Degree			
MSc	2	3	2
PhD	2	0	2

[a]ICT: information and communication technology.

panel) was organized on October 18, 2016 and was facilitated and observed by two of the authors (RW and JD). Subsequently, the second expert panel (health science expert panel) interview was organized on October 31, 2016 and was facilitated by two of the authors (JD and JvdW). The sessions were organized at a location that was most convenient for the experts (Eindhoven and Amsterdam, The Netherlands). To increase the reliability and validity of the results, the moderators followed the same protocol, and one moderator attended both sessions.

In alignment with the NGT, each session consisted of three consultation rounds [33]. In these three rounds, the goal was to rank and prioritize PA–related app features (Figure 1). To facilitate interaction, name tags were placed in front of the experts, and the experts were positioned in a half-circle. The moderator facilitated the discussion, provided instructions about the assignments, and ensured that all experts had an equal say. If necessary, the moderator asked for clarification of the answers provided by the experts.

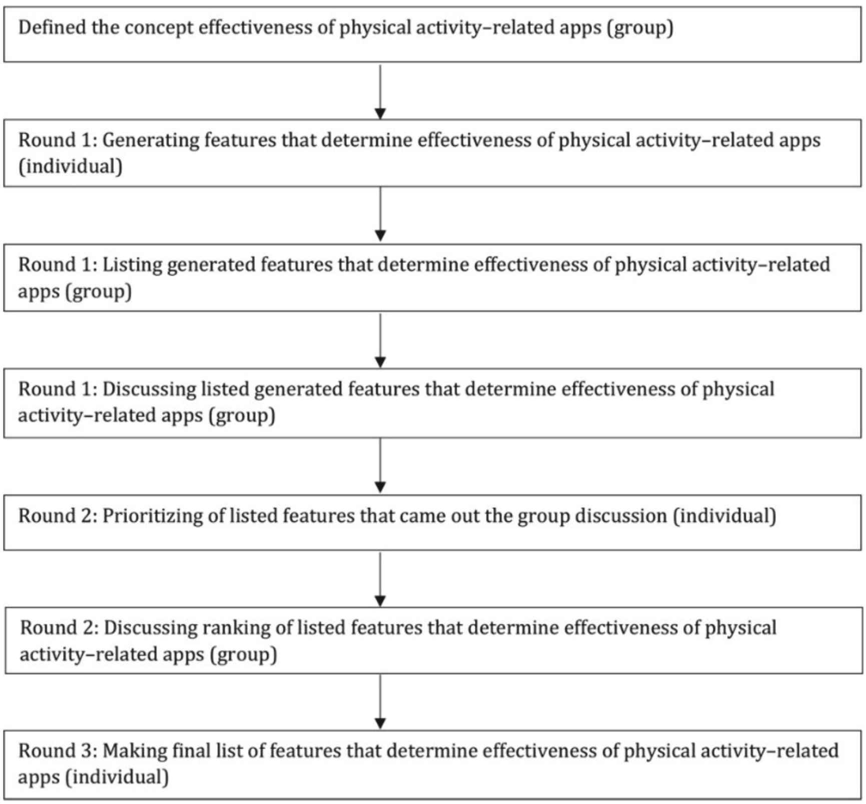

Figure 7.1. *Three rounds of the nominal group technique.*

In a short introduction, the moderator explained the framework of the session. The moderator asked the experts to focus on running, cycling, and walking apps for recreational athletes, with a goal to start and maintain sports participation. After this introduction, all participants introduced themselves and explained their experience with PA–related apps. Subsequently, the moderator informed the experts about the purpose of the research project and the protocol. To set a framework for the assignments in the sessions, we asked the experts to define the concept "effectiveness of apps." The experts discussed in their own sessions their shared idea about what effectiveness meant to them (social construction). In the first round, the experts were asked to individually list all app features that they found necessary for effectiveness of PA–related apps for sport participation. After that, these features were collected, explained, and listed on a white board. In the second round, the experts were asked to individually rank the 10 features they found most important. Subsequently, these rankings were collected, presented on a screen, and discussed groupwise. In the last round, the experts individually made a final list of their 10 most important features. In addition, they were also asked to appoint a score to each feature (0-100), to indicate importance. The duration of both expert panel sessions was 2 hours.

3.4. Data analysis

3.4.1. Nominal group ranking

On the basis of the third round, the 10 most important features per expert were collected. The features generated by the expert panel sessions were combined into one list per panel. We calculated the frequency of the features in the top 10, as well as the mean importance score per feature. Differences between groups were not calculated because of small sample size.

3.4.2. Qualitative analysis

The sessions were audiotaped and videotaped and transcribed verbatim. On the basis of these transcripts, a list of features generated by each group and their definitions was created. The transcripts were read and reread by one of the authors (JD). After that, a thematic analysis was conducted on the qualitative data from the expert panels. This thematic analysis focused on the answers that illustrated and supported the experts' ranking choices. The coding was performed manually based on a coding framework that was developed inductively. This coding frame was discussed and checked by a coinvestigator (JvdW) who was a moderator as well (investigator triangulation) [29].

4. RESULTS

4.1. Structure of results

The results from this study are presented in three sections. The first section shows how the experts defined the concept effectiveness of PA–related apps as a starting point of the discussion. The second section presents the various features that were ranked and their importance. The third section provides some of the overarching themes that were extracted from the panel sessions. These themes can be considered important areas to address in the development of a new app rating scale.

4.2. Definition of effectiveness

At the start of the panel sessions, the experts defined the concept effectiveness of PA–related apps to delineate the topic.

In the first expert panel, the experts agreed that an app was effective if a (safe, sustainable, and healthy) change of behavior was established. Experts from the second panel (health science expert panel A and health science expert panel B) agreed on that and added that an app was effective if it could change behavior determinants such as knowledge, attitude, risk perception, and awareness to influence behavior on the long term.

4.3. Nominal group ranking

In total, 51 features were collected in round one. After selecting, prioritizing, and discussing these features in round two and three, 25 features remained and were ranked by the experts in both expert panels. Table 7.2 shows for each panel frequency of the features in the top 10, as well as the mean importance score per feature (on a scale of 0-100). The total frequency of individually ranked features ranged from 1 to 9. The features that were perceived as most important by the technology expert panel (with industrial designers and information technologists) were applied feedback and feedforward (anticipating on future behavior or goals; 91.3) and fun (91.3). Besides those two features, look and feel and flexibility were also mentioned most often (all n=4 [n denotes the number of experts]). The importance scores of these two features were considerably lower (43.8 and 41.3, respectively). The experts in the health science expert panel A (behavior change and human movement sciences) found instructional feedback (95.0), motivating feedback (91.3), and monitoring or statistics (90.0) most important. The features that were ranked most often (number of experts=4) were monitoring or statistics, motivating feedback, technically properly working, tailoring starting point, fun or pleasure, and usability. The importance scores of these features were high as well (82.0-95.8).

Experts in the health science expert panel B found motivating or challenging (95.0), monitoring or statistics (95.0), and peer rating and use (92.0) most important. Usability, anticipating or context awareness, and privacy were ranked by all experts in this subpanel, with importance scores ranging from 16.7 to 85.0.

4.4. Qualitative analysis

During the panel sessions, the experts elaborated on the features they ranked and explained why they found them important. This section outlines the overarching themes that were found. Each theme is discussed below and illustrated with quotes of the experts.

4.4.1. Combination behavior change, technical, and design features needed

In line with the expertise of the expert panels, features for behavior change as well as technical and design features were considered as important for effectiveness of PA–related apps. For instance, in the technology expert panel next to technical and design features, applied feedback, fun, rewards, and context awareness were ranked in the top 10. In addition, in health science expert panel A and health science expert panel B, next to behavior change features, reliability, usability, works good technically, and visibility were ranked in the top 10. Experts in technology expert panel indicated that, for these features, in general, domain specific knowledge is required, as illustrated in the following quote:

Basically applied feedback includes knowledge of sports, motivational support, and quality of coaching, and depends on the intended application. [Technology expert panel, expert in industrial design]

Table 7.2. *Features ranked by experts in round 3 (based on top 10 ranking)*

	Expert panel 1		**Expert panel 2**		**All experts**	
Feature	**Mean importance score***	**Frequency**	**Mean importance score***	**Frequency**	**Mean importance score***	**Frequency**
Instructional feedback			95.0	2	95.0	2
Motivating / challenging			95.0	1	95.0	1
Monitor / statistics			92.5	5	92.5	5
Peer rating and use			92.0	1	92.0	1
Applied Feedback & Forward (motivating and qualitative coaching)	91.3	4			91.3	4
Motivating feedback			91.3	4	91.3	4
Stability	90.0	1			90.0	1
Engagement			87.5	2	87.5	2
Works good technically			87.5	4	87.5	4
Tailoring starting point			85.0	4	85.0	4
Continues tailoring			85.0	3	85.0	3
Fun / pleasure	91.3	4	79.4	5	83.3	9
Rewards	65.0	2	95.0	1	80.0	3
Usability	60.0	1	86.0	7	77.5	8
Social	80.0	2	72.5	3	75.0	5
Reliability			75.0	2	75.0	2
Theoretical (scientific) base / evidence + BCT's			75.0	2	75.0	2
Check on health			73.3	3	73.3	3
Visibility / exposure / reputation			73.0	2	72.5	2

Table 7.2. *Continued.*

	Expert panel 1		**Expert panel 2**		**All experts**	
Feature	**Mean importance score***	**Frequency**	**Mean importance score***	**Frequency**	**Mean importance score***	**Frequency**
Coaching styles			70.0	1	70.0	1
Tailoring content that cannot be changed			70.0	1	70.0	1
Connectivity	70.0	2			70.0	2
Costs			70.0	1	70.0	1
Fit to user / everyday life / tailoring	71.7	3	60.0	1	65.8	4
Sustainable training plan			60.0	1	60.0	1
Anticipating / context awareness	35.0	2	60.4	5	51.9	7
Flexibility / adjustable/ adaptive	41.3	4	60.0	1	50.6	5
General information healthy behavior					50.0	1
Increase awareness	50.0	2			50.0	2
Look and feel	43.8	4			43.8	4
Portability	40.0	1			40.0	1
Privacy			16.7	3	16.7	3

*On a scale from 0-100 †Importance score controlled for the mean importance score per feature

4.4.2. Extended feedback and tailoring is advised

Experts emphasized that a feedback option, as well as extended tailoring, needs to be integrated in a PA–related app. Several feedback options were suggested, such as motivational feedback (positive framing) and instructional feedback (health science expert panel A), as illustrated in the following quote:

You should be approached in a positive way, even if you haven't done anything that day. [Health science expert panel B, expert in persuasive technology]

Coaching styles in a PA–related app matter as well and should be tailored to the individual athlete (health science expert panel B). Tailoring in general can be applied in several ways: at the moment a person starts using the app or continued tailoring during the whole process of using an app. This tailoring should be aligned with the current level of health, knowledge, functioning, personal goals, competitiveness, PA, and personal characteristics. One expert stated the following:

To me, it is important that the tailoring should fluctuate with one's life. [Health science expert panel B, expert in behavior change]

Another element of tailoring is the flexibility of the app, in other words being able to adjust the app and adaptivity of the app. One expert stated the following:

For instance, if your running performance improves, the app should develop as well. [Technology expert panel, expert in industrial design]

One step further would be that the app should anticipate on the user. For instance, by accounting for schedules and location. This feature was described as context awareness and was discussed in all panel sessions. One expert stated the following:

That you reckon with someone's context. That it can account for the fact that not all things go as planned. [Health science expert panel B, expert in persuasive technology]

As an example, a recommender system was described. A recommender system is a machine learning, information-retrieval software tool that predicts what a user may or may not like or need [32]. It can provide suggestions based on these predictions.

4.4.3. Theoretical or evidence base is the standard

Two experts from health science expert panel A and health science expert panel B indicated that in general, a theoretical or evidence base was important for the effectiveness of PA–related apps. Some examples of BCT's were briefly mentioned, including self-regulation, goal setting, overview of results, tailoring, monitoring, context awareness, nudging, and self-learning. Other BCT's were discussed more in detail in the panels, such as fun, social component, monitoring, rewarding, feedback or coaching, tailoring, and information about healthy and safe sport participation. Besides

BCT's, other potential theories were mentioned, such as technological- and medical-based theories or engagement theories for the development of apps, as illustrated in the following quote:

There are many other theories for building apps, and you could take these into account as well. It is not only about behavior change. The app could be built based on a technical or medical view or engagement theories as well. [Health science expert panel A, expert in health sciences]

One expert in behavior change highlighted that an evidence and a theoretical base are two different things. An app can be based on a theoretical model but can lack an evidence base. The transtheoretical model was used as an example. One expert stated the following:

For instance, the Transtheoretical model, which is a typical theoretical foundation. If you look at the empirical evidence, it is not that good. [Health science expert panel A, expert in behavior change]

The same expert indicated that an expert rating of the PA–related app could also be interpreted as an evidence base.

4.4.4. Entry requirements related to app use

These are minimum conditions that support the use of the app. Examples are looks and usability, image of the app, and other requirements such as privacy and costs of the app.

At first, form, language, design, tone, and interaction were described as important entry requirements for an effective app. Second, usability was found important. It was defined in several ways and was related to functioning and simplicity of the app. One expert stated the following:

Does the app do what you expect from it and do specific functions work properly. It shouldn't be too complex and searching for functions should not take too much time. [Health science expert panel B, expert in injury prevention and monitoring]

Furthermore, according to an expert, usability of an app could be related to motivation to be active; the technical application and design of push notifications directed at motivating the app-user matter. He stated the following:

Usability, or ease of use, does it motivate you? Think about a push notification if you haven't done a task. This is a more functional application to motivate you. Not so much the knowledge and content are important, but also the technical application of a push message. [Technology expert panel, expert in ICT service design]

Stability, reliability, and robustness of the app were related to usability as well, as illustrated in the following quote:

So actually it is about how much you trust the app. [Technology expert panel, expert in ICT service design]

A third requirement was that the app should function properly, without bugs. Moreover, being able to connect the app to other tools (such as an online platform, activity tracker, or smartwatch) or being able to exchange data between platforms (i.e., portability) contributes to the usability of the app.

Experts from the health science expert panel B noticed that the image of the app may contribute to the effectiveness of a PA–related app. The image of the app depended on the reliability (credibility and properly functioning measurements and feedback), visibility, exposure, and popularity of the app. Exposure was described as brand awareness. One expert stated the following:

If there are a thousand apps in the app stores, you should be able to look at a screen shot and know "this is what I was looking for"...This has to do with exposure and marketing. [Health science expert panel A, expert in behavior change]

Two other entry requirements were discussed: costs of the app and privacy. Some experts thought that people would be more willing to download an app if it is free. However, according to some of the experts, you could see it as an investment as well. When you invest money in an app, then you may be more motivated to continue using it and potentially stay active as well. Two experts thought the price-quality ratio was more important for the effectiveness of an app, than the price only, as illustrated in the following quote:

The price does not determine the quality! That is not how I experience it. [Technology expert panel, expert in ICT service design]

Privacy was described as an upcoming topic. In other words, what do you have to say about your data, but additionally, what do app owners do with the collected data of users? The experts indicated that knowing how the privacy of your data is secured is an important entry requirement.

5. DISCUSSION

5.1. Principal findings

In this study, we conducted expert panels using the NGT to determine the perception of experts on which features are important for effectiveness of PA–related apps for participation in individual, recreational sports. A total of 25 features were ranked. Applied feedback and feedforward and fun were the most important features for experts in the field of industrial designers and information technologists. Instructional feedback, motivating feedback, motivating, or challenging and monitor or statistics, and peer rating and use were the most important features for experts on behavioral, health, and human movement sciences. The features monitoring or statistics, motivating feedback, technically properly working, tailoring starting point, fun or pleasure, usability, flexibility, look and feel, anticipating or context awareness, and privacy were frequently ranked in the top 10 as well. In line with the expertise of the two expert panels, features for behavior change as well as technical and design features were collected.

A qualitative analysis of the reasons behind the expert's choices showed four overarching themes: (1) combination behavior change, technical, and design features needed, (2) extended feedback and tailoring is advised, (3) theoretical or evidence base is the standard, and (4) entry requirements related to app use.

5.2. Comparison with prior work

The experts found a theoretical framework important; they ranked several features that were previously defined as BCT's in the taxonomy of Abraham and Michie [1]. Some of the ranked features were included in the MARS as well, such as engagement, usability, customization, and aesthetics [38]. However, based on the results of this study, more advanced features seem necessary to support sport participation. For instance, tailoring was an important feature with several subdomains, such as tailoring on start level, continued tailoring, adaptivity, and flexibility of the app. In contrast, the MARS only includes one question about customization [38]. A recent review suggested that a tailored approach in PA–related apps may increase their efficacy [36] which is in line with the present results. Furthermore, Op den Akker et al (2014) proposed a framework for tailoring of real-time PA coach systems [28]. The key concepts of this framework were feedback, interhuman interaction, adaptation, user targeting, goal setting, context awareness, and self-learning, which corresponds partly to our findings. Most of these concepts, such as feedback, adaptation, goal setting, context awareness, and self-learning were mentioned by the experts. In summary, the features the experts in this study described as important were in line with previous studies; however, subcategories of these features were ranked that were not perceived as evenly important. Potentially, a more detailed analysis of app sub features is necessary to determine the quality of PA–related apps for individual, recreational sport participants.

