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Social Mediated Touch in Jogging

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Abstract

Currently, joggers encounter difficulties in finding a compatible running partner due to time and location constraints or differences in physical capabilities. Yet online jogging communities or technologies do not solve these issues as a means of social support during jogging is limited. Social mediated touch can be the solution as it simulates touching each other over a distance through haptic stimulation. Therefore, the aim of the thesis is to design a wearable that allows for real-time social mediated touch during running. This thesis follows an auto-ethnographic research approach because this allows for fast iterations, quick design adaptations and easy access to data. This way, the researcher can design an intuitive functioning haptic wearable. For more details, please see Chapter 3.

To gain an understanding of the jogging domain, an exploratory interview with joggers was conducted (see Section 2.1 in Chapter 2). The results showed that most joggers use a smartphone, sports watch or running application and that the social aspect of jogging is particularly evident for staying motivated. However in current technologies, joggers miss the competitive or collaborative aspect. The analysis on current running technologies in Section 2.3 highlighted that the social support during the run was missing and that the support after the run only had temporally effects. To understand how social support can enhanced the current jogging experience, a literature review in Chapter 2 was conducted to investigate the potential of haptic stimulation in jogging. Vibrotactile feedback, including coin vibration motors, is most preferred for providing a sense of touch to the body because it is non-intrusive, compact, cost-effective, safe, effective on any part on the body and suitable for various applications. To allow a feeling of togetherness over a distance, a social mediated touch such as a pat on the back or gentle stroke on the arm can be included through apparent motion.

Apparent motion creates a sensory illusion in touch through activating a sequence of vibrations. However, the literature review was not inclusive on the most comfortable body locations for vibrotactile feedback.

Based on the results of Chapter 2 and the *Ideation* phase in Chapter 4, a concept was created to provide haptic feedback based on compared travelled distance in order to provide a meaningful social mediated touch. To do so, a web server was required to store the sending and receiving of social touches and the GPS locations for calculating the travelled distances. The smartphone allows for a WiFi connection for the micro controller to provide haptic feedback accordingly.

To fully understand the intended user experience of the system, two modular prototypes were created and tested between the researcher and potential end users. The evaluations in Chapter 7 demonstrated that the combination of haptic feedback based on compared travelled distances and a social mediated touch is key when addressing competitive as well as social joggers. Despite current running technologies, this is the first running technology that allows joggers to understand how other joggers are performing and send social support accordingly throughout the run.

Acknowledgements

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Chapter 1

Introduction

Human beings use the sense of touch to interact with the world around them [9]. The sense of touch plays a significant role in interpersonal relationships as it is able to evoke both positive and negative emotional experiences. [10]. Although current communication systems still primarily rely on vision and hearing, social mediated touch is a form of interaction that allows people to touch each other over distance by making use of haptic stimulation [9]. Over the years, the interest in social mediated touch has increased, resulting in the development of numerous prototypes and studies. In particular, recent research has shown that haptic technology for the purpose of interpersonal touch over a distance is able to convey a ”touch-like” feeling, even without another person being physically present [11].

Especially in individual sports like jogging, this type of interaction could be significant in terms of social support. For example, Baldi et al. [12] showed that exercising together helps to share the fatigue of exercising, reduces the risk of diseases and creates a positive attitude towards physical activity and social cohesion. However, finding a compatible jogging partner or running group might be difficult due to time or location constraints as well as a difference in physical capabilities. This problem can be solved by connecting geographically distant participants in order to help extend the availability of participants [13]. This allows joggers to, for example, save time in busy schedules [13]. Some emerging systems have been proposed to support these social activity experiences. However, research on the benefits and downsides of applying mediated interactions in running activities as opposed to face-to-face interactions is still limited [14]. As a result, the lack of understanding of this particular relationship restricts the development of social mediated touch in running activities, resulting in limiting users to employ its full potential. Therefore, this bachelor project focuses on creating a haptic wearable that allows joggers to run together over a distance through implementing social mediated touch and GPS location-based haptic feedback. This allows joggers to receive feedback from the system in the form of a social mediated touch, such as a pat on the back in order to motivate or extend physical capabilities. The thesis will follow an auto-ethnographic research approach due to COVID-19 restrictions. This way, small selective iterations can be quickly executed without the involvement of the end user, which allows the researcher to design an intuitive functioning wearable. A profound elaboration on this research approach can be found in Chapter 3.