One expert highlighted that it is important to pay attention to the health aspects and safe sport participation. This was supported by the other experts (although not ranked in top 10). This matches with one of the BCT's (provide information about behavior-health link) as defined by Abraham and Michie [1]. The MARS offers an option to rate the potential impact of the app on the user's knowledge, attitudes, and intentions related to the healthy behavior [38]. However, according to the experts, these features seem essential and therefore, need to be included in the assessment of the quality of apps.

The experts rated and prioritized several types of features, including design, technical, and behavior change features. Interestingly, they also emphasized that domain specific knowledge should be integrated into PA–related apps. Technical features such as stability, portability, and connectivity were not included in the MARS [38]. In the MARS, some technical elements can be scored as yes or no in a checkbox. This does not indicate the degree in which this feature is integrated or designed. In line with our results, a previous study proposed that technical modalities in apps need to be considered in a taxonomy for mHealth apps [27]. Examples are the device type (which device is needed), interface (user-friendly interface), operating system type (e.g., Android or iPhone operating system, iOS, Apple Inc), and features (audio, video, email). In summary, current app ranking tools often focus mostly on one domain [1,17]. For instance, the MARS focuses mostly on behavior change [38], whereas the taxonomy of Olla and Shimskey focuses mostly on technical features [27]. We suggest that a multidisciplinary approach is suitable when examining the quality of PA–related apps. Behavior change, design, and technical features need to be assessed in a PA–related app rating scale.

The results of this study indicate that experts find some features from the top 10 more important than others. For instance, instructional feedback was ranked most important and privacy as least important in the health science expert panel. This may suggest that an app rating scale should apply a weighing of the items. Additionally, the qualitative analysis also showed that there are some entry requirements for the

effectiveness of a PA–related app. Without these features, the app probably will not be used. Therefore, we suggest that an app rating scale should contain a specific subsection in which entry requirements should be scored.
Interestingly, the experts indicated that more advanced features are needed to support sport participation. However, we need to keep in mind that the PA–related apps available in the app stores often lack a theoretical or evidence base and do not include advanced features. For instance, to the best knowledge of the authors, current PA–related apps do not take into account more advanced forms of tailoring, such as context awareness or tailoring on starting level and continued tailoring as suggested in this study. This highlights a gap between desired features in an optimal PA–related app and the features that are included in PA–related apps at this moment.

5.3. Strengths and limitations

A strength of our study was that we included experts from different expertise in the panels. Our study is subject to some limitations as well. First, several potential experts (2x12) were selected and invited for the sessions; however, many of them were not able to attend the session because of practical matters. Therefore, the number of experts was low. This may have decreased the generalizability of the results. Next, a convenience sample of experts were selected, as the experts needed to be able to travel to one of the two locations. This selection method could have resulted in selection bias, which could imply that we may have missed some important perspectives. Still, we were able to select experts with relevant experience and knowledge of development and evaluation of PA–related apps. Therefore, we think that these 11 participants provide a quite good representation.

We selected experts based on their scientific and professional expertise and therefore, think the experts had knowledge about current literature on PA–related apps. However, it is still possible that the experts believe that certain features are important for effectiveness of PA–related apps that in fact objective evidence may show are not effective. In the development of an improved PA–related rating scale, it is therefore recommended to combine the results of this study on expert opinions about important features with a literature review.

6. CONCLUSIONS

Taken together, the results show that experts from different fields of expertise think that a variety of features, including design, technical, and behavior change, are considered as important for the effectiveness of PA–related apps for sport participation. These results may assist in the development of an improved app rating scale for these apps that can indicate the quality. In other words, which PA–related apps could motivate (beginning) individual recreational sport practitioners during sport participation and support or help them with a healthy active lifestyle. On the basis of the results of this study, we recommend for the development of an improved PA–related app rating scale:

- To rate as well behavior change features as design and technical features
- Include assessment of theoretical or evidence base of the app
- A more detailed analysis of app sub features, for instance tailoring on start level, continued tailoring, adaptivity, and flexibility of the app
- Rate if the app informs about healthy and safe sports participation
- Rate entry requirements such as usability, bugs in the app, and image

The results of this paper are relevant for PA–related app designers as well. On the basis of this study, our advice is to work together with experts from different domains in the development of PA–related apps, take into account factors related to app use and app engagement (entry requirements), and make sure the app has a theoretical or evidence base. Furthermore, this paper indicates which features may be important to include in a PA–related app.

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8

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APP DECISION TOOL

On the basis of experts' opinions, Chapter 7 described which features in apps are pertinent and vital for stimulating and maintaining participation in individual, recreational sports. Experts agreed that working together with other experts from different fields of work is crucial as an interdisciplinary approach facilitates integration of knowledge of each field. We conclude that to design running-related technology, it is of prime importance to understand societal and personal needs (Chapter 6) and combine knowledge of different domains (Chapter 7). This chapter is a case study on such a design. We show a prototype that could support runners in the decision-making process for choosing running-related technology. This designed artefact is a decision tool that helps runners choose for themselves the most suitable app. This chapter also presents a methodological contribution; we derived three design principles from our design process. These principles can be used by designers who develop similar tools in the future.

1. ABSTRACT

In recent years, there has been an exponential increase in the use of health and sports-related smartphone applications (apps). This is also reflected in App-stores, which are stacked with thousands of health- and sports-apps, with new apps launched each day. These apps have great potential to monitor and support people's physical activity and health. For users, however, it is difficult to know which app suits their needs. In this paper, we present an online tool that supports the decision-making process for choosing an appropriate app. We constructed and validated a screening instrument to assess app content quality, together with the assessment of users' needs. Both served as input for building the tool through various iterations with prototypes and user tests. This resulted in an online tool which relies on app content quality scores to match the users' needs with apps that score high in the screening instrument on those particular needs. Users can add new apps to the database via the screening instrument, making the tool self-supportive and future proof. A feedback loop allows users to give feedback on the recommended app and how well it meets their needs. This feedback is added to the database and used in future filtering and recommendations. The principles used can be applied to other areas of sports, physical activity, and health to help users to select an app that suits their needs. Potentially increasing the long-term use of apps to monitor and to support physical activity and health.

2. INTRODUCTION

Recent years have witnessed an exponential increase in the availability and use of sports-related apps [7]. This low-cost, mainstream technology to monitor sports performance is embedded in people's daily life. Especially among runners, research shows that about 50-75% of (event) runners use a running-related app [4,7].

App-stores are stacked with thousands of sports-, fitness- and health-apps, with new apps launched every day. This comes with a significant challenge for users. There is an overload of available apps [12], making it hard for users to decide which apps from the existing large inventory meet their needs, leading to frustration or doubts during the decision process and sometimes even resulting in not choosing any app at all [11]. Thereby, it is also hard for users - often even impossible - to assess the qualities and limitations of an app before downloading it. The existing star-ratings in app stores can give users an idea of the quality of apps [6]. However, assessing the app based on the number of stars-based user reviews can be unreliable [2]. Acknowledging this problem, scholars developed instruments to review the quality of app content (e.g. [10]). Yet, these tools are mostly domain-specific and are limited in scope. We present an online tool that supports the decision-making process to choose an app based on its content quality. We will describe the development of this tool and give insight into its three design principles. Which are (1) app content quality scores are matched to the users' needs with apps that score high in the screening instrument on those particular needs, (2) users can add new apps to the database via the screening instrument, making the tool self-supportive and future proof and (3) a feedback loop allows users to give feedback on the recommended app and how well it meets their needs. For this study, we focused on runners and running apps.

3. DEVELOPMENT OF THE TOOL

We constructed and validated a screening instrument to assess app content quality. In parallel, we investigated the features runners need or wish in an app. Results of both methods served as the input for the built of the tool through various iterations with prototypes and user tests.

3.1. Construction and validation of the screening instrument to assess app quality

App-stores descriptions and ratings do not provide enough information to select the app that matches a user's need. To address this limitation, we relied on the construction of a screening instrument, developed to assess the qualities of apps from a multidisciplinary perspective. We combined a literature review and expert evaluations to gain insight into the qualities of apps. Then, we constructed an app quality screening instrument that was validated by researchers and end-users.

3.2. Developing an app quality screening instrument

To come up with features that are important to address app quality, we conducted a literature search. Combinations of search terms in different databases were used to identify relevant articles based on the content of the abstract and discussion section. The selected articles were used to construct a list of features related to app quality. In our case, aspects from existing screening instruments and taxonomies (e.g. [10] were used together with empirical evidence from (1) health and behavioural science literature, such as exercise guidelines and behaviour change techniques (e.g.

taxonomies of Behaviour Change [1], and insights from (2) design research literature, such as user-experience (e.g. [8]), and (3) persuasive design (e.g. [5]). Our literature search resulted in just over a hundred features that were important to address app quality. Next to the literature review, eleven experts in the fields of Industrial Design and Engineering, Computer Science, Human Movement Science and Behavioural Sciences participated in expert panels. For full details of this study see [3]. Results of the literature review and the expert panels were combined to construct the Sports App Screening Tool (SAST), encompassing 16 constructs (e.g. goal setting, monitoring, user experience), with a total 64 items scored on a 3-point-Likert scale.

3.3. Validation SAST

The SAST was tested and validated by researchers and end-users. First, five researchers (not study-related) independently and blindly screened the ten most downloaded running apps with the SAST. Interrater reliability was measured with Cohen's κ and was found to be sufficient (a ^{3} 0.669). Second, the validity of the items together with the scores on the items was discussed in a group session with all five researchers. Small adjustments were made to the items, mostly of linguistic nature.

Third, we conducted a user study to determine the applicability of SAST. We used Participatory Action Research with 15 end-users (i.e. recreational runners). These participants used three apps with the highest scores in SAST (Nike + Run Club, Runkeeper and Strava) for three weeks. Via a questionnaire, the applicability of SAST for the selected runners was assessed. According to the runners, the items in the SAST were clear. However, the ease of use of SAST was dependent on the user's level of experience with apps. Less experienced or unexperienced app-users had more trouble using SAST. Again small, mostly linguistic, adjustments were made to the items.

3.4. Getting insight into users' needs

Parallel to the development of SAST, the user needs were investigated. Fifteen runners (the same sample who participated in the Participatory Action Research) filled in an open-ended questionnaire. Questions inquired about the feature's runners need or wish. Participants indicated that the user-friendliness of an app is the most important criteria: "often app builders try to fill up the app with as many features as possible, while it turns out that no matter how complete an app is, it will not be used when the usability is low" (participant 12). The survey also showed that (1) being able to monitor progress, (2) comparing current data with previous data and setting goals, (3)

getting rewards, (4) getting feedback, and (5) sharing data with others are the functions mentioned as 'needed' by the runners.
We used this information (the screening of the ten most popular running apps and the obtained insight into users' needs) to build a prototype of the app decision tool.

A simple online platform with screen mock-ups was built (see figure 8.1): (1) user profile and user goals, (2) selection of important features, (3) filtering and matching, and (4) returning the results. A fifth building block was added subsequently and will be discussed later in the paper.

It was important to make the prototype tangible to get concrete feedback from users. Simultaneously with this prototyping phase, we conducted several sessions with end-users. We showed them the first prototype and asked them to talk us through everything that came up their mind. This think-aloud method [9] not only gave us insight into the prototype itself but also into users' cognitive processes during the selection of an app.

We further developed the content, for example by reformulating the questions in the first building block. The question 'What are you looking for' was added (see figure 8.2, screen 1). Only if the answer turned out to be that the user was looking for an app with more functionalities than the current app, the step to fill in the user goals was skipped, the user is directly forwarded to 'selection of important features.' For the second building block, the functional requirements were initially derived from the survey on user needs. The user tests revealed additional categories such as 'music', 'giving general information', etc. The think-aloud thus also revealed that we should help users in their decision process by pre-selecting features based on their user goals. For example, if a runner chooses that (s)he is physically active for social reasons and to become fitter, in the third screen the functions: setting goals, work with training schedules and sharing results would be pre-selected (see figure 8.2, screen 3).

Besides information about which features are important according to the users, information was also needed about how advanced the feature should be. For this, we developed so-called, in-depth questions that provide more detail about an important function (see figure 8.2, screen 4). The in-depth questions corresponded to the items in SAST. For example, if a runner selects 'I can set goals', this corresponds to one of the 16 constructs of SAST, namely Goal Setting. Because this construct consists of six items, six matching in-depth questions are asked, for example 'set individual goals myself'. This connection between the SAST and the in-depth questions allows us to directly match user needs with the scores of the apps on SAST. This direct match between the scores on the SAST and the question asked in the tool is one of the three design principles.

At this moment in the design process, additional iterations with end-users were conducted. We decided to publicly release the decision tool to collect in-situ data on how it is used and what choices are made by users. Simultaneously with the release of the system, we continued iterating and developed a fifth building block.

3.5. Making the tool future-proof

To deal with the rapidly growing world of (smartphone) apps, we attempted to make the tool future proof by adding two principles (i.e. design principle 2 and 3): a screening function for end-users and a feedback loop. The screening principle for users allows new apps to be screened by users and added to the database. SAST is used to act as a neutral entry point to add apps to the database (see figure 8.1, block V). The final principle is the feedback loop, which invites end-users to give feedback on the decision process (only if they are willing to contribute to the validation process). After three weeks, the end-user receives an e-mail to rate the experience with the app. This user feedback is used to improve the filtering of the apps in the database in relation to the in-depth questions, important functions and goals.

3.6. From first prototype to stable release

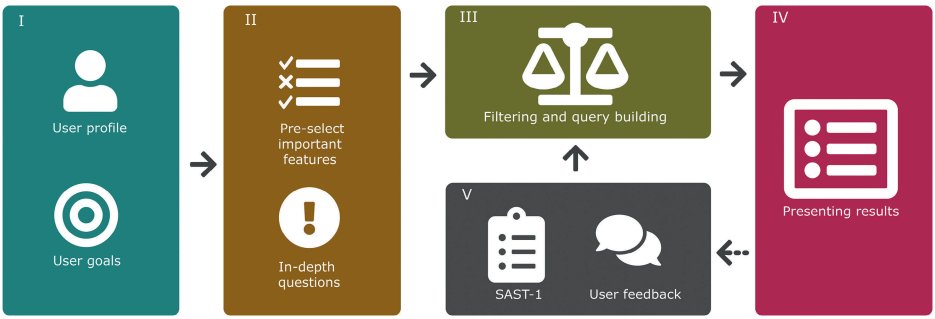

Figure 8.1. *Primary building blocks of the decision tool: (i) user profile and goals, (ii) selection of important features, (iii) filtering, (iv) presenting results, and (v) feedback loop and adding new apps*

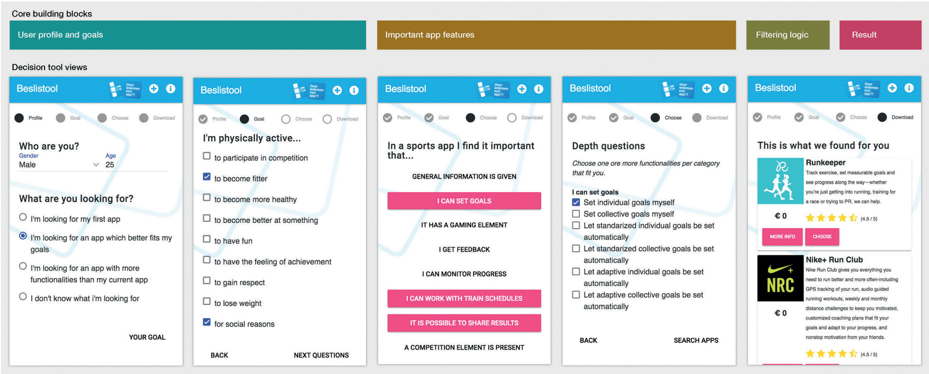

Figure 8.2. *The sequence of screens of the decision tool, including an outline of the core building blocks at the top bar. In the first screen (left) the user profile is determined. The second screen enquires about the user goals, or 'why they want to be more physically active'. These two screens together form the first building block. Next, the user selects the features they find important. A pre-selection is made to help the user. Then they fill out the in-depth questions on the features they deem important. After the fourth screen, the decision tool filters and match apps that fulfil the runners' needs. The matching apps are presented on the fifth screen and the user can download the app of their choice.*

4. DISCUSSION AND CONCLUSIONS

In this paper, we deployed a methodology to develop an online tool that supports the decision-making process to choose a smartphone application. We illustrated the method through a running-apps case study. Our approach included the development of a screening tool, the assessment of user needs, and iterative prototyping based on user testing, which resulted in a decision-making tool relying on three design principles. First, the direct match between the scores on the SAST and the question asked to users in the tool. Second, a screening principle where users can add new apps to the database through the SAST, to make the tool self-supportive and future proof. Third, a feedback loop allows users who followed the tool's recommendation to give feedback on the recommended app. This feedback is added to the database and therefore directly used in future filtering and recommendations. Besides these principles, the multidisciplinary approach is an essential asset in this context. This approach supports some practicalities like working on different aspects simultaneously, i.e. development of the screening tool was done simultaneously with the research on user needs and the iterations on the prototype were done parallel to the end-user testing. More importantly, we experienced that multidisciplinarity was required in several stages. For instance, the development and validation of the SAST where expertise of different disciplines were combined. But also, during the built of the first prototype where all disciplines were present to integrate the different expertise from the beginning of the process, making decisions that work for all the disciplines. Therefore, we managed to integrate all disciplines. Thereby, we argue that multidisciplinarity is not only required in this particular study, but that it applies to the whole domain of sports, health, and design. Where approaches from several perspectives are necessary to design meaningful tools, services, and practices.

4.1. Limitations and future work

First, we adjusted the screening tool to the needs of the end-users. In the future, we should consider making different versions of the screening tool, one that applies to end-user, but also a more extended version that could be used by researchers or experts. This could provide the decision tool with more detailed information. Second, we recommend fellow designers who want to follow our approach to integrate the feedback loop immediately in the first prototype. Adding it subsequently led to a limitation that the feedback loop was not user-tested. Finally, we used the same sample of runners in different steps. We would recommend broadening the view and feedback by recruiting new runners for each step. Finally, our three design principles should be applied to other contexts in the future, for instance, a different category of health apps or with different expertise within the teams.

4.2. Conclusion

The overall approach presented in this paper, as well as the underlying design principles, can be applied to other areas within sports, physical activity, and health to help users to select an app that matches their respective needs. The overarching goal is to eventually increase more diversity and long-term use of apps to monitor and support physical activity and health.

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Enriched with a description of the design process derived from another paper where we addressed the design process in a more elaborate fashion:

2. Steven Vos, Mark Janssen, Jos Goudsmit, Coen Lauwerijssen, and Aarnout Brombacher. 2016. From Problem to Solution: Developing a Personalized Smartphone Application for Recreational Runners following a Three-step Design Approach.[2] In *Procedia Engineering*, 799–805. DOI:https://doi.org/10.1016/j.proeng.2016.06.311

[2]Author contributions: Conceptualisation, SV, MJ, JG, and AB; methodology, SV, MJ, and JG; software, MJ, JG, and CL; analysis, SV, MJ, and JG; writing – original draft preparation, SV; writing – review and editing, MJ, JG, SV, and AB.

**Chapter is written in American English

INSPIRUN
E-COACH APP

Chapter 8 described design principles for the design of online tools that support the decision-making process of runners to choose smartphone applications. This method is illustrated in a case study on running apps, where we made a design artefact of the decision tool. In this chapter, we also create a design artefact. We will describe the design process of the Inspirun e-coach app, which uses a personalised coaching approach with automatic adaptation of training schemes. This app stimulates goal perception, motivation, and is personalised. We will present both the development process of the app, as well as the underlying algorithms and implementation of the app.

1. ABSTRACT

Among runners, there is a high drop-out rate due to injuries and loss of motivation. These runners often lack personalized guidance and support. While there is much potential for sports apps to act as (e-)coaches to help these runners to avoid injuries, set goals, and maintain good intentions, most available running apps primarily focus on persuasive design features like monitoring, they offer few or no features that support personalized guidance (e.g., personalized training schemes). Therefore, we give a detailed description of the working mechanism of Inspirun e-Coach app and on how this app uses a personalized coaching approach with automatic adaptation of training schemes based on biofeedback and GPS-data. We also share insights into how end-users experience this working mechanism. The primary conclusion of this study is that the working mechanism if provided with accurate data) automatically adapts training sessions to the runners' physical workload and stimulates runners' goal perception, motivation, and experienced personalization. With this mechanism, we attempted to make optimal use of the potential of wearable technology to support the large group of novice or less experienced runners and that by providing insight in our working mechanisms, it can be applied in other technologies, wearables, and types of sports.

2. INTRODUCTION

In recent years there has been an exponential increase in the availability and use of sports and physical activity-related monitoring devices such as smartphone applications (apps), activity trackers, and sports watches [1,2]. This increased use of these monitoring devices is consistent with trends like Quantified Self [39] and mHealth [10], which emphasize the potential of these monitoring devices to contribute to a healthy and active lifestyle by supporting behavior change [15]. In particular, smartphones have several advantages. They are widely used, are embedded in everyday life [7,44], and allow people to collect data anywhere, anytime [9]. Since most people already have a smartphone (up to 76% of adults) [40] and apps are relatively cheap, often even free of charge, apps are accessible for almost everyone. The use of sports apps in Western Europe is mainly reflected in individual, recreational sports such as running, cycling, walking, and fitness. Mainly among runners, apps are widely used. Research shows that approximately 50–75% of (event) runners use a running app, especially novice or less experienced runners [20]. Among these runners, there is a high drop-out rate due to injuries and loss of motivation. Because these runners often lack personalized guidance and support. While there is much potential for sports apps to act as (e-)coach to help these runners to avoid injuries, set goals, and maintain good intentions [12,19,44]. While most available running apps primarily focus on persuasive design features like monitoring, they offer few or no features that support personalized guidance (e.g., personalized training schemes) [29,30].

In this paper we show how we designed (prototyped and tested) Inspirun. Inspirun is an e-coach app for runners, that offers a personalized coaching approach with the automatic adaptation of training schemes based on biofeedback and GPS-data. First, we provide a short overview of related work. Second, we describe our design-approach. Third, we give a detailed description of the working mechanism of Inspirun. Then, we introduce the study protocol how we tested Inspirun. Finally, we present the results of the end-user test, and discuss the results of the testing.

3. RELATED WORK

Persuasive technology is studied extensively in the literature, also in relation to apps. A framework called Persuasive Systems Design (PSD) model is widely used for designing and evaluating systems that influence the attitudes or behaviors of users [33]. A review of Matthews et al. [29] on persuasive technologies used in apps, concludes that the most commonly used persuasive feature was self-monitoring. Thereby, apps often use data that is collected by the app to motivate the user to stay engaged (i.e., rewards, reminders, and suggestions). Matthews and colleagues [29] also conclude that many proven persuasive features are not utilized. Personalization is an example of one of these features that is (often) not implemented. Personalization is described by PSD framework as offering personalized content and services to the user. So, a tailored or personalized feature is one that is adapted to the characteristics of the end-user [4]. Specifically for running, Van Hooren et al. [19] propose a framework to optimize real-time feedback for reducing injury risk and improving performance and motivation. They argue that personalized real-time feedback on workload and running technique can be provided based on the individual preferences, experiences, and motives. For example, personalizing the type of feedback to suit preferences of the runner or personalizing the runners' training session to suit the runners' workload capacity. Research on the development of running (and other sports) related apps include systems that use several persuasive features as described in the PSD model. These technological systems can be divided into three different groups of studies, based on their objectives.

The first group of studies focuses on improving running technique to minimize injury. For example, Aranki et al. [2] developed RunningCoach, a mobile health system that monitors and gives feedback on running cadence to optimize it, and (possibly) minimize running injury. They use self-monitoring and a way of tailoring (feedback can be changed by the user) as a persuasive feature in their system. Another example is Runmerge, an app developed by Kiss et al. [23], which enhances body awareness using visualization of their steps to help runners towards a better running experience. Authors found that enhanced proprioception (i.e., 'knowing your body') can be beneficial for everyday running training. Nylander and Tholander [32] developed Runright, which provides real-time visual and audio feedback about the current running rhythm. Their non-interpretive visualization led users to their interpretation of the feedback. Valsted et al. [43] developed Strive, a wearable that aims to assist runners in achieving rhythmic breathing; a breathing technique that potentially leads to improved running results and lower injury risk. The user's understanding of feedback patterns based on self-monitoring was assessed.

A second topic that is often studied is the social aspects of running. In this category, dialogue and social support features are common. For example, Timmerman [42], investigated how technology can support a group of runners. In line with that, Mueller et al. [31] investigated how technology can support the social aspects of running. By introducing 'Jogging over a Distance', a system that allowed runners all over the world to run together using an audio-based social comparison feature. Further, HeartLink [6], a system that broadcasts live biometric data to social networks, and RUFUS [24], a system that enabled runners to communicate with supporters using 'praise' during races, are examples that also focus on the social aspects of running.

The third group of studies aims to enhance the motivation of runners. For example, the e-coaching ecosystem [3] offers interactions between end-users and human trainers to enhance motivation and stimulate a healthy and active lifestyle. Again, social support features are used as part of persuasive technology. A human trainer was essential in this design. Runners were more engaged when professionals offered or supervised the training sessions, compared to a group of runners with self-made training sessions and no supervision. Whereas most work related to motivation is focused on novice runners, Knaving et al. [25] determined a framework and guidelines to design technology for experienced runners.

In conclusion, most of the discussed studies do use persuasive features, mostly social support, or dialogue support features (as classified in the PSD-model). None of them implement personalization features in general, and none of them aim to personalize training sessions based on the runners' workload capacity.

4. DESIGN-APPROACH[1]

Inspirun was designed by a multidisciplinary team. This team was composed of experts in behavioral sciences (n = 1), human movement sciences (n = 2), electronic engineering (n = 2), and industrial design (n = 1). All experts were selected based on their educational background and having at least 5 years of experience in this domain. To understand the runner and to serve their interest and needs, crossovers between these different fields of work were necessary.

4.1. Focus groups end-users and professionals

The essential features for the application development were distinguished in multidisciplinary iterations, using qualitative research methods. First, five focus groups with runners (group size 5-10 participants) were conducted. The main was to discuss desired features of the most ideal running application. The group dynamic was stimulated by the use of cards displaying the different runner profiles. Second, five mind mapping sessions with professionals and senior students from different disciplines (psychology, human movement sciences, industrial design, and engineering) were organized in winter 2014 - spring 2015, on different locations. During these sessions the MoSCoW method was applied to define the essential features of the smartphone application [18].

[1]Based on Steven Vos, Mark Janssen, Jos Goudsmit, Coen Lauwerijssen, and Aarnout Brombacher. 2016. From Problem to Solution: Developing a Personalized Smartphone Application for Recreational Runners following a Three-step Design Approach. In Procedia Engineering, 799–805. DOI:https://doi.org/10.1016/j.proeng.2016.06.311

Runners following a Three-step Design Approach. In Procedia Engineering, 147, 2016, 799-805.

The results of this phase (focus groups and the multidisciplinary iterations with professionals) resulted in a list of six essential features:

- start or improve running in a healthy and fun way,
- personalized training schedules that fit runners profiles,
- scheduling has to take into account runners' work-life balance,
- tailored feedback on progress while running (cf. runners profiles),

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- a combination of perceived intensity and body feedback (heart rate), GPS data (distance, location, route, time) to adjust selected training scheme for the next training session, and
- capture data which can be used for monitoring.

4.2. Prototyping inspirun

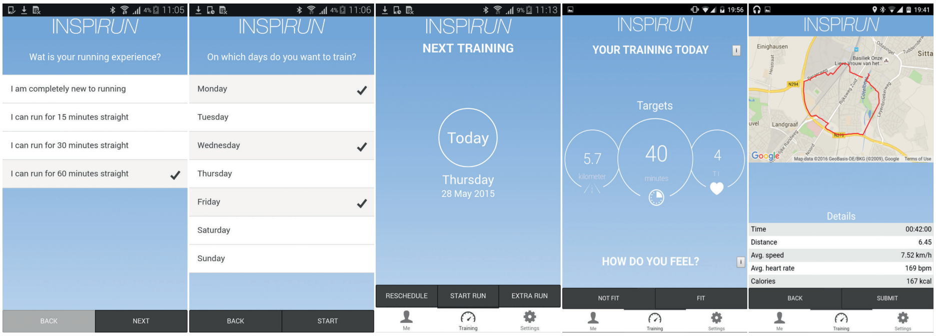

Figure 9.1. *The Inspirun personalized running coach*

Next, a first functional and aesthetic design for the user interface was created, incorporating all the user screens and the logical order between these. This formed, after review, the starting point of the implementation project in which an end-user ready product was developed. The implementation started with reverse engineering the API of the undocumented heart rate monitor (Wahoo TICKR X), followed by setting up the database structure to contain all training schedules and personal information. Step by step the various screens were added and tested, and specifications and user design modified along the process. After completion of the first alpha prototype for Android smartphones, three user studies were conducted, which input was used again to improve the application.

Inspirun is built with the Ionic Framework, and therefore is essentially a browser application, making heavy use of JavaScript and AngularJS. In addition, D3 is used for rendering vector graphics. A training session is the main ingredient for the Inspirun application. It bundles a considerable amount of sub-components together in order to provide an easy and intuitive interface to the entire training functionality of the application. A training session can only be started when there is an active GPS signal and connection to the Bluetooth heart rate monitor (see Figure 9.1).

The smallest pieces of information of a registered training are the data points. These are snapshots of an active training session, taken every 10 seconds. A data point stores vital information such as heart rate, running speed and GPS coordinates. In order to determine the block route, all data points coordinates are joined in an array of blocks. These blocks are subsequently combined in schemes. Schemes determine what kind of blocks each training consists of, how long these blocks are and the training intensity of the blocks. Each intensity level of a user is linked to both running speed and heart rate. Given an intensity profile and training results, Inspirun calculates how precisely a runner followed his personal schedule, or rather, how compliant he was to the target speed and heart rate per training block.

The training schedule is the combination of multiple training sessions, the associated blocks of that training, and a snapshot of the current user profile. With this information the runner may be presented an overview of the training to be done. In addition, this allows easy retrieval of target speed and heart rate at any moment during the training. For detailed explanation see next paragraph 5 'Working mechanisms of Inspirun'.

4.3. User testing and results

The application was validated in context and qualitative feedback on the system was collected in three user studies (n=28). In these user studies different versions of the application were evaluated and tested, using participative action research [26]. In user study 1, the first version (version 0.1) of the application was tested. A questionnaire with open-ended questions were used to gather qualitative data on five dimensions derived from the Mobile Application Rating Scale (MARS) [38]: (i) functionality, (ii) engagement, (iii) aesthetics, (iv) information and (v) app specific features. Based on the results of user study 1 the application was improved to a version 0.2. In user study 2 the same approach was used. Version 0.2 was tested and results from the open-ended questions were structured according to the earlier mentioned dimensions. Further improvements were implemented in version 0.3. The third user study focused especially on the novelty of the application. Features tested were: (i) match between provided training and running level and (ii) match between running profile and runner.

The main results of the three user studies are provided in Table 9.1. The majority of the participants were positive about the personal approach and expect that this app will have a positive effect on their motivation and ability to run. In the user studies, both experienced and unexperienced runners have participated (n=28). In user study 1, participants used version 0.1 of Inspirun. The results (see Table 9.1) were categorized according to the five dimensions (based on MARS) [38], which resulted in a number of improvements in version 0.2: (i) greater accuracy in running speed, (ii) implementation of sound and spoken feedback matching the psychographic profiles, (iii) ability to pause and abort a training session, (iv) more clear overview of the training session and (iv) several minor technical issues were solved. Next, experienced runners and researchers participated in user study 2. Again open-ended questions were categorized and as resulted in following improvements: (i) alignment between spoken feedback/ information and provided training intensity, (ii) being able to scroll through full training history, and (iii) training session adapts PRP when you choose the ‘not fit’ option. The third user study was aimed especially on the fifth dimension: app specific features. Only some minor bug fixes like pausing the music were not aligned with spoken feedback, volume of spoken feedback varies randomly and some crashes when saving training sessions needed to be fixed.

4.4. Implementation phase

In the implementation phase, a version 1.0 will be released, results from user study 3 will be implemented. A larger scale test will be enrolled using a quantitative intervention design. Participants use the app for a period of 10-13 weeks and complete at least a full trainings schedule of 20 sessions. Before, during and after this period, motivation and perceived advantages with regard running and to the use of app will be monitored over time. After completing a full trainings scheme, MARS will be used to measure quality of the application regarding the same five categories as previously used. See for study protocol and results of the implementation phase; paragraph 5 and 6.

Table 9.1. *Results of three user studies during prototyping phase, sorted by the dimensions derived from the Mobile Application Rating Scale [38]*

	User study 1	**User study 2**	**User study 3**
N	10	6	12
User type	Experienced / unexperienced runners	Experienced runners / researchers	Novice runners
Date	04/2015-06/2015	09/2015	12/2015
Engagement	Satisfaction with personalized approach Feedback on running speed is good but only provided through visual and vibration cues on the smartphone, audio feedback is lacking. The next training is planned 'today' The runner has to fill his user credentials every time	Spoken instructions and feedback are appraised. Instruction at the start of a training block and feedback during a training block are mixed up in some cases.	When listening to music in the background the pause is not consistent with the spoken feedback. Satisfaction with provided information while running
Functionality	Easy to use application Several technical issues: Running speed accuracy is not consistent Pairing the heart rate monitor In some cases 'starting training' freezes the application	Good compliance with other tracking apps and devices for Heart rate and running speed. The application blocks when submitting the training session and the data gets lost	Easy to use as a starting runner Some issues in saving training sessions.
Aesthetics	Feedback timer during running is too small Pause button during running is too small The visual representation of the training session is not logic to the runner Modern 'Look and Feel'	Scaling problems on a couple of screens. (training overview and RPE screen after training)	
Information	More textual explanation is needed for several functions (test sessions,		

Table 9.1. *Continued.*

	User study 1	**User study 2**	**User study 3**
N	10	6	12
App Specific features:	What if running type changes over time? Test training sessions were incorrect engineered	Some technical issues according to the calculations for the runners profile Only the last 10 training sessions are available in the history section.	Running type has consistent outcome Provided training schedule match running level Satisfaction with guidance for running speed and heart rate Targets for heart rate and running speed seems consistent with running level.

5. WORKING MECHANISMS OF INSPIRUN

5.1. Algorithm that automatically adjusts the training schemes

To create an algorithm that automatically adjusts the training scheme, we analyzed the approach that experienced coaches and trainers use when creating training schedules for runners. Interviews with experienced coaches and trainers (those who had at least 5 years of experience in coaching and training) revealed that in general, most coaches and trainers take the following steps (see also Figure 9.2):

- Collect data about the runners' current running level
- Select running goals for the upcoming training period and analyze the data of the current running level.
- Select training sessions that match their level and contribute to the running goals.
- Monitor during the running session and coach during/after the running session (comparing the executed data to the prescribed data).
- Adjust the next training session based on the comparison of prescribed and executed data.
- Continue iteratively with step 4 and step 5.