1.1 Research questions

The main research question of this bachelor thesis is: *How to design a wearable that allows for real-time social mediated touch during running from an auto-ethnographic perspective?* This particular aim has been divided into the following sub-questions to be able to fully understand the described fields and their interrelated interactions:

1. How do joggers motivate each other while jogging? How can social mediated touch enrich the experience of jogging?

2. What is the state of the art of technology and social communication incorporated in sports, and in particular in jogging?

3. How can a smartphone and its network be used to compare the travelled distance of joggers and to provide haptic stimulation?

4. Which body parts are the most preferred by users of wearable vibration systems and especially in jogging?

1.2 Structure of the report

The remainder of this report is organised as follows. In Chapter 2, a literature review is conducted on haptic feedback and social mediated touch in jogging. This literature review provides a foundation of the knowledge on the described topic. The literature review is followed by a state of the art describing existing products and research projects that provide ways of haptic feedback or social communication in jogging to understand how existing products are perceived and used by joggers. Furthermore, in Chapter 3, the methods for the interview and auto-ethnographic research approach are discussed as well as the used design process technique. In Chapter 4 the initial idea is created and the user group is explored including user scenario's and a stakeholder analysis. These results are used to specify the main components and to set up project requirements (Chapter 5), in order to create it (Chapter 6), and to evaluate it and provide a reflection (Chapter 7). Finally, in Chapter 8 the outcome is discussed, concluded by Chapter 9, in which conclusions and recommendations are given.

Chapter 2

State of the Art

Designing a wearable in order to enhance the social aspects of jogging, includes understanding the state of the art. Hence, a literature review is conducted to broaden the knowledge about social mediated touch and the potential of haptic stimulation in jogging, resulting in insights in possibilities to combine these fields. Furthermore, the state of the art also involves the evaluation of existing products and projects including understanding current means of social communication in jogging. For example, this comprises understanding how joggers use various technologies including fitness trackers and sports watches. Although social mediated touch has not been implemented yet in jogging, it is interesting to examine how existing relevant products and systems incorporate a way of haptic stimulation and social support. This way, pitfalls and opportunities can be detected before the prototype is created.

2.1 Exploratory interview with potential users

To get insight in the potential of social mediated touch for jogging, an online semi-structured interview with an exploratory approach was conducted to gain an understanding on how joggers motivate each other while jogging and how social mediated touch could enrich the experience of jogging[1]. A semi-structured interview was chosen as it allows to explore topics more in-depth which might be more difficult to achieve in a fully structured interview or a survey [15]. Ten participants were recruited with a non-probabilistic manner, particularly through heterogeneity sampling. Heterogeneity

[1]The summaries of the transcripts can be found in Appendix A.

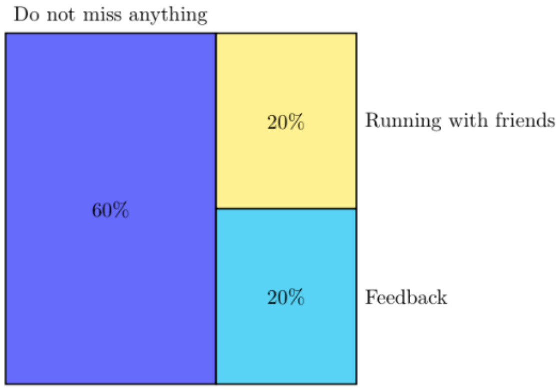


Figure 2.1: What do joggers miss during a run?

sampling is a method used for brainstorming or nominal group processes such as concept mapping when ideas have to be sampled, not people [16]. This method requires a diverse range of participants to be sampled. Relevant to this research is the effect of jogging experience on the participant's motivation to jog and their use of technology. Therefore, interviewees have been sampled to cover a wide range of jogging experience. Interviewees were ranged in three categories according to their level of jogging experience. First, a beginner would include a jogger with less than two months to no jogging experience. Second, an intermediate jogging would have a jogging experience of less than a year. Third, an expert would include experienced joggers with more than one year of jogging experience. According to [15], this type of sampling can be considered valid when performed correctly in Human-Computer Interaction (HCI) research, as HCI research differs in its nature compared to other academic communities for lacking large, well-structured data sets. This section will provide a summary and analysis on the results of the interview.

According to [17], joggers appreciate the opportunity for technology to support their jogging experience. The results of the interview agree as all participants use a means of technology during a run such as a smart phone or a sports watch. The purpose of these technologies is to determine a route prior to the run, or to track, analyse and view the results after the run. The average running session takes around 45 minutes. As Figure 2.1 indicates, two participants miss running with friends because of the current COVID-19 situation which denies runners of associations to run together.

Furthermore, two participants miss a comprehensive means of feedback during and after the run. One participants solved this solution by buying a sports watch for analysis after the run. Although six participants do not miss anything while jogging, five participants would be interested in incorporating a social aspect in jogging through a means of running together over a distance or through participating in run challenges with friends. However, the joggers disagree on how this should be achieved. Some joggers agree that audio communication would be interesting to use during a run, but are not sure if they would really appreciate it because they have never tried it before. Others do not want to be distracted while jogging and, therefore, propose a haptic feedback system, but are not sure if they would approve it because of the same reasons as stated before. Participants also contradict in how this social aspect should function in terms of collaboration or competition. Some do, however, agree that in order to facilitate jogging together over a distance, it would be interesting to know where the other jogger is running such as if the other jogger is in front, behind or jogging at the same pace. This way, it feels as if the joggers are running together. Yet all participants agree that they like jogging because they see that they improve after every run. Moreover, the majority of the participants take their smart phone and keys with them during a run. More experienced runners take a sports watch in addition. The results also showed that the potential target group would be intermediate to expert running as they will most likely be interested in the social aspect of jogging and because they use a smart phone in order to call someone in need or to track and analyse the run.

2.1.1 Conclusion

The results of the interview highlighted the motivation of joggers and what they currently miss while jogging. First, the target group will most likely be intermediate to expert runners because they utilise technology such as a smartphone during and after a run, which means that the final prototype can utilise the Internet connection and GPS location of the smartphone to provide meaningful location-based feedback and a means of social mediated touch accordingly. Second, the prototype should have a minimum battery life span of 45 minutes to occupy the average running time of the majority of the joggers. Third, some joggers showed to miss a competitive or collaborative aspect while jogging. This is significant as it highlights the potential of this project.

2.2 Literature review

A literature review is composed in order to get insight in how to apply social mediated touch to a human body in motion. As this is a novel subject, two main subjects will be discussed and evaluated individually: the potential of haptic stimulation in jogging, and social mediated touch. Currently, no research exists on the intersection of these subjects. Section 2.2.1 focuses on defining the sense of touch, the possibilities of providing haptic stimulation to the human body, and how to successfully implement haptic stimulation while jogging. Section 2.2.2 discusses the human need for social touch, a touch over a distance through social mediated touch, and existing haptic wearable that provide a means of social mediated touch. The conclusion of these results will give an estimation how to combine social mediated touch in wearable technology with jogging.

2.2.1 The potential of haptic stimulation in jogging

Humans can receive information through the sense of touch in order to interact with the world around them [9]. Touch can be defined as the sensation evoked when the skin is exposed to mechanical, electrical, thermal or chemical stimulation [18]. The wide range of sensors incorporated in the skin provides humans the means to perceive heat, pressure, itch, pain and irritation [19]. It allows humans to interact with external objects in terms of texture, weight, size and shape and also supports the location of body parts in time and space [9], [20]. For many behaviours, physical contact is required in order to obtain the exact information about the immediate environment. The sense of touch, also referred to as "haptic", provides this information through discriminative aspects related to detecting, differentiating and identifying external stimuli, in order to quickly make decisions on consequent behaviour [20], [21]. Furthermore, the sense of touch is highly significant in interpersonal relationships as it is able to evoke positive emotional experiences such as an intimate touch by a partner, as well as negative experiences like a sudden unwanted touch by a stranger [10]. Although technologies for human-computer interaction and sensory substitution systems exist, current communication technology still primarily rely on vision and hearing [9]. Haptic technology can act as a replacement for the existing auditory and visual instructions as the instructions given through the vibrations also incorporate amplification of auditory and visual instruction adding a new dimension in situations where communication is hindered such as sports [22]. Although haptics have been incorporated in stationary settings, research on haptics in motion and especially running is still limited [23]. Yet to answer the main research question of this bachelor thesis:

> *How to design a wearable that allows for real- time social mediated touch during running from an auto-ethnographic perspective?,*

an understanding on haptics in running activities is required. Therefore, the aim of this paper is to evaluate the potential of haptic stimulation in jogging by conducting a qualitative literature review.