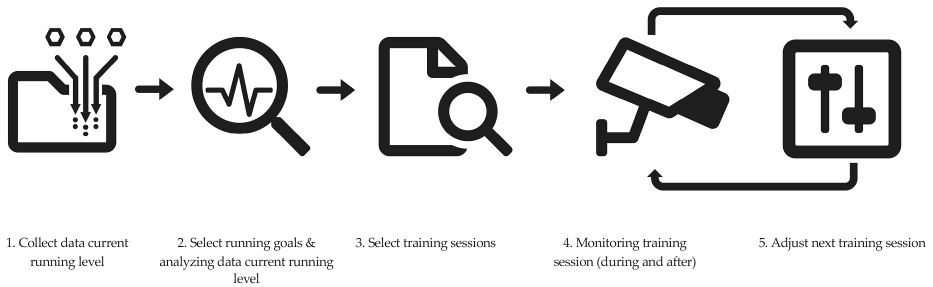

Figure 9.2. *Steps taken by coaches and trainers when creating training schedules for runners. Final step is to continue iteratively with step 4 and step 5.*

5.1.1. Step 1 and 2: Data and analysis of the current running level and select running goals.

To collect the runners' current running level and select running goals for the upcoming training period (Step 1), we first designed a questionnaire to give insight into their current running level and running goals. Runners had to choose one of four possible answers: 'I am completely new to running', 'I can run for 15 min without walking', 'I can run for 30 min without walking', or 'I can run for 60 min without walking'. Next, the running goal selection in our system was based on this self-declared current running level. If they were completely new to running, the easiest running goal (running 15 min without walking) was automatically assigned. If they were already able to run for 15 min without walking, again a running goal was automatically assigned, namely running 5 km without walking. If a runner was able to run 30 or 60 min without walking, he/she was allowed to choose their own goal. Available options were (i) running 5 km faster, (ii) running 10 km without walking, or (iii) running 10 km faster (see Figure 9.3 for a simplified flowchart and Supplementary File S1 for the full detailed flowchart).

In order to collect objective data about runners' current running level, we designed different test programs that consist of three running sessions. For each test session, we collected the heart rate (body feedback), GPS-data, and the perception of the training intensity (Rating of Perceived Exertion (RPE-score), a subjective parameter). In the test sessions, Inspirun only gave instructions to the runner but no feedback. For example, in the first session one of the instructions was: 'start running at a comfortable pace' and 'you are doing well if you breathe heavily but are able to have a conversation as well'. With this instruction, runners started running at their own comfortable pace. Meanwhile, the app registered heart rate data, running speed, and RPE-score. During the test sessions, information was collected on the heart rate values and RPE scores for different running speeds (jogging, easy running, comfortable speed, hard running, and very hard running) We labelled this relation between speed, heart rate, and RPE as the Personal Running Profile (PRP). See Table 9.2 for an example, of a current PRP after the three test sessions.

5.1.2. Step 3: Select training sessions that match their level and contribute to the running goals

The second step in the process was the selection of training sessions that match the runner's current running level and that contribute to their goal. We used five generally accepted training principles (i.e., individualization, progression, overload, variation, and objective and subjective monitoring of the performance [14,22,28]) in combination with the expertise of the human movement scientists, involved in the development of the Inspirun e-coach, to create training schedules. For each goal (e.g., running 5 km without walking), a training schedule was constructed. In total, a schedule consists of 20 sessions divided over several weeks, dependent on the number of sessions per week (between 1 and 3). To make the training schedules and sessions applicable to all runners, we chose to personalize training sessions based on workload and intensity. This means that the training schedule (i.e., distance, total time, and type of training) was the same for a runner with the same running level and goal, while the intensity varies per runner. We chose RPE as the parameter for intensity because of its validity, reliability, and internal consistency [13,17]. In the app, there is an explanation how runners should use the RPE score. For each score the runner can read an explanation how this RPE should feel in terms of breathing, the ability to talk, and the RPE is expressed in words like, hard/very hard/comfortable [13]. See Table 9.3 for some examples of training sessions.

5.1.3. Step 4: Monitoring during the running session and coaching during/after the running session (comparing the executed data to the prescribed data)

The third step is to monitor each running session and coach the runner (by comparing the performance data to the prescribed data). To prescribe a training session, the most current PRP (current PRP is an average of the last six sessions) is used for each session (see Table 9.4 for an example). This means that for each RPE present in that specific session, the matching speed and heart rate are selected. For example, in Table 9.5, all data of session 7 of participant 7 is shown. Session 7 consists of blocks between RPE 3 and 8. The current PRP (see Table 9.4, PRP before session 7) of this participant is used to prescribe the speed and heart rate at a given RPE (e.g., at RPE 4, HR 124 bpm, speed 10.1 km/h). To coach the runner during the run, prescribed data and real-life data are constantly compared. This means that, for instance, when accordingly, the PRP of the prescribed heart rate in the RPE7 block should be 141 bpm, but real-life data shows heart rates that deviate more than 5 bpm from the prescribed heart rate, the app reacts with feedback. This feedback is given in a natural way, by giving the instructions to increase or decrease running speed. If a runner, in this example, has a real-life heart rate of 154 bpm, he/she is instructed to slow down, to lower the heart rate to the prescribed range of 136–146 bpm (141 ± 5 bpm). Whereas if the runner runs with for example 133 bpm, he/she is instructed to speed up, in order to increase the heart rate to the prescribed range of 136–146bpm (141 ± 5 bpm). Immediately after the training session, Inspirun asks the runner to fill in the RPE. In this case, it is expected that the runner fills in RPE of 7 for this block. If he/she does this (i.e., the filled-in RPE matches with the prescribed RPE), then the data from that running block will be used to improve the data of RPE7 in the PRP. If not, and for instance, RPE of

8 is given (while RPE7 was prescribed), the data of that running block is used in the data of RPE8 in the PRP.

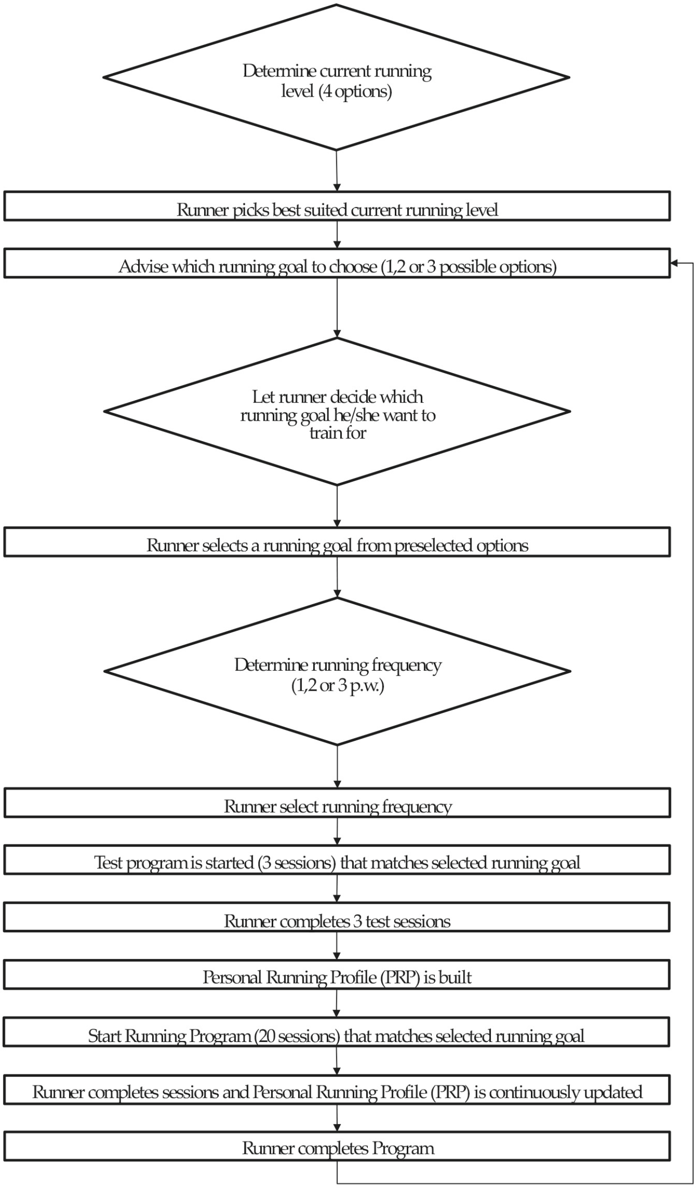

Figure 9.3. *Simplified flowchart of Inspirun. Starting from the running experience, to running goal, and which training scheme fits best.*

After each training session, the system calculates a compliance-score based on the match of the actual monitored data (i.e., the heart rate and the mean running speed of the training blocks) with the prescribed data. A score of 100% means that the monitored data matched completely with the prescribed data. A score above 100% indicates that a runner performed better than expected (e.g., lower heart rate at a given speed or lower perceived intensity/higher running speed at prescribed heart rate), while a score below 100% means that a runner did not perform as well as expected. When calculating the compliance-score, only training blocks with an RPE of 4 or higher are taken into account, because an RPE score of 3 or lower is only used as recovery between intervals. Therefore, the first minute of every interval is not used in the calculation. The reason for this is that increase and decrease in heart rate was delayed compared to speed. After 60 s, heart rate should be levelled off and/or in steady-state (depending on the intensity) and then the relation to speed is meaningful and useful to calculate the match between prescribed and actual performance. Eventually, this compliance score gives insight into the progression of the runner and feedback for the runner how well the training session was executed. See Table 9.5 for the compliance scores of participant 7. This runner scored a total compliance-score of 97%, which indicates that the actual heart rate and speed were in line with the current PRP.

Table 9.2*. Example of a current Personal Running Profile (PRP) after the three test sessions, heart rate values (beats per minute), and Rating of Perceived Exertion (RPE) scores for different running speeds (kilometres per hour) (jogging, easy running, comfortable speed, hard running, and very hard running).*

	Test 1			**Test 2**			**Test 3**			**Current PRP**		
Pace	RPE	Speed	Heart rate	RPE	Speed	Heart rate	RPE	Speed	Heart rate	RPE	Speed	Heart rate
Jogging	4	10.0	121	4	10.2	124				4	10.1	123
Easy							5	11.6	139	5	11.6	139
Comfortable	6	12.3	145	6	12.2	146	6	12.1	143	6	12.2	145
Hard				7	13.8	156	7	13.4	150	7	13.6	153
Very Hard							8	14.8	173	8	14.8	173

Table 9.3. *Examples of training sessions within a training scheme, different intensity blocks are highlighted. Illustrated sessions use different types of intervals (short and long), have a duration between 27 and 32 min, and the intensity varies between RPE3 till RPE8.*

Session	Time in Minutes per Session																				
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**
1	4	4	4	6	6	6	3	7	7	4	8	8	3	3	7	7	4	8	8	3	3
2	4	4	4	6	6	3	7	7	8	7	7	7	7	8	7	7	7	7	8	7	7
3	4	4	4	6	6	6	3	6	6	6	6	6	6	6	6	7	3	3	6	6	6
4	4	4	4	6	6	3	6	6	6	6	6	7	7	7	6	6	6	6	7	7	7
5	4	4	4	6	6	6	3	8	8	8	3	7	7	7	3	6	8	6	3	7	7
6	4	4	4	6	6	3	6	6	7	7	8	7	7	7	7	6	6	7	7	7	7

Session	Time in Minutes per Session										
	22	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**
1	7	7	4	8	8	3	3	4	4	4	4
2	3	3	4	4	4	4					
3	6	6	6	6	6	7	3	4	4	4	4
4	6	6	6	3	4	4	4	4			
5	7	3	8	8	8	3	3	4	4	4	4
6	8	7	7	3	3	4	4	4	4		

Table 9.4. *Current PRP before session 7 from participant 7. Heart rate in beats per minute, speed in kilometres per hour.*

Current PRP before Session 7		
RPE	**Speed**	**Heart Rate**
1	0	0
2	7.20	115
3	7.74	120
4	7.85	124
5	7.99	125
6	9.00	133
7	10.01	141
8	11.02	155
9	11.99	169
10	12.24	173

5.1.4. Step 5: Adjust the next training session based on the comparison of prescribed and executed data

In the final step, the data of the newly completed training is added to the PRP. The average heart rate and the average speed per training block are computed. In line with the calculation of the compliance-score, the first minute is not taken into account.

We illustrate this with the example from Table 9.5. Towards the end of the session, there is a training block of 4 min on RPE7 (which is highlighted). The average speed is calculated by averaging 9.54, 9.35, and 8.41 km/h, and the heart rate by averaging 141, 144, 145. In this case, resulting in 9.1 km/h and 143 bpm (assuming the runner did perceive this running block as RPE of 7). This 9.1 km/h and 143 bpm at RPE 7 are added to the PRP.

Before the start of every new session, the data of the last six training sessions are used to calculate average heart rates and average speeds per RPE (as seen in Table 9.4). These values are labelled as the current PRP. In the case of participant 7 (illustrated in Table 9.4), the PRP after session 7, uses the data of session 2, 3, 4, 5, 6, and 7, (which are the last 6 sessions) and the data of session 1 is not included in the PRP anymore. By doing this, the PRP is constantly updated, and the runners' profile is continuously evaluated. Furthermore, as a consequence of using an average over six sessions, outliers (i.e., an exceptional good or bad training session) have minimal impact on the PRP. However, as a runner improves over time, the PRP gradually adjusts, and thus, the prescribed intensity for the next training session changes gradually, minimizing the risk of injury [27].

Table 9.5. *Overview of the data of session 7 from participant 7. Showing the prescribed intensity in RPE, speed (in kilometres per hour) and heart rate (in beats per minute) in the first columns, the actual monitored data (while running) in the middle columns, and the compliance scores in the last columns.*

	Prescribed		**Actual**		**Compliance**		
Intensity	**Speed**	**Heart Rate**	**Speed**	**Heart Rate**	**Speed**	**Heart Rate**	**Total**
4	7.85	124	6.79	99	*	*	*
4	7.85	124	7.83	128	100%	103%	97%
4	7.85	124	8.10	132	103%	107%	97%
6	9.00	133	8.65	136	*	*	*
6	9.00	133	8.65	142	96%	107%	90%
3	7.74	120	6.09	125	**	**	**
5	7.99	125	8.28	121	*	*	*
5	7.99	125	9.73	146	122%	117%	104%
5	7.99	125	9.79	149	122%	119%	102%
5	7.99	125	9.85	148	123%	119%	104%
5	7.99	125	9.08	146	114%	117%	97%
5	7.99	125	9.30	148	116%	119%	98%
5	7.99	125	9.24	145	116%	116%	99%
3	7.74	120	5.63	125	**	**	**
3	7.74	120	5.17	99	**	**	**
6	9.00	133	8.54	130	*	*	*
6	9.00	133	9.83	145	109%	109%	100%
6	9.00	133	9.27	144	103%	108%	95%
6	9.00	133	10.01	148	111%	112%	100%
6	9.00	133	8.11	145	90%	109%	83%
6	9.00	133	9.43	143	105%	107%	98%
6	9.00	133	9.53	147	106%	111%	96%
3	7.74	120	5.75	129	**	**	**
3	7.74	120	5.13	100	**	**	**
7	10.01	141	7.52	113	*	*	*
7	10.01	141	9.54	141	95%	100%	95%
7	10.01	141	9.35	144	93%	102%	91%
7	10.01	141	8.41	145	84%	103%	82%

Table 9.5. *Continued.*

	Prescribed		Actual		Compliance		
Intensity	**Speed**	**Heart Rate**	**Speed**	**Heart Rate**	**Speed**	**Heart Rate**	**Total**
3	7.74	120	6.33	129	**	**	**
3	7.74	120	6.02	111	**	**	**
8	11.02	155	12.09	145	*	*	*
8	11.02	155	13.49	169	122%	109%	112%
8	11.02	155	12.78	171	116%	110%	105%
8	11.02	155	12.26	170	111%	110%	102%
3	7.74	120	6.46	154	**	**	**
4	7.85	124	7.19	132	*	*	*
4	7.85	124	7.75	137	99%	110%	89%
4	7.85	124	8.18	138	104%	111%	94%
4	7.85	124	8.15	141	104%	114%	91%
4	7.85	124	7.96	139	101%	112%	90%
5.66	8.87	132.75	9.21	141.51	107%	110%	97%

* Not calculated since it is the first minute this block. ** Not calculated since RPE < 4.

6. STUDY PROTOCOL

6.1. Study protocol

We designed a study protocol to get insight into (i) how end-users experience the personalization of the training schedule, and (ii) whether this approach motivates them to keep running. Between spring 2018 and autumn 2018, we posted a call on various social media to participate in our study. All runners that were injury-free and were willing to train for one of the five goals Inspirun focusses on could participate. The participants had to (i) run at least once a week and (ii) use the Inspirun app until they completed a training schedule consisting of 20 training sessions. We used online questionnaires and the data collected by the Inspirun app to monitor the participants over time. Ethical approval for the study was obtained by the Ethical Research Committee of Fontys University of Applied Sciences. An introduction letter informed the participants about the purpose of the study, the anonymization of the data, and the incentive (Wahoo TICKR X) they would receive when completing the 20 training sessions. In total, 43 runners reacted that they want to participate in our study, of which 19 participants agreed to participate in the study and complete all training sessions.