Following this objective, Section 2.2.1.1 focuses on defining touch as it is important to understand the nature of human touch for providing constructive and meaningful haptic stimulation. In Section 2.2.1.2 haptic interfaces will be discussed including possibilities of applying a sense of touch to a human body. Section 2.2.1.3 discusses the potential of haptic stimulation in jogging and Section 2.2.1.4 presents the conclusions and recommendations for this study.

2.2.1.1 Defining the sense of touch

Touch allows humans to interact with the environment through kinesthetic and cutaneous senses. Researchers agree that touch can be divided into two sub-systems: the kinesthetic system for the proprioception of muscles and ligaments tension, and the tactile system which relies on the perception of details through skin receptors [9], [12], [24]–[26]. The kinesthetic system allows humans to have sensory awareness of the location and movements of body parts, and it also allows the human being to assess external forces. For instance, while raising one's arm with closed eyes, the kinesthetic system can tell where the arm is located and that the arm is moving.

The cutaneous system (or tactile system), instead, focuses on the tactile, thermal, pain and itch sensing sub-modalities [20]. This particular system, therefore, focuses on detecting texture, temperature and shape [12]. This is done through different receptors embedded in the skin and their receptive afferents [9]. Each receptor has its own degree of sensitivity to a specific type of sub-modality [9], [24]. An example of a particular cutaneous process is the sensing of temperature through thermoreceptors and mechanoreceptors in the skin. These receptors sense the deformation or displacement on the skin through stretching, vibration or pressure. The sensory information conveyed from the nerves of the receptors is then guided to the central nervous system. Additionally, Alahakone and Senanayake [24] argue that mechanoreceptors are especially fundamental for haptic interfaces as they provide a sensation of touch on the skin. Altogether, the distinction between kinesthetic and cutaneous systems defines the nature of touch and shows possible directions for applying haptic stimulation to a human body.

2.2.1.2 Haptic interfaces

Vibrotactile feedback is preferred for providing a sense of touch to the body because it is non-intrusive, compact, cost effective, safe, effective on any part of the body and because it is suitable for various different applications. Although research of Huisman [27] state that an exact sense of touch on the body is yet to be artificially created, distinct actuators incorporated in haptic interfaces can come close to simulating a sense of touch. Haptic interfaces are a means of communicating information through the sense of touch by applying pressure, force or vibration [24]. Based on the type of feedback, this can be further arranged in force feedback (kinesthetic) and tactile feedback. According to [24] and [9], force feedback systems aim to stimulate the kinesthetic receptors by applying force on limbs which can be felt through the muscle. Alahakone et al. [24] highlights that downsides to this type of feedback are a limited range of motion, meddlesome to the user, and can restrict the freedom of motion greatly. Baldi et al. [12] and Demircan et al. [28] also argue that kinesthetic feedback is not suitable because it is often obstructive and restricts the user in motion, whereas cutaenous stimuli are effective and non-intrusive. However, Haans and Ijsselstein [9] state that kinesthetic feedback conducted in their research on manoeuvring a ring with distant users, significantly increased the user's performance level and a sense of togetherness. This shows great potential for kinesthetic feedback on task-performance and the experience of presence. Yet these findings require more research for a proper validation.

As mentioned earlier, [12], [24], [28] agree that tactile feedback is most suitable for haptic stimulation on the human body. Tactile feedback can be applied on the body through mechanical, electrotactile or vibrotactile actuators that deform or cause a displacement to the skin [9], [27]. Mechanical actuators are small elements that press on the skin without any vibration interventions. These actuators can be dynamically regulated by, for instance, shape memory metals [9]. Electrotactile actuators generate a sense of touch by producing a small electrical current through the skin [24]. However, according to [24], this type of feedback was perceived as painful to the user and caused fatigue to the skin, which makes the use of this type of feedback unfavourable in sports. Vibrotactile stimuli consist of vibrating elements that provide information through small forces or cues varying in frequency, waveform, duration, intensity or amplitude [22]. Vibrotactile feedback is often provided by compact and light-weighted vibration motors, creating a variety of different feedback types such as navigation, sports applications and human motor learning. In particular, Baldi et al. [12] highlight that the means of small wearable devices, make cuteanous stimuli most appropriate for providing haptic stimulation to the body. The simplicity of the vibrotactile devices allows for flexibility in personalising the intensity of the vibration to every user's preferences, while it also supports customisation to any configuration such as a wearable belt, a suit or a handheld device [24]. Notably, vibrotactile stimuli can be perceived stationary as well as in locomotion. According to [22], vibrotactile stimuli at the spine and thighs are accurately perceived in both stationary as well as locomotion position at physical effort levels of 50, 70 and 90%. For providing a smooth motion on the skin a periodic vibrotactile burst of 150 Hz is preferred according to [25].