Before their first run, participants had to complete the first questionnaire (T0) to gather information on their socio-demographics, running experience, and previous experience with apps and wearable technology. After three running (test) sessions (T1), participants received a second questionnaire every five sessions (T1, T2, T3, T4, T5). This questionnaire focused on their experiences with the app over the last sessions. Participants continued to receive this questionnaire until they had completed the training schedule (=20 sessions). After completion of the training schedule (T5), an additional third questionnaire (T6) was provided to score their experience over the full test period (see Table 9.6). Overall, we thus covered the different timespans of user experience; anticipated, episodic, and cumulative experience as defined by Roto et al. [34].

Table 9.6. *Timeline of the three questionnaires (Q1, Q2, and Q3).*

	T0	T1	T2	T3	T4	T5	T6
Timespan of experience	Anticipated experience	Episodic experience					Cumulative experience
When	Before using the apps	After 3 test sessions	After 5 training sessions	After 10 training sessions	After 15 training sessions	After 20 training sessions	After 20 training sessions
Question-naire	Q1: Background information	Q2: Experience with the app over the last sessions					Q3: Experience with the app over the full test period
Number of responses	19	19	19	19	19	19	16

6.2. Measures

The first questionnaire (used at T0) was constructed similarly to previous research of Janssen et al. [8,20,21] and Clermont et al. [5] containing a set of variables including (i) socio-demographic variables; (ii) running-related variables; and (iii) previous experience with wearable technology. The socio-demographic variables include gender, age, and level of education. The group of running-related characteristics consists of variables that are directly related to running and that define the level of running involvement: running frequency (number of runs per week), running distance

(distance in kilometre per week), active participation in running (years of active running participation), running context (individual, with friends, colleagues and/or running groups, or running clubs), and the most practiced sport (running/other sport).

For T1–T5, a second questionnaire was used. With this questionnaire, we measured the user experience over the last five training sessions with three items (5-point Likert, ranging from 1 = completely disagree to 5 = completely agree) focused on goal perception, motivation to keep running, and personalization. In item 1, we asked whether they felt that the training sessions contributed to their goal. In item 2, whether Inspirun motivates them to run, and in item 3, whether the intensity of the training sessions was accurately adjusted to their running level. For all items, we gave them the option to explain why they gave that particular score (open-ended question).

The third questionnaire (T6) retrospectively measured the entire experience of the automatically adjusted training sessions and motivation to keep running throughout all training sessions. We used the same three items as in the second questionnaire, but we asked the participants to assess these items over the entire testing period instead of the last five training sessions.

6.3. Analysis

Frequencies and descriptive analyses were run on (i) socio-demographic variables; (ii) running-related variables; and (iii) experience with technology. Secondly, descriptive analyses (mean, sd) for all three items, for every questionnaire (T1–T6) were calculated. Third, possible differences in these three items over time (between T1, T2, T3, T4, T5, and T6) were investigated using the non-parametric version of repeated measure (Friedman). Finally, Spearman correlations were analyzed between the three items using all answers (T1, T2, T3, T4, T5, and T6 combined).

7. RESULTS

7.1. Participants

Ten of the 19 runners that completed the training schedule are female. The participants' age ranged from 21 years old to 60 years old (averaging 35 years). Of which, 85% is higher educated, and 10 of them are fulltime employed. Among the 19 participants, the distribution over the different running goals was relatively equal (see Table 9.7). Although none of them belonged to the beginner group (those who could not run 15 min without walking), two of the 19 runners did not participate in running before (but were still capable of running 15 min without walking). Five of the 19 runners perceive running as their main sport. The running experience ranges from less than 3 months to 5 or more years of experience. Whereas most runners run 0 to 5 km per session and run once or twice a week. Finally, out of the 17 that ran before, 13 runners run mostly individually, the rest runs in a sports club, with friends, family, or small running groups.

7.2. Motivation and goal perception

Item 1 on goal perception and item 2 on motivation were both answered 111 times (T1–T6), the goal perception scored an average of 3.95 (SD = 0.88) and the motivation to keep running scored on average 4.01 (SD = 0.99) (see Table 9.8 and Figure 9.4).

On both items, no score of 1 out of 5 (totally disagree) was given. On item 1 goal perception, 9 times a negative score (disagree) was given, 17 times a neutral score of 3 out of 5, 55 times a positive score of 4 (agree), and 34 times the maximum positive score of 5 out of 5, meaning that they totally agreed with this item. On motivation (item 2), 11 times a negative score was given (again only scores of 2 out of 5), 20 times a neutral score of 3 out of 5, 36 times a positive score of 4, and 44 times the maximum positive score of 5 out of 5. The optional open-ended questions revealed that overall, most runners perceived the sessions as challenging but not too hard. They also had the feeling that they (slowly) progressed over time. Some runners perceived this as positive, while others as negative. In contrast, the negative influencers of the motivation were mostly the irritation of trying to reconnect the heart rate sensor while running and the summary after the run when it gave incorrect speed or heart rate due to measuring flaws.

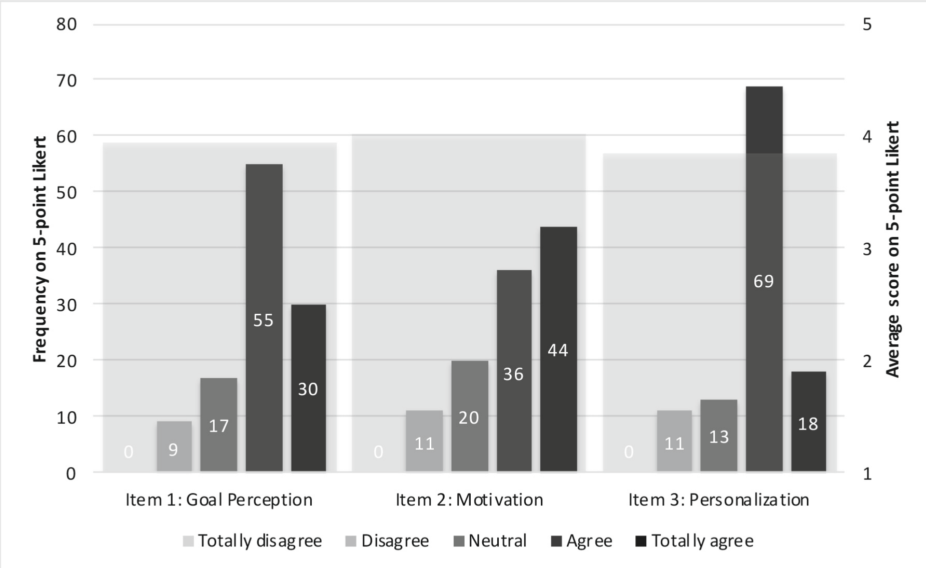

Figure 9.4. *Frequency of given answer on a 5-point Likert scale on items 1, 2, and 3 (left y-as) and the average score of items 1, 2, and 3 (right y-as).*

7.3. Personalization

On average (N = 111), the personalization of the session with regards to the running level was assessed as 3.84 (SD 0.82) on a 5-point Likert scale (Table 9.8).

Out of 111 times this item was answered, 11 times a negative score was given and 13 times a neutral score of 3 out of 5. Most participants explained these scores. Reasons mentioned were related to the accuracy of the speed measurement, that the speed was not measured accuracy and that therefore they had the feeling that the scheme could not personalize accordingly. Therefore, also instabilities of the Bluetooth connection between the phone and the heart rate monitor were given as a reason, therefore heart rate connection was sometimes lost during running, causing inaccurate heart rate measures. We checked these claims by analyzing the app data and indeed, for these particular runners, the heart rate or GPS data was missing from the PRP for multiple runs. Finally, the runners mentioned that some sessions were too easy and that they had the feeling that the app was adjusting too slow or being too conservative. They felt they could progress faster than the algorithm prescribed. Another explanation why they scored negatively or neutral mentioned that they expected a different personalization, for example on the type of session (i.e., interval or endurance training) and on time and distance (i.e., self-selecting the distance, instead of prescribed by the app), rather than adjustments on intensity. Those who were positive (*n* = 87) about the personalization (scoring a 4 or 5) experienced the gradual increase of the intensity as pleasant. They (again) stated that the sessions were challenging without being too hard (Figure 9.4).

7.4. Relation between personalization, motivation, and goal perception

For all three items, there was no significant difference between anticipated, episodic, and cumulative experiences, meaning that no differences were found across time during the testing period. Spearman-correlations ($n = 111$) revealed a moderate to strong positive relation between items. Goal perception is moderately correlated to the motivation to keep running, with an explained variance of 48% ($r = 0.695$, $p < 0.001$). Goal perception also correlates moderately with personalization, with an explained variance of 36% ($r = 0.597$, $p < 0.001$). While motivation to keep running correlates also moderately with personalization, with an explained variance of 32% ($r= 0.563$, $p < 0.001$). These analyses show that if scores on one of the items increase, in 32% to 48% of the cases, the score on the other items increases too.

Table 9.7. *Overview of all descriptive variables for each participant of the first questionnaire.*

Participant	Goal	Age	Gender	Education	Currently a Runner	Main Sport	Active Participation in Running	Average Training Distance per Run	Frequency per Week	Running Context
1	05 km	42	Male	Middle	Yes	No	<1 year	0–5k	2x	Individually
2	05 km	21	Female	Higher	Yes	No	<3 months	0–5k	1x a year	Individually
3	05 km	48	Male	Higher	Yes	No	<3 months	0–5k	1x a year	Individually
4	05 km	40	Female	Middle	No					
5	05 km	26	Female	Higher	No					
6	05 kmfaster	26	Female	Higher	Yes	No	1–3 years	0–5k	1x	Individually
7	05 kmfaster	41	Male	Higher	Yes	Yes	1–3 years	6–10k	1x	Small Running Groups
8	05 kmfaster	33	Female	Higher	Yes	No	1–3 years	0–5k	1x	Individually
9	05 kmfaster	37	Female	Higher	Yes	Yes	1–3 years	6–10k	2x	Friends and Family
10	05 kmfaster	23	Male	Middle	Yes	No	<3 months	0–5k	1x	Individually
11	10k	22	Male	Higher	Yes	No	1–3 years	6–10k	1x	Individually
12	10k	60	Male	Higher	Yes	No	1–3 years	0–5k	2x	Friends and Family
13	10k	21	Female	Higher	Yes	No	<3 months	0–5k	1x	Individually
14	10k	43	Male	Higher	Yes	No	>5 years	0–5k	1x a month	Individually
15	10k	41	Female	Higher	Yes	Yes	>5 years	0–5k	2x	Small Running Groups
16	10 kmfaster	30	Female	Higher	Yes	Yes	1–3 years	6–10k	3x	Individually
17	10 kmfaster	35	Male	Higher	Yes	No	1–3 years	6–10k	1x	Individually
18	10 kmfaster	42	Female	Higher	Yes	No	>5 years	11–15k	2x	Individually
19	10 kmfaster	43	Male	Higher	Yes	Yes	>5 years	11–15k	1x	Individually

Table 9.8. *Mean scores and standard deviations on all items.*

	Item 1: Goal Perceptions		**Item 2: Motivation**		**Item 3: Personalization**	
	Mean	SD	Mean	SD	Mean	SD
T1	4.05	0.85	4.37	0.83	3.95	0.91
T2	3.95	0.78	3.95	1.03	3.95	0.52
T3	4.16	0.83	4.11	1.10	3.84	0.90
T4	3.95	0.85	4.00	0.94	3.79	0.79
T5	3.84	0.83	3.84	0.96	3.84	0.90
T6	3.75	1.13	3.81	1.11	3.69	0.87
Average	3.95	0.88	4.01	0.99	3.84	0.82

* all tested for Friedman repeated measures, no sign between T1–T6 for any item.

8. DISCUSSION AND CONCLUSIONS

8.1. Personalization of training session

Inspirun was designed to provide personalized training schemes based on biofeedback, GPS-data, and RPE. The present paper gave a detailed description of the working mechanism; the personalized coaching approach with the automatic adaptation of training schemes based on biofeedback and GPS-data and aimed to give insight into how end-users experience this working.

The primary conclusion of this study is that the working mechanism (if provided with accurate data) automatically adapts training sessions to the runners' physical workload and stimulates runners' goal perception, motivation, and experienced personalization.

Our user study revealed that in general, the personalization of the intensity of the training sessions was experienced as personalized by the participants. Participants, whose data collected with the app was complete and without flaws and gaps, found that the sessions were accurate, and experienced them as personalized. We expected that using generally accepted training principles (i.e., individualization, progression, overload, variation, and objective and subjective monitoring) to personalize and adjust the session would works. In line with Van Hooren et al. [19] who stated that workload can be used as characteristics to personalize. Indeed, our findings confirm that building a feature that personalizes the workload (PRP) on both subjective (RPE) and objective (HR and Speed) aspects of intensity seems to be a good combination to develop a mechanism that is sensible for change and is robust enough to deal with fluctuation between sessions. We used personalization as a persuasive feature derived from the Persuasive Systems Design (PSD) model [33], in which personalization is a feature that is not often used in persuasive design, despite its potential [29].

For runners whose data collected by the app was incomplete or inaccurate, the mechanism was not perceived as personalized. This is in line with challenges described in previous research, for example, Seshadri et al. [36] showed that when developing sensor technology we should design robust and easy-to-wear systems with improved signal to noise ratios. Wan an et al. [1] stated that there are still many challenges before the actual implementation of technology in practical applications, they also refer to noisy signals and challenging issues regarding the power source. Specht et al. [37] investigated satellite-based solutions to identify positioning (time, distance, and speed) and found that the existing systems (e.g., GPS) are not accurate. Especially when more intense activities are performed, the processing of raw data needs to improve in order to provide accurate and meaningful feedback [16]. In our case, running can be classified as intense activity-gaps in heart rate data caused problems in the automatic calculation of the next session.

For example, some runners had problems with the Bluetooth connection between the heart rate monitor and their phone. While running, the Bluetooth connection was lost, and the app did not collect heart rate data. Instead it writes zeros in the dataset. In most cases, this caused a much lower average heart rate over a training block (due to many zeros). Consequently, making the app think that the automatically generated heart rates were too high in relation to running speed and RPE. The same goes for inaccuracies in running speed. Runners experienced some problems when running in wooded and hilly areas, resulting in mostly lower speeds than expected, making the app think that the session was too challenging to complete when this was actually due to the environment (i.e., sandy surfaces, altimeters) accuracy of the GPS signal (i.e., cutting corners, densely vegetated areas). The mechanism of creating automatically and personalized training sessions thus seems to work when provided with complete and accurate data, although the robustness of the mechanism, especially how it deals with flaws in the dataset needs improvements. In future work, first of all, the Bluetooth connection must be improved. Second, to make the mechanism more robust, the algorithm must be adjusted so that incomplete datasets (e.g., with too many zeros) are not used or used differently in the PRP.

8.2. Motivation to keep running

On average, the participants were quite positive about the influence on the app on their motivation to keep running. The open-ended question revealed that the reasons for scoring lower on motivation are essentially the same as the reasons that lowered the experienced personalization. In both cases, the bug that caused disconnection of the heart rate monitor and the resulting incomplete and inaccurate data were mentioned. Therefore, we expected that personalization and motivation influenced each other, both negatively as positively. Based on the Self Determination Theory [35] and the Fogg Behavior Model [11], we argue that sessions that match with the physical capacity of the runner are more fun to complete, giving the runner a sense of achievement, and increasing the motivation to keep running and challenging themselves. While sessions that are too easy or too hard are not fun to complete and negatively influence the intentions to keep running.

A correlation revealed a relation between experience personalization (item 3) and motivation (item 2). If scores on experience personalization increased, in 32% of the cases the score on motivation increased too (or the other way around). As this only explained one-third of the variance, there must be more underlying reasons and variables that explain variances in the scores. We did not include items on injuries, yet we know from literature (e.g., [41]) that having an injury (i.e., being not fit) negatively influences the motivation. Finally, in future work, we see many opportunities to further improve the app by exploring features that could increase the autonomy of the runner or enhance social cohesion. Since for now the app strongly focusses on enhancing the (self) competence of the runner.

8.3. Limitations and future work

In this study, we faced some technical challenges, like the inaccuracy of the data, due to Bluetooth disconnections. A solution here might be technical improvements. We logged all data with the app, so hopefully, future analysis on that data can find the causes of the random disconnections. Another solution might be implementing a warning signal when data is inaccurate, and that the runner must reconnect otherwise the app stops recording the training session. Or allowing the user to remove flawed data, using a more user-centered approach. Therefore, we could make the mechanism more robust, and the algorithm must be adjusted so that incomplete datasets (e.g., with too many zeros) are not used or used differently in the PRP. New ‘rules’ should be constructed and programmed before further testing among runners so time gaps between sessions should be taken into consideration. The Inspirun does not detect time gaps between sessions (e.g., four weeks of no training between session 5 and 6) and therefore it does not take into account potential detraining effects. Furthermore, in line with the third guideline ‘how to design for runners’ described by Knaving et al. [25], who advised building systems that strengthen the runners’ intrinsic motivations, which is the most autonomous form of motivation within the Self Determination Theory [35], we see a lot of opportunities to improve the personalization of the app by giving more autonomy to the runner or stimulate social-support. For example, the option to choose different types of training sessions, or choosing between two sessions that are preselected by the app or sharing sessions with others. Finally, in the current version, an average of six sessions is used to calculate the PRP, given the feedback of several runners that they thought that Inspirun was adjusting in a slightly too conservative (too slow) way, in future iterations the possibility to personalize how the Inspirun adjusts, especially for those runners who adapt better or faster to the stimuli could be explored. A solution here might be technical (improving the technology) or user-centered (giving control to a user to remove flawed data).