By comparing the classifications of haptic interfaces, [12], [24], [28] agree that vibrotactile feedback is most safe and applicable in various fields in comparison to electrotactile and force feedback systems. Demircan et al. [28] further state that vibrotactile feedback can be provided through coin vibration motors. Coin vibration motors are non-invasive, cost-effective, small in size, safe in use and effective on almost all body parts. Lederman and Klatzky [25] also agree on this theory and note that the stimulus for a tactile and smooth motion on the skin should be periodic, such as a vibrotactile blast of 150 Hz, for optimal haptic perception. All things considered, vibrotactile feedback is found to be the most appropriate for providing a sense of touch in motion, because it is non-invasive, safe, low cost and effective and because they can be displayed by means of small wearable devices.

2.2.1.3 Discussion

Hirano et al. [29], Baldi et al. [12] and Peeters et al. [22] have stated that haptic stimulation in jogging is most suitable because of its efficacy, intuitiveness, intimacy and because it does not occupy hearing or seeing. Peeters et al. [22] and Demircan et al. [28] explain that in noisy and busy environments as found in sports, haptics can be of significant value for replacing, integrating or intensifying auditory and visual instructions by providing real-time, intuitive and simple vibrotactile feedback to the user. The application of vibrotactile cues especially are an opportunity for communication related to instruction or feedback [22]. Hirano et al. [29] agree with [28] and [22] and add that auditory feedback occupies hearing, which can result in discomfort and confusion.

Furthermore, Demircan et al. [28] showed that staggered vibrations are more meticulously perceived by the user during a run. As the cognitive load required for perceiving the vibration is less in comparison to continuous vibrations, staggered vibrations allow rest periods for the user, which in turn can decrease the dullness of stimulation related to continuous stimulation. Alahakone et al. [24] support this notion and continues that repeated vibrations create discomfort as neural adaptations arises resulting in desensitisation.

Lastly, the positioning of the vibrotactile system on the body can be significant for its efficacy and the user's comfort. For example, Peeters et al. [22] state that vibrotactile signals at the thighs and spine are best perceived stationary, but also during physical effort levels of 50, 70 and 90%. Baldi et al. [12] agree that the spine is preferred for detecting vibrations in remote social walking, but also note that the wrist is as significant as the spine, with arms and ankles next in line. Baldi et al. [12] explain their finding by elaborating that tactile sensitivity is influenced by the positioning of the receptors in the skin, their distance regarding the actuators, the stimulation frequency, the age of the users and hairy and bony skin areas which are better sensed. According to [12], the ankles would be best for haptic cues in motion. Research of Hirano et al. [29] also argue that the ankles are preferred for determining running pace, as knees and wrists would be difficult to identify for pace identification. Research of Machida et al. [30], instead, signified that vibrations in motion are best perceived at the ears, wrists, hands, feet and especially the neck. However, the neck was perceived by participants as the least comfortable and preferable. To sum up, as these studies do not both conform in a social and jogging context, this highlights that extended research is required before verifying what body parts are suitable for providing vibrotactile stimuli while jogging. Nevertheless, research of [24] and [28] have showed that staggered vibrations are preferred and best perceived while jogging as continuous vibrations might become numb and obtrusive to the jogger.