Besides the above-mentioned technical limitations and future work recommendations, there are also methodological recommendation for future work. In this study we aimed to give insight into how end-users experience the working mechanism of Inspirun. In future work it could be interesting to look into the effect of Inspirun on aspects such as performance, motivation, and injury-free running, compared to other interventions (such as other apps or standardized training schemes).

8.4. Conclusions

Inspirun was designed to provide personalized training schemes based on biofeedback, GPS-data, and RPE. The primary conclusion of this study is that the working mechanism (if provided with accurate data) automatically adapts training sessions to the runners' physical workload and stimulates runners' goal perception, motivation, and experienced personalization.

With our work, we attempted to make optimal use of the potential of wearable technology to support runners. In particular, the large group of novice or less experienced runners who lack guidance. This work also contributes to the emerging area of designing for running and wearable technology trends by providing working mechanisms that are applicable to other technologies, wearables, and types of sports. Consequently, we hope that runners profit from technologies like the Inspirun to run injury-free and keep motivated.

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DISCUSSION

Wearable technology has been extensively adopted in running. Apps and sports watches enable runners to measure pertinent parameters to track their performance, stay motivated, and connect with other runners. Although apps and sports watches can be helpful in supporting runners in their running, drop-out rates because of injuries or demotivation are still high. The overarching aim of this doctoral research is to understand recreational runners' motives and behaviour to support the design of running-related technology. We formulated two research questions:

1. *What are the motives and behaviour of recreational runners in relation to the usage of running-related technologies?*
2. *How can we design running-related technology that matches the motives and behaviour of recreational runners?*

1. SUMMARY OF THE MAIN FINDINGS

Section 1 showed that recreational runners are a heterogeneous and diverse group in terms of their socio-demographic, behavioural, and psychographic characteristics and that apps and sports watches are widely used among runners. Chapter 2 showed that almost 90% of the event runners used at least one monitoring device during the last year. More than half of the participants reported the use of apps. The most popular apps were Runkeeper (50.8%), followed by Runtastic (16.0%), and Nike + Running (11.1%). Compared to app users, there were slightly more sports watch users (60.5%). Garmin was found to be the most popular brand among users of sports watches (43.9%), whereas Polar (27.4%), TomTom, and Nike (both 7.4%) were used less. The use of apps and sports watches is affected by socio-demographic as well as sports-related behavioural and psychographic characteristics. A distinctive profile of users relates to a specific type of monitoring device. Apps are more likely to be used by younger, less experienced, and less involved runners. Therefore, apps could target groups of novice and inexperienced runners, who run primarily individually without professional guidance and are more likely to drop-out from running owing to personal reasons. Older and more experienced runners with higher involvement are more likely to use sports watches. This group of runners is more often involved in sports clubs with professional guidance.

In Chapter 3, a typology of runners – in terms of their AIOs about running was constructed. We investigated how different types of runners use running-related technology. Four types of runners were identified:

1. Casual individual runners: These are runners who identify themselves the least with running and are the most susceptible to quitting the sport for individual motives and score the lowest on competitiveness.
2. Socially competitive runners: These runners prefer to compete with others and are the most susceptible to quitting running, especially for social reasons (e.g. the drop-out of a co-runner).
3. Individual competitive runners: These runners are focused on improving their performance and are not much susceptible to quitting running. They identify themselves strongly with running.
4. Devoted runners: These runners score highly on perceived advantages of running and identification with running.

Casual individual runners and socially competitive runners can be described as beginners and the most inexperienced runners. Casual individual runners are the keenest app users. Among individual competitive runners and devoted runners, sports watches are used the most. This also applies to older and more experienced runners with a higher level of commitment. These individual competitive runners and devoted runners are characterised by a high training volume and a performance-orientated motivation.

Chapter 2 also showed that the reasons to quit running, and the extent to which runners are sensitive to those reasons, differ according to the type of runner. Hence, in Chapter 4, we focused more in-depth on perceived reasons to quit running [48]. The results showed that runners generally see individual rather than social reasons for quitting running. Physical constraints or injuries are the most important reason to quit running, which is in line with previous studies [22,24,40,53,71], followed by being tired of running. Less experienced runners were more likely to quit running, and runners who identify themselves with running were less likely to perceive individual motives to quit running. In general, we showed that a combination of socio-demographic (e.g. gender and age), running behaviour (e.g. running experience, context, frequency), and motives (AIOs) influence one's perceived reasons to quit running.

Chapter 2–4 indicated that running experience is related to various other variables, such as technology use and motives to quit running (i.e. beginner and inexperienced runners use apps and are more susceptible to quitting). In Chapter 5, we focused on the running environment of these runners. In general, we found that green and lively running routes and a comfortable running surface were pivotal factors for an attractive and restorative running environment. Compared to experienced runners, these green and lively elements in the running environment and hindrances by cars were more important for less experienced runners than other runners.

Section 1 provided insights into the motives and behaviour of recreational runners in relation to the use of running-related technology. Runners differ in terms of socio-demographics, running behaviour, and AIOs. These characteristics relate to the kind of technology they use, how they use the data acquired by these technologies, how susceptible they are to quit running and how they experience their environment. Therefore, different types of runners should be targeted differently. The consumer profiles in Chapter 2 and the typology in Chapter 3 can provide designers and engineers of running-related technology a valuable insight into which characteristics determine the use of running-related technology and could help them better target the runners' needs through personalised and differentiated approaches. The distinction between the different types of runners allows designers and engineers to target runners' needs better. Moreover, policymakers involved in public health may use these typologies and profiles to specifically target runners and match their policies to the needs of runners. Trainers, coaches, and physiotherapists can also benefit from our findings. They could, for example, support runners to match running-related technology with their AIOs. Thereby, Chapters 3 4 provide directions for designing in running, such as which reasons to quit running are most perceived and how an attractive running environment should look like for different runners.

In the field of HCI, giving insight into the values, needs, user experience, and interests of end-users is common, and user-centered approaches are an essential part of the design process. Yet, the findings presented in Chapters 2–5 are based on quantitative data from large samples of end-users. Constructing typologies using a clustering approach can help designers differentiate between different types of end-users and their interests. The typology also provides a solid basis for developing personas. This step of understanding the end-users is of crucial importance in designing running-related technology. For example, apps which are widely used by beginners and inexperienced users, and known for their accessibility, scalability, and potential, can benefit from this approach. Most popular commercially available apps do not fulfil this potential to support and guide runners and do not provide any form of personalisation yet.

There is a gap between the runners' needs and interests and the existing running-related technology. Runners have a hard time keeping up with all the newly introduced technologies and finding the right products. The available products often do not meet their needs for support and guidance while running. Therefore, to narrow down this gap, we explored the associated design space in Section 2 to provide insight into how we can design for recreational runners. Chapter 6 showed that an open and explorative approach, with attention to envisioning and creating a clear vision, seems beneficial for the quality of the design concept. This is likely because, in the field of sports, the design space is enormous and requires a distinctive approach. Therefore, envisioning both societal and individual needs is imperative. Spending more time envisioning and understanding societal and personal needs more thoroughly could be beneficial for the following design phases.

Chapter 7 questioned whether the quality of currently available apps is sufficient to support recreational runners and identified on the basis of experts' opinions which features in apps are important for stimulating and maintaining participation in individual recreational sports (i.e. running, cycling, and walking). This study showed that, as compared to experts in behavioural, health, and human movement sciences, industrial designers and information technologists considered other features to be more important. More importantly, the experts agreed that working together with experts from different domains for the development of apps is essential. An interdisciplinary approach allows the knowledge of each field to be integrated, ensures that all important factors relating to app use and engagement are considered, and guarantees a theoretical foundation.

Chapters 6 and 7 concluded that understanding the societal and personal needs and combining knowledge of different domains is necessary. Therefore, in Chapter 8, we have combined these principles with the insights into runners' motives and behaviours from Chapters 2–5. We deployed a methodology to develop an online tool that supports the decision-making process to choose a smartphone application. We illustrated the method through a running-app case study and made an artefact of the tool. We came up with three design principles that can be used to develop a self-supportive and future-proof decision tool. First, the direct match between the scores on the Sport App Screening Tool (SAST) and the questions asked to users in the tool. Second, a screening principle where users can add new apps to the database through the SAST, to make the tool self-supportive and future proof. Third, a feedback loop that allows users who followed the tool's recommendation to give feedback on the recommended app. This feedback is added to the database and therefore directly used in future filtering and recommendations. These underlying design principles can be applied by designers and engineers in the field of sports, physical activity, and health to support users select an app that matches their respective needs. This will help increase more diversity and long-term use of apps to monitor and support physical activity and health.

Chapter 9 attempted to show the potential of apps (and their accessibility and scalability) to support and guide beginners and inexperienced users. We designed an app that uses personalisation and objective measures of training load to support and guide runners while training for their goals. Therefore, we developed Inspirun, an e-coach for runners. Inspirun is a running app that offers a personalised coaching approach with an automatic adaptation of training schemes based on biofeedback and GPS data. This study showed that the working mechanism (algorithm) in the Inspirun that automatically adapts training sessions to the runners' physical workload, stimulates the runners' goal perception, motivation, and experienced personalisation. With this algorithm, we endeavoured to make optimal use of the potential of app technology to support the large group of novice or less experienced runners and that by providing insight into our working mechanism.

2. CONTRIBUTIONS

This dissertation has three types of contributions: empirical, methodological, and artefact contributions. First, our empirical contribution consists of four large-sample survey studies (a total of 9,270 runners) that gave new insights into runners' motives and behaviour towards usage of running-related technologies. We constructed consumer profiles and a typology of runners, showed possible reasons to quit running and contextualised the running behaviour through perceptions of the running environment. For designers, these insights are highly valuable at the beginning of their design process; we anticipate that designers can 'hit the ground running' with our understanding of runners.

Second, this dissertation has two artefact contributions: the Inspirun e-coach and the app-decision tool. In the Inspirun e-coach app, we applied a personalised approach to match the needs of the runner, not using a 'one-size-fits-all'. The decision tool supports runners in the decision-making process for choosing running-related technology. This artefact shows a different way of looking at product development. Engineers and designers most often strive to improve existing technology or create new innovative technology. With our approach, we argue that – from an end-user's view – there is need to look for newer or more ingenious technology. It is essential to better match existing technology with the needs of end-users. Finally, this dissertation has a methodological contribution. We proposed three design principles that can be used for designing a similar kind of decision tool or recommender system in the field of sports and health. We acknowledge that this contribution is limited in terms of generalisation towards the whole design community. The three presented design principles are highly valuable for those designers and engineers who endeavour to develop similar systems.

3. DISCUSSION

3.1. Understanding runners

There are a number of factors that markedly influence the behaviour of end-users. Different frameworks and approaches can be used to understand end-users. To provide insight into the runner's behaviour and motives (both intrapersonal and interpersonal), we applied a heterodox-based approach [18,19,63,66] in Chapters 2 and 3, and incorporated socio-demographic variables, running behavioural variables, and psychographic characteristics. In Chapter 5, we used a socio-ecological framework, which is also frequently employed in studies on physical activity [60] and sports participation [25,39]. This approach acknowledges the influence of intrapersonal and interpersonal motives (cf. the heterodox-based approach), and includes the environmental level, which puts the runner's perspective into context. We argue that it is important to understand end-users on all these levels. In the field of Human–Computer Interaction, it is common to study end-user behaviour to get insight into their values, needs, user experience, and interests. The most common approach is to conduct research on end-users [43] using a combination of inquiry methods, such as interviews, observations, surveys, or design probes, which can be synthesised under the form of journey maps and personas (see e.g. [12,27,45,49,50,55]). This qualitative approach of creating a journey or fictional characters representing a certain user type is an essential part of the design process within a user-centered approach. In addition to this qualitative approach, a quantitative approach can also be used to gain insight into end-users. In this approach, a target group is segmented on the basis of a large number of data points. Both approaches have their strengths and are wise to combine, because the quantitative approach gives more representativeness, allows to visualise the sizes of different segments, supports decisions on segments, and provides insight into key differences between groups of runners. For example, Stragier et al. [65] argue that a segmented approach is preferable to tailor app interfaces to user motivations. It helps designers differentiate between different end-user types and their interests. While the qualitative approach provides deeper and more subjective insights, it allows more contextualisation, and it gives designers a clear idea of their end-users. We argue that these qualitative and quantitative approaches complement each other and should be integrated as many technological systems are still not able to reach their target group of product users [14,50,55,61]. We thus propose to first use a quantitative approach to segment the target group (i.e. the construction of a typology/types of end-users), and second, use a qualitative approach based on the typology to enrich the quantitative data, for example, by creating personas.

3.2. Working interdisciplinary

Numerous studies highlight the importance of teamwork and interdisciplinary work [1,4,7,8,20,41,57,67]. Interdisciplinary research has become essential to tackle the societal and scientific complexities of different problems [67]. An interdisciplinary approach can be described as multiple teams working together, but still from a discipline-specific base [1,57]. The members of different teams use and integrate theoretical frameworks from different disciplines, combine designs and methodologies that are not limited to any particular field and use the perspectives and skills of all involved disciplines throughout the design process [1]. This dissertation evidenced that experts agreed that working together with experts from different domains is crucial in the development of technologies such as sports and health related apps, since an interdisciplinary approach allows for combining knowledge of each field [32].

The artefacts presented in Chapters 8 and 9 were designed by dint of an interdisciplinary approach. Our approach supported a number of practical issues, such as concurrently working on different aspects. For example, the development of the screening tool was accomplished in parallel with the research on user needs, and iterations on the prototype were performed in parallel with end-user testing. More importantly and in congruence with other studies [1,4,7,8,20,41,67], we experienced that interdisciplinarity was required at several stages. From the beginning of the design process, experts from different disciplines were present so that design decisions could be made collectively. We argue that to understand runners and serve their motives and behaviour, a convergence between these different fields of work are of prime importance [31,33,75]. Interdisciplinarity is not only required in the case studies in this dissertation, but it also applies to the full domain of designing for sports, health, and vitality. Our domain has various complex societal and scientific problems to solve, and thus using diversified perspectives is imperative to design meaningful and impactful tools, services, and practices.

Research shows that interdisciplinary research can promote knowledge, insights, and understanding from multiple perspectives [41]. Interdisciplinary projects lead to higher quality outcomes compared to projects where complex problems are tackled using fragmented approaches or a separate approach for each discipline. Even when all disciplines are separately addressed (multi-disciplinary approach), the final integration of those findings may affect the solution of the problem, and could result in misleading conclusions [41]. Interdisciplinary research has many advantages, yet these collaborations are not self-evident [8]. Blandford et al. [8] distinguish seven lessons for interdisciplinary research to overcome the misunderstanding between group members on topics such as research methods, definitions of key terms, ethics, and publications. Communication plays a key role and is an essential aspect of interdisciplinary research. Conversations and connections proffer new insights for everyone [51]. Thompson et al. [67] argue that this communication is enhanced by trust, speaking the same language, humour, and backstage talk between team members. Ultimately, the biggest challenge is to increase mutual understanding and appreciation of the research traditions of the different disciplines to bridge the gap between traditions and disciplines [8].

3.3. Design perspectives

To capture the relationship between the designer and the design context Tomico et al. [68] distinguish three design perspectives, namely the first-person perspective, the second-person perspective, and the third-person perspective. Although researchers [42,64,68,69] use slightly different definitions of the three perspectives, they all share the following characteristics. The first-person perspective refers to designing based on your own (current and past) experiences as a designer within this context and is also described as designing for oneself within society. The second-person perspective refers to designing together with the users. The designer is socially involved and facilitates co-design sessions. In the third-person perspective, the designer is designing for people and society in general. On the basis of available knowledge and sources, designers design for people without involving users and professional experts. In general, one can see that the perspectives —or combinations of— used differ for each designer. For example, the designers' educational background influences in which perspective they are mainly trained and feel comfortable. Researchers trained in the field of social sciences and humanities typically apply the second-person and third-person perspectives. Designers trained in arts and design more often apply the first-person and second-person perspectives. Besides the educational background, research shows that maturity of designers also matters. Senior designers tend to navigate more easily between the design perspectives [13] than their novice counterparts. This is in line with our findings delineated in Chapter, 6 which shows that envisioning both societal and personal needs to form a third-person perspective is essential to create a clear vision, which in turn enhances the quality of the design concept. While in our Hackathon-study the future designers mostly adopted a first-person perspective, which limited their vision on both the users and societal needs, research has evidenced that combining different perspectives and methods leads to more sophisticated designs [2,5,6,9]. Each perspective has its own strengths and, therefore, transitions between different perspectives, not just using each perspective separately or consecutively, are beneficial to the design outcome. The third-person perspective enhances thinking regarding alternatives and makes the designer receptive to different methods, data, ideas, and concepts [64,68]. In this research, we used this approach while gathering large representative data samples about the runners' motives and behaviours. The second-person perspective is about putting end-users in context, to really understand them; it is concerned with what the designer learns from the end-users to empathise, get inspired, and understand the end-user [64,68]. This perspective was used in both case studies by including runners in the design process of both the app-decision tool (Chapter 8) and as the Inspirun e-coach (Chapter 9). Using a second-person perspective results in designs that are more likely to be implemented, since they fulfil a desired need. The first-person perspective has its strength with the commitment of the designers as they are a part of the design, and this often results in intrinsic motivation of designers, self-reflection, joy and designing on intuition [64,68]. Using our own experience in coaching recreational runners, we applied this first-person perspective in combination with second- and third-person perspectives in the development of the Inspirun e-coach.

3.4. Towards an incremental and scalable approach

User- or human-centered designs refer to approaches that use a common scheme of iterative cycles of investigation. These approaches are characterised by analysing user needs, generating ideas, and an iterative process of rapid prototyping and testing. The idea is that each cycle builds on the lessons learnt from the previous cycle [52] and develops into a more refined and comprehensive prototype. This cyclic process results in products with higher usability and a better fit with the users' needs. This form of continuous testing and iterating with the end-users often leads to incremental development of the design rather than a disruptive or radical development. The major difference between these forms of development is whether the design is perceived as a continuous modification of previously accepted technology (i.e. 'doing better what we already do') or whether it is a complete change of frame (i.e. 'doing what we did not do before'). This latter kind of approach, on the one hand, is the centre of attention in innovation studies (e.g. [10,11,70]). Radical innovations often take considerable time to be accepted [52] and rarely live up to the expectation when first introduced. Incremental product innovation, on the other hand, takes advantage of already established technologies and products, and is characterised by low costs, improved performance, and rapid acceptance and adaptation.

With our design of the Inspirun e-coach app, we chose an incremental approach. First, we capitalised on the established usage of running apps. We relied on the already accepted use of apps, since research [15,34,35,75] has evidenced that mostly novice and inexperienced runners use apps for running, whereas more experienced runners use sports watches. The former group of runners is also observed to be the most prone to drop-out; we, therefore, focused on apps as a technology that is already accepted within this group. There is also a relatively small group (< 10%) [34,35] of runners that does not use any technology while running, chiefly because they deem it unnecessary or find it unsuitable for their running needs [35]. This group of non-users of apps is an interesting group to study; however, in the view of theoretical models that try to explain behaviour and technology usage, we chose to focus on running app-users in order to have a large impact. Our target group already intended to uses apps (e.g. in terms of the theory of planned behaviour [3]) and already accepted the app technology (in terms of the Technology Acceptance Model [16]). Second, we used apps in our incremental approach because apps are considered as a matured and implemented technology [23]. This has the advantage that app technology has already proved its worth among runners. We were aware that this limited the disruptive and radical innovation possibilities in our research. For example, Menheere [46] presented an overview of design opportunities and design exemplars that extend the boundaries of rather traditional product design for runners (e.g. tangible products with unusual functionalities and interactions). We argue that commercially available apps (such as Runkeeper, Runtastic, or Strava) have not reached their limit in incremental innovation, and there is still room to fully exploit the potential of app technology (such as 24/7 data acquisition, data analytics, real-time feedback). Third, we adopted a scalable approach. We developed algorithms that mimic the professional routines of running coaches. We are aware of the limitations of app technologies, yet owing to the high number of runners, the impact of such an approach can be considerable. Moreover, this algorithm can easily be transferred to existing running-related apps.

We acknowledge that both incremental and radical innovations have concomitant merits and shortcomings, and that as Norman [52] states (*p84*): 'Without radical innovation, incremental innovation reaches a limit. Without incremental innovation, the potential enabled by radical change is not captured'. However, in this research, we consciously chose to rely on apps as an accepted and matured technology that is scalable for the public.

3.5. Running behaviour and drop-out

In Chapters 8 and 9, we focused on the gap between the runners' needs and interests and the available running-related technologies. We prototyped two different approaches to narrow down this gap. We tried to help runners in their choice of a (better) running app. This tool helps runners in their choice of a running app, either as their first app or as an app that replaces their current app with the one that better suits their needs. This approach serves a broad spectrum of runners, which also includes runners who are already using an app for running. The runners in this group are already into running and seek a technology that could help them maintain running, reach their goals, or attain more from their running sessions. This approach also serves runners who are searching for their first app because they started with running or made the decision to use an app to support their running experience. This range of runners, that we target with our decision tool, can be described as runners who just started with running till runners that already have been running for some time. If we relate this to a well-known behaviour change model, the Transtheoretical Model of Behaviour Change [54], we can see that runners are situated in the *action* and *maintenance* phase. This model describes five stages of behaviour change, where the first three are concerned with creating awareness and encouraging people to change their behaviour, whereas the last two are the action and maintenance phases. Runners in the *action* phase have recently changed their behaviour (started with running) and intend to keep moving forward with that change. Runners in the *action* phase who sustain the behaviour change for at least six months and intend to maintain the same further move to the so-called *maintenance* phase. Runners who actively participate in running for six or more months are in this final stage.

The Inspirun e-coach serves a similar range of runners. Mostly, it serves runners in the action phase by supporting runners to run at a workload suitable for them. Runners in the maintenance phase indeed could also use Inspirun, for example, to accomplish more challenging goals such as running 10 km in a faster time. However, we believe that this design has the most potential in the first few months after people start running. It allows them to experience how balanced training sessions (on workload) should feel and avoid common mistakes, such as training too hard and too much.

We are fully aware that our artefacts support runners who already decided to run and do not serve potential runners or those who are unaware if they will be runners sometime in the future. From a research perspective, these latter target groups are highly interesting, but require a completely different approach, which we did not address in this dissertation.

The decision tool and the Inspirun e-coach are primarily targeted at novice and inexperienced runners as compared to the experienced runner. In the existing literature, there is no consensus on the definition of a novice or inexperienced runner. Some scholars (e.g. [40]) describe runners as inexperienced on the basis of the number of years they participate in running, while others [58] use the level of competition (regional/national) or performance to distinguish between inexperienced and experienced runners. In most of our studies [17,34,35], we used a combination of different behavioural characteristics to indicate the runners' experience. For example, being active in running for one year or less, a low running frequency, or a high involvement in other sports (not seeing running as their main sport), can be regarded as signs of less experienced runners. We argue in our studies that there is no need for a sharp distinction between inexperienced and experienced runners, although our design artefacts are targeted at novice and inexperienced runners because they are more prone to drop-out. We are aware that also experienced runners' cope with motivational and physical challenges of running and may plausibly benefit from our designs. However, we did not target this group specifically; we might have made different design choices in this case.

Running is not all roses; a significant group of people drops out from running because of injuries or demotivation [24,40,71], and novice runners face a markedly higher risk of RRI as compared to more experienced runners [44,71]. Some sort of guidance could be favourable to support this group of runners [31,74,75]. We designed the Inspirun e-coach to mimic the behaviour of a trainer/coach and hypothesised that this could reduce drop-out due to injuries and demotivation. By minimising training errors (i.e. irregular and unbalanced training), we aimed to reduce injuries. This app uses both objective and subjective workload to calculate a personalised training session to avoid running too hard and too much and create challenging but doable training sessions. We expected that personalised sessions and motivation influenced each other. On the basis of the Self-Determination Theory [59] and the Fogg Behaviour Model [21], we argue that sessions that match the runner's physical capacity are more enjoyable, provide the runner with a sense of achievement, and motivate them to continue running. Sessions that are too easy or too hard are not quite enjoyable and negatively influence the intentions to keep running. We conducted a three-month user test with the prototype of Inspirun e-coach and found that Inspirun positively influenced the runners' goal perception and motivation to continue running and runners felt that the personalised training sessions were 'challenging but not too hard'. However, we did not gauge motivation or the number of injuries during the testing. Therefore, we cannot make any deductions regarding the effects of Inspirun on those variables. We thereby acknowledge that keeping runners motivated and injury-free is complicated and influenced by a multitude of factors [28]. In our design, we covered physical aspects related to injuries, such as overtraining and overuse. Next to personalisation on the workload, physical recovery was included. Each training session was followed by a no-running day. We did not include the cognitive and emotional aspects of recovery, although research [29,30,36,37] shows that these aspects are equally crucial. For instance, focussing on running on a given pace, the disappointment about (lack of) training progress or dealing with getting injured. To promote the well-being and health in running, runners need ‘complete’ recovery between running sessions, considering not only physical, but cognitive and emotional recovery as well [29,30,36,37].

4. METHODOLOGICAL CONSIDERATIONS AND LIMITATIONS

The strengths and limitations of our studies have been discussed in detail in the corresponding chapters. This paragraph addresses more generic limitations and considerations of this doctoral research.

4.1. Samples and variables

Certain aspects should be considered when interpreting the results of this doctoral research concerning the samples and variables used in the studies in Chapters 2–5 and the selection of participants and experts in Chapters 6 and 7.

4.1.1. Survey samples and variables

In Chapters 2–5, we used data from the Eindhoven Running Survey (ERS). Standardised online questionnaires were used to amass data in 2014, 2015, and 2016 (ERS2014, ERS2015, and ERS2016) among participants of the Eindhoven Marathon, a yearly running event that consists of different running distances (42.2 km, 21.1 km, 10 km, and 5 km). Event runners are an interesting target group because running events can be considered instrumental in the rising prominence of recreational running [62,73,76,77]. In the studies discussed in Chapters 2,4, and 5, we used subsets of the Eindhoven Running Survey based on a selection of running distances. These subsets do not necessarily represent the full range of event runners. Therefore, each study with its specific samples must be interpreted in its own context. In addition, the standardised online questionnaires were in Dutch. Hence, only Dutch-speaking event runners could participate in our studies. This should be considered while interpreting the overall

results, and empirically grounded statements for all runners in all cultures should not be made.
Concerning the measured variables in the ERS, we derived the questions from previous research [63,66,73,76] including socio-demographics, running-related characteristics and AIO's on running. We acknowledge that these concepts do not represent the complete range of variables that allow to understand recreational runners' motives and behaviours, for example we did not include other concepts such as self-efficacy and self-regulation. In our approach we focused on variables that were closely related to running related apparel and materials (including wearable technology). As we aimed for an incremental approach and focused on concepts that are easy to interpret and apply for designers.

4.1.2. Selection of the participants and experts

Chapter 6 described our study in which we mapped the design process during a Hackathon. We had no control over the recruitment of participants. The participants were all junior, future design engineers. Hence, we had a unidisciplinary composition of our sample. If we had involved senior (experienced) designers, we would likely have seen different decisions throughout the design process.

During the Hackathon, the participants tackled broad issues in the field of sports and vitality. Although running was explicitly included, it was not the central theme of the Hackathon. Nevertheless, this study with inexperienced designers and engineers provided valuable insights for the design of running-related technology. A Hackathon has a great advantage of going through a design cycle in a brief time. However, this does not allow us to generalise to design processes with less time pressure. It is, therefore, useful to monitor design and engineering processes over a more extended period in follow-up research.

In our study in Chapter 7, we used expert panels. In accordance with a convenience sample, 11 experts with different expertise participated in these panels organised at two locations. Although we had an equal mix of the various expertise's at both locations, this may have caused a selection bias. Because of our location-based approach, several experts knew each other from previous meetings. This facilitated interaction during the discussions but may also have affected the focus of the discussions.

4.1.3. Explorative character

Both Chapters 8 and 9 are based on exploratory studies. Because we wanted to explore the design space in these studies, exploratory design was the most appropriate approach. This design can have the disadvantage that it is difficult to make generalised statements. For example, in Chapter 9, we provided insight into how end-users experience the working mechanism of the Inspirun. In this study, we faced some technical challenges related to the Bluetooth connection of the heart rate monitor with the smartphone. This affected the user experience with the Inspirun, and as a result, some runners dropped out during the testing period. The participants completed at least 20 training sessions (usually 6–10 weeks of training). We measured their experiences with the app over time. We asked about how they experienced the adaptation of the training sessions and to what extent the app stimulated the goal perception, motivation, and personalisation. We did not conduct long-term tests and therefore cannot make any claims about the impact of our design on the number of dropouts and whether (and how) it affects motivation, nor can we make any claims about injury-free running because of our design. With our study we were, however, able to demonstrate the potential of personalisation in running-related technology to address healthy running.

4.2. Running-related technology

In the studies in Chapters 2–5, the participants were asked what technology they used and how they used that technology. This provided valuable insights into the technology they used, the data that were monitored, and how this data were used. We only focused on wearable monitoring devices such as sports watches and smartphone applications. We did not ask whether they used other running-related technologies (e.g. pressure-sensitive insoles, power meters, and biometric shirts). We did not assess the intensity of using and the reasons why they used those wearable devices. Furthermore, the decision-making processes that led to the use of monitoring devices were not included in these studies.

4.3. Drop-out

In this dissertation, we explored strategies to (i) close the gap between runners' expectations and needs and commercially available technologies and (ii) personalise training sessions. We assumed that these strategies positively impact drop-out. In our studies, we investigated perceived reasons to quit running and applied these in our designs. Understanding the perception of runners is of paramount importance to develop products and/or interventions to lower drop-out rates. Yet, we did not study the actual drop-out rates. This would require a longitudinal study design.

5. IMPLICATIONS FOR FUTURE RESEARCH AND PRACTICE

5.1. Interdisciplinary teams needed to 'solve' problems

As discussed before, tackling societal and scientific complexities of problems requires an interdisciplinary approach. We believe that crossovers between different disciplines are necessary to address the needs of recreational runners. We learnt that the design space is large and envisioning societal and personal needs are critical. Therefore, spending more time contemplating thoroughly on understanding societal and personal motives and behaviours may result in higher quality design concepts [32]. Other researchers [5,6] have asserted that there are differences between the routines and approaches of future and senior designers. Future designers spent less time on problem scoping. This supports our study where the time spent by future designers on problem scoping and envisioning was positively correlated with quality of the design concept [6]. Second, our analyses revealed that the future design engineers did switch between strategies, yet the strategies of envisioning and thinking (from RTDP [26]) were rarely incorporated [32]. In line with Wilson et al. [78], we found that future design engineers rarely iterated between phases in the design process. For example, none of the participants went back to the envisioning or empathising during the making of the prototype. Atman et al. [6] showed that the amount and type of information gathered to understand the problem also differed. Senior designers collected more information and covered more categories than less experienced designers. The former also had more transitions between design activities and design steps than less experienced designers [6]. It is suggested that a higher quality design primarily lies in the qualitative nature of how designers spend their time rather than how much time they spend [6]. Furthermore, to address complex societal issues, high-quality design requires an interdisciplinary approach [72]. The most challenging part of an interdisciplinary approach is to understand each other. Misunderstandings between experts over definitions of key terms, research methods and traditions, expected results, and other similar issues must be overcome. Therefore, we advocate the stimulation of crossovers, where complex problems are tackled together with experts from various fields. Possible ways to stimulate crossovers are by research journals and publishers, which could stimulate interdisciplinary research by, for example, special issues with interdisciplinary research or other opportunities such as proposals for funding; interdisciplinary research can be stimulated at universities. In our opinion, universities, where the next generation of designers is trained, are the most logical place to encourage crossovers and interdisciplinary work. In practice, this means that educational programmes should emphasise understanding the motives and behaviours of end-users. Next, to involve end-users from the early start of design projects, it is vital to incorporate relevant insights from various disciplines. This does not mean that a future engineer or designer should become a specialist in, for example, human movement and behaviour. Instead, future engineers and designers should be trained to look beyond their fields and encouraged to work in authentic real-life settings with professionals and students with diverse backgrounds on shared challenges (challenge-based learning). To future-proof their education, it is crucial to educate them to work in interdisciplinary settings. The first but often neglected step is to appreciate and use others' knowledge and opinions. In practice, this means exposing future designers to complex societal problems to force the development of those skills. They can be taught the fundamentals within the safe environment of a university campus, but it is critical to create opportunities for them to work together with professionals and other students with various backgrounds in hybrid learning environments such as hubs, co-locations, and living labs. Such living labs are extremely attractive open innovation landscapes for collaborative activities and target the complexity of today's societal challenges [38].

5.2. The step beyond: a running ecosystem

Each kind of technology has its advantages and limitations. Therefore, it is important to be aware of the disadvantages and to use the advantages for runners' benefit. One of the strengths of apps is the accessibility and acceptance among novice and inexperienced runners. They can support recreational runners, especially during and directly after running sessions through monitoring and feedback of the running performance. However, looking at the bigger picture, (i) low-cost wearable technologies such as apps are not enough to help people to run injury-free, stay motivated or even get into running, and (ii) more and more sensors will soon be available to measure all kinds of running parameters and collect (a plethora of) data.

We argue that this requires a running ecosystem with different kinds of technologies that are integrated and work together seamlessly, utilising the qualities of that kind of technology. Future work should look into an ecosystem where data collected during running (e.g. by apps or watches) is used to create new running experiences (long) before, during, and (long) afterwards the actual run (e.g. [47,56]. It is important that this ecosystem presents and provides feedback on this collected data so that it is meaningful and understandable to the runner.

6. GENERAL CONCLUSIONS

To conclude this work, we argue that technology has the potential to support runners in healthy and enjoyable running. Unfortunately, this potential is currently not sufficiently exploited and understanding the motives and behaviour of recreational runners is not yet adequately considered when designing running-related technology. A user-centered design approach is essential, whereby a combination of quantitative and qualitative data can give designers real insight into the design space around running and genuinely understand the needs and interests of runners. Interdisciplinary working is also an essential part of this approach. This promotes knowledge, insight and understanding from multiple perspectives, which ultimately leads to better quality outcomes. We chose a user-centered approach, with iterative cycles of prototyping and testing, focusing on the continuous adaptation of previously accepted technology to fully exploit the potential of existing technology. Due to the large number of runners already using such technology, the impact of such an approach can be significant. Ultimately, it is about making running a fun and enjoyable part of a healthy lifestyle.

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APPENDIX

QUESTIONNAIRE ERS

SAMENVATTING

ABOUT THE AUTHOR

LIST OF PUBLICATIONS

ACKNOWLEDGEMENTS

QUESTIONNAIRE ERS2016 (FROM CHAPTER 3)

SECTION 1 AIOs running

Please respond to the following statements by checking the box that best reflects your opinion on each of the following items.

	Strongly disagree	Disagree	Neural	Agree	Strongly agree
The possibility to run on your own is an important reason to be involved in running[4]					
The possibility to run at any time is an important reason to be involved in running[4]					
The possibility to run in your own environment is an important reason to be involved in running[4]					
Running is a social sport[3]					
Running is appealing for both men and women					
Running is a competitive sport[6]					
Running is appealing for both youngsters and the elderly					
Running is an exciting sport[3]					
Running is for those who persevere					
Running is easy to fit into daily life					
Running is good for your condition[1]					
Running is good for your health[1]					
Running is an individual sport					
Running gives you energy[1]					
Running is good for your mental recovery[1]					
I am proud to be a runner[3]					
I feel connected with other runners[3]					
Running is a performance sport[6]					
I consider myself to be a real runner3					

To which extent do you agree that the following items are a reason for you to quit running? Please respond by checking the box that best reflects your opinion.

	Strongly disagree	Disagree	Neural	Agree	Strongly agree
My running partners quit running[2]					
My running group falls apart					
My trainer / coach is leaving[2]					
Increasing financial costs involved in running					
Preference for another sport[5]					
Reduction of leisure time[5]					
Tired of running[5]					
Physical constraints or injuries[5]					

Continue to SECTION 2

SECTION 2 technology use

Did you use a monitoring device, sports watch, or smartphone application during running in the last 12 months?

- o Yes, I used a sports watch (go to SECTION 2 sport watch)
- o Yes, I used a smartphone application (go to SECTION 2 app)
- o No, I did not use any sports watch or smartphone application (go to SECTION 2 no use)

SECTION 2 sport watch

You stated to use a sport watch during running in the last 12 months.
Which parameters do you monitor with your sports watch? (Multiple answers possible)

- o Distance
- o Time
- o Speed
- o Heart rate
- o Other, please specify

What do you do with the data collected from your watch? (Multiple answers possible)
o Nothing
o I use the data to review my session after the run
o I use this data to monitor my progress overtime
o I use this data to adapt my training / running schedule

Continue to SECTION 3

SECTION 2 app

You stated to use a smartphone application during running in the last 12 months. Which parameters do you monitor with your app? (Multiple answers possible)
o Distance
o Time
o Speed
o Heart rate
o Other, please specify

What do you do with the data collected from your app? (Multiple answers possible)
o Nothing
o I use the data to review my session after the run
o I use this data to monitor my progress overtime
o I use this data to adapt my training / running schedule

Continue to SECTION 3

SECTION 2 no use

You stated not to use any sports watch or smartphone application during running. Why not? (Multiple answers possible)
o Running with a smartphone/watch is ignorant
o It has no added value
o There is no need for me to use it
o It doesn't fit with my running experience

Continue to SECTION 3

SECTION 3 Running habits and Socio-demographics

Which distance did you run during the event?
o 5km
o 10km
o Half Marathon
o Marathon

Is running your main sport?
o No
o Yes

When did you start running?
o less than 1 year ago
o 1 to 3 years ago
o 4 to 5 years ag
o More than 5 years ago

On average, how many kilometres per training session do you run?
o 0-5 km
o 6-10 km
o 11-15 km
o 16 or more km

How often do you run?
o Once a week or less
o 2 times a week
o 3 times a week or more

How often did you participate in running events in the last 12 months?
o This event was my only running event
o 2-4 times a year
o 5 or more times a year

In which setting do you normally run? (Choose the best fit)
o Mainly or solely on my own
o Mainly or solely with friends, colleagues, small groups
o Mainly or solely with a running club

What is your age?
[scroll-list]

What is your gender?
o Male
o Female

What is your employment status? Are you currently?
o A student
o Full-time employed
o Part-time employed
o Not employed

What is the highest degree or level of school you have completed?
o Lower or middle education
o Higher education
o University

SAMENVATTING

Hardlopen is een van de populairste recreatieve en ongeorganiseerde vrijetijdssporten. Door de populariteit, het gemak bij de beoefening en de mogelijke voordelen voor de gezondheid, heeft hardlopen een groot potentieel voor de bevordering van een actieve en gezonde levensstijl. Ondanks deze voordelen brengt hardlopen ook een belangrijke uitdaging met zich mee: hardlopen staat bekend om zijn hoge drop-out cijfers. Dit uitvalspercentage is het grootst bij beginnende, onervaren hardlopers. Begeleiding van deze hardlopers door middel van draagbare technologie zou kunnen helpen om hen te ondersteunen en hiermee drop-out te voorkomen. Zo kunnen smartphone apps en sporthorloges, trainingsschema's aanbieden, hardlopers met elkaar in contact brengen, en hardlopers in staat stellen allerlei hardloop gerelateerde parameters te meten. Ondanks dit enorme potentieel van apps en sporthorloges om hardlopers te ondersteunen bij het monitoren van trainingsactiviteiten en het geven van motiverende feedback, is er dus nog steeds een aanzienlijke groep mensen die afhaakt bij het hardlopen. Met name vanwege blessures en/of demotivatie. Daarom heeft dit promotieonderzoek tot doel de motieven en het gedrag van recreatieve hardlopers beter te begrijpen, om hiermee hardloop gerelateerde technologie te ontwerpen die aansluit bij de motieven en het gedrag van recreatieve hardlopers.

Twee onderzoeksvragen zijn geformuleerd in dit proefschrift:

1. Wat zijn de motieven en de gedragingen van recreatieve hardlopers in relatie tot het gebruik van hardloop gerelateerde technologie?

2. Hoe kunnen we hardloop gerelateerde technologie ontwerpen die aansluit bij de motieven en het gedrag van recreatieve hardlopers?

Om de eerste onderzoeksvraag te beantwoorden, zijn er vier grootschalige vragenlijst-onderzoeken uitgevoerd (hoofdstukken 2-5), die bijdragen aan een beter begrip van de motieven en het gedrag van recreatieve hardlopers in relatie tot het gebruik van hardlooptechnologie.

Studie 1 (hoofdstuk 2) richtte zich op het profiel van hardlopers die hardloop gerelateerde apps en sporthorloges gebruiken. Uit de analyses bleek dat 9 van de 10 evenementenlopers ten minste één van deze apparaten gebruikt, waarbij meer dan de helft van de deelnemers meldde dat ze een app gebruiken. In vergelijking met app-gebruikers waren er iets meer sporthorlogegebruikers (60,5%). Verder bleek dat sociodemografische, sport gerelateerde, en psychografische kenmerken het gebruik van apps en sporthorloges beïnvloedden. Zo werden apps vaker gebruikt door jongere, minder ervaren en minder betrokken hardlopers. Terwijl oudere en meer ervaren hardlopers met een hogere betrokkenheid zijn eerder geneigd sporthorloges te gebruiken. Diezelfde groep hardlopers is ook vaker betrokken bij sportclubs met professionele begeleiding. Terwijl de app-gebruikers, de beginnende en onervaren hardlopers, vooral individueel lopen zonder professionele begeleiding en vaker om persoonlijke redenen stoppen met hardlopen.

In de volgende studie (hoofdstuk 3), die voortbouwde op studie 1, werd een typologie van hardlopers (gebaseerd op motieven en gedrag) opgesteld. We onderzochten hoe verschillende profielen van hardlopers verschillen in hun gebruik van hardloop gerelateerde technologie. Er werden vier types van hardlopers geïdentificeerd: casual individuele hardlopers, sociaal competitieve hardlopers, individuele competitieve hardlopers en toegewijde hardlopers. De casual individuele hardlopers en de sociaal competitieve hardlopers kunnen worden omschreven als beginners en de meest onervaren hardlopers. Onder de casual individuele hardlopers vonden we de meeste app-gebruikers. Bij de individuele competitieve hardlopers en de toegewijde hardlopers worden sporthorloges het meest gebruikt. Deze laatste twee types hardlopers worden gekenmerkt door een hoog trainingsvolume en een prestatiegerichte motivatie. Dit is in overeenstemming met studie 1, waar de gebruikers van apps ook jonger en minder ervaren zijn.

Hoofdstuk 4 (studie 3) richtte zich op mogelijke redenen om te stoppen met hardlopen. Op basis van een grootschalige enquête, stelden we vast dat hardlopers in het algemeen meer individuele dan sociale redenen zien om te stoppen met hardlopen. Onder de individuele redenen zijn blessures en geen zin meer hebben, de belangrijkste redenen om met hardlopen te stoppen. Daarbij waren minder ervaren hardlopers meer geneigd om te stoppen met hardlopen en meer ervaren hardlopers juist waren minder geneigd om individuele motieven te zien om te stoppen met hardlopen.

In hoofdstuk 5 (studie 4) werd onderzocht hoe hardlopers hun loopomgeving ervaren en hoe dit verschilt tussen hardlopers. Uit de resultaten bleek dat alle hardlopers willen dat hun routes aantrekkelijk en rustgevend zijn. Minder ervaren hardlopers vinden een groene, natuurlijke en levendige loopomgeving belangrijker dan hun meer ervaren collega's.

Het eerste deel (vier studies) verschafte inzicht in de motieven en het gedrag van recreatieve hardlopers in relatie tot het gebruik van hardloop gerelateerde technologieën (RQ1). We toonden aan dat recreatieve hardlopers een heterogene en diverse groep vormen in termen van hun sociodemografische, gedrags- en motivationele kenmerken. Deze kenmerken hebben betrekking op het soort hardloop gerelateerde technologie dat ze gebruiken, hoe ze de door deze technologieën verkregen gegevens gebruiken, hoe vatbaar ze zijn om met hardlopen te stoppen en hoe ze hun omgeving ervaren. Daarom zou bij het ontwerpen van hardloop gerelateerde technologie rekening gehouden moeten worden met verschillende types recreatieve hardlopers.

Wij stellen dat er een discrepantie bestaat tussen de behoeften en interesses van hardlopers en de bestaande technologie op het gebied van hardlopen. Hardlopers vinden het moeilijk om alle nieuwe technologieën bij te houden en de juiste producten te vinden. Vaak voldoen de beschikbare producten niet aan hun behoeften ten aanzien van ondersteuning en begeleiding tijdens het hardlopen.

In het tweede gedeelte van dit proefschrift, bestaande uit vier hoofdstukken (hoofdstukken 5-9), onderzochten we daarom hoe we hardloop gerelateerde technologie kunnen ontwerpen die aansluit bij de motieven en gedragingen van recreatieve hardlopers (RQ2).

Studie 5 (hoofdstuk 6) analyseerde het ontwerpproces tijdens een hackathon gericht op sport en vitaliteit. De studie toonde aan dat meer tijd besteden aan het bedenken en begrijpen van maatschappelijke en persoonlijke behoeften van eindgebruikers gunstig lijkt te zijn voor de volgende ontwerpfasen en uiteindelijk resulteert in kwalitatief betere ontwerpresultaten.

Vervolgens, in hoofdstuk 7 (studie 6), gebruikten we panels met experts uit verschillende gebieden om zicht te krijgen op hun opvattingen over hoe sport-gerelateerde draagbare technologie ontworpen zou moeten worden. Uit deze studie bleek dat de experts het erover eens waren dat interdisciplinaire samenwerking essentieel is bij het ontwikkelen van sport- en beweeggerelateerde apps. Een dergelijke interdisciplinaire aanpak maakt het mogelijk om de kennis van verschillende domeinen te integreren, en zorgt ervoor dat cruciale factoren met betrekking tot app-gebruik in overweging worden genomen. Ook versterkte het de theoretische onderbouwing van de ontwikkelde apps.

We concludeerden uit hoofdstukken 6 en 7 dat het begrijpen van de maatschappelijke en persoonlijke behoeften en het combineren van kennis van verschillende domeinen noodzakelijk is. Daarom combineerden we in de laatste twee studies van dit proefschrift deze principes met de inzichten in de motieven en gedragingen van de lopers (hoofdstukken 2-5).

Aan de hand van twee casestudies hebben we twee ontwerpen ontwikkeld. Het eerste ontwerp ondersteunt hardlopers in hun keuzeproces voor het kiezen van een geschikte hardloop-app (studie 7). Ons tweede ontwerp maakt gebruik van personalisatie en objectieve maten van trainingsbelasting om hardlopers te ondersteunen en te begeleiden tijdens het trainen voor hun doelen (studie 8).

In Studie 7 (hoofdstuk 8) hebben we een hardloop-app casestudie gebruikt om een methodiek met drie ontwerpprincipes te illustreren en een daadwerkelijke beslistool te ontwerpen. Eerst hebben we een screeningsinstrument (Sport App Screening Tool) geconstrueerd en gevalideerd om de kwaliteit van de inhoud van apps te beoordelen. Dit diende als input voor het bouwen van de tool en resulteerde in een online tool die zich baseert op kwaliteitsscores om de behoeften van de gebruikers te matchen met apps die hoog scoren in het screeningsinstrument op die specifieke behoeften. Gebruikers kunnen nieuwe apps toevoegen aan de database via het screeningsinstrument, waardoor de tool zelf ondersteunend en toekomstbestendig is. Via een feedback lus kunnen gebruikers feedback geven over de aanbevolen app en hoe goed die aan hun behoeften voldoet. Deze feedback wordt toegevoegd aan de database en gebruikt bij toekomstige filtering en aanbevelingen.

Studie 8 in hoofdstuk 9 is een casestudie waarin we proberen tegemoet te komen aan de behoefte van hardlopers aan ondersteuning en begeleiding tijdens het hardlopen. We ontwierpen de Inspirun e-Coach app die gebruik maakt van personalisatie en objectieve metingen van trainingsbelasting om hardlopers te ondersteunen en begeleiden tijdens het trainen voor hun doelen. Ons algoritme gebruikt ervaren inspanning, biofeedback en GPS-data om de fysieke belasting van de lopers voor de volgende trainingssessie te berekenen. Een gebruikersonderzoek van 3 maanden toonde aan dat de automatische aanpassing van de trainingssessies aan de fysieke belasting van de lopers, de doelperceptie, de motivatie en de ervaren personalisatie stimuleerde. Met dit algoritme hebben we optimaal gebruik gemaakt van de mogelijkheden van app-technologie om de grote groep beginnende of minder ervaren hardlopers te ondersteunen en dat door inzicht te geven in ons werkingsmechanisme.

In het laatste hoofdstuk (hoofdstuk 10) bespreken we de motieven en het gedrag van recreatieve hardlopers ten aanzien van hardloop-gerelateerde technologie en gaan we dieper in op de vraag waarom het potentieel van hardloop-gerelateerde technologie onderbenut wordt om hardlopers te ondersteunen en te begeleiden. Ten slotte denken we na over hoe we dit meer diepgaande inzicht in recreatieve hardlopers kunnen gebruiken om meer gepersonaliseerde producten en diensten te ontwerpen. Dit vereist dat de eindgebruiker bij het ontwerpproces wordt betrokken. Deze inzichten kunnen ontwerpers helpen bij het ontwikkelen van hardloop-gerelateerde technologie. Ten slotte presenteren we implicaties voor het onderwijs en ideeën voor toekomstig onderzoek.

ABOUT THE AUTHOR

Mark Janssen was born on the 7th september 1988. He completed his bachelor degree as Physical Education-teacher in 2009 at Fontys University of Applied Sciences. Next, he achieved his master degree in Human Movement Sciences at the VU University Amsterdam in 2012. In 2010 he started working as a lecturer at the School of Sport studies at Fontys University of Applied Sciences. He developed and lectured several educational programs on Exercise Physiology, Sports Coaching and Motor Learning. In 2014 he started to work as a lecturer-researcher at the research group Move to Be (also at the School of Sport Studies at Fontys University of Applied Sciences). He integrated his research insights into newly developed courses such as Research in Society, Innovation of Technology in Sports and ‘Beweegontwerper’. In 2016 he received a research grant ‘promotiebeurs voor leraren’ from the Netherlands Organization for Scientific Research. With that grant he started his PhD-research in which he focused on the motives and behaviours of recreational runners to understand them. He investigates how to design running-related technology that matches the motives and behaviours of those runners. After obtaining his PhD, Mark will continue his work as lecturer-researcher, at the research group Move to Be at Fontys University of Applied Science.

LIST OF PUBLICATIONS

Publications marked with an * are part of this dissertation

Journal articles

Mark Janssen, Jos Goudsmit, Coen Lauwerijssen, Aarnout Brombacher, Carine Lallemand, and Steven Vos. 2020. How do runners experience personalization of their training scheme: The Inspirun e-coach? *Sensors* 20, 16 (2020), 1–19. DOI:https://doi.org/10.3390/s20164590 *

Daphne Menheere, **Mark Janssen**, Mathias Funk, Erik van der Spek, Carine Lallemand, and Steven Vos. 2020. Runner's perceptions of reasons to quit running: Influence of gender, age and running-related characteristics. *Int. J. Environ. Res. Public Health* 17, 17 (2020), 1–12. DOI:https://doi.org/10.3390/ijerph17176046 *

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Demonstrators and workshops

Inspirun e-coach demonstrator featured at Dutch Design Week '19, *Personalized Running Experience*. 2019

App-decision tool demonstrator featured at Dutch Design Week '19, *Personalized Running Experience*. Eindhoven 2019

Wie gebruikt welke apps? Workshop given at Looptrainersdag. 2018 Arnhem

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