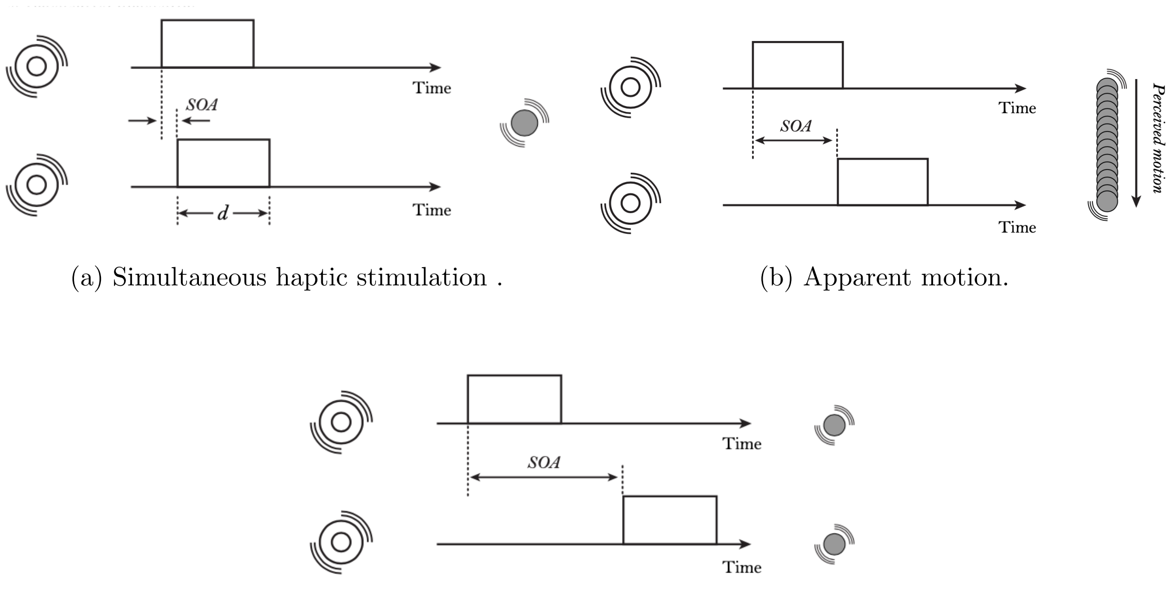
2.2.1.4 Conclusion and recommendations

The aim of this literature review is to evaluate the potential of haptic stimulation in jogging. This was done by conducting an exploratory literature research with a qualitative approach, which resulted in defining touch and haptic interfaces. The literature review allowed for the discussion of the potential of applying haptic stimulation to jogging. The results showed that vibrotactile feedback is the most safe, non-invasive, cost-effective, small, light-weighted and effective on almost all body parts as compared to alternative described methods to provide a sense of touch. This was further elaborated by highlighting that vibrotactile feedback can be well perceived while running, especially through providing staggered vibrations. However, the results showed that no conclusion could be found on the best perceived body location for haptic stimulation while jogging, as it depends on the user tasks. All the above mentioned, asks for an extension of this literature research in providing more research on the best perceived locations on the body for haptic stimulation.

2.2.2 Social mediated touch

As mentioned earlier, the sense of touch is important for detecting, differentiating and identifying external stimuli [20], [21]. However, research has shown that next to discriminative properties, humans also have a neurophysiological system that allows for affective properties of touch: social touch [31], [32]. Social touch includes all events in which humans can touch each other such as when shaking hands, hugging or in bumping into each other in a crowded metro [10]. Research of Cascio et al. [14] and Haans Ijsselstein [10] showed that social touch has especially profound psychological effects in sharing social reward, communication, attachment, and emotional regulation from infancy throughout life. During infancy, social touch is considered to be of high importance as a lack of touch can result in negative consequences to the infants well-being in later life such as over-sensitivity [14], [27]. However, social touch also contributes to the perpetuation of social relationships and the development of collaborative and sexual behaviour later in life such as romantic relationships [33]. Social touch between partners releases oxytocin which is a hormone that plays an important role in social bonding and supports the formation of stable relationships [34]. According to [27], the pain rating of an agonising stimulus decreases when a partner is holding one's hand unlike the touch of an external object or a stranger's hand. Nonetheless, the effects of social touch are not limited to romantic or sexual relationships [14]. For instance, a social touch by a stranger is able to lower one's heart rate, which could be helpful to reduce stress [27].

The quality of the touch is also important for its efficacy. For example, infants were found to increase smiling behaviour during a gentle stroking touch, but not during a static touch [14]. This is especially important for long-distance social interaction technology which at present primarily focuses on audio and vision, whereas the advancement of long-distance interpersonal touch is still in development [14]. This long-distance interpersonal touch, called social mediated touch, can be defined as a means of touching each other over a distance through a means of tactile or kinesthetic technology [10]. Yet research of Huisman [27] addresses that some differences with real-life social touch arise. First, the technique on how a touch is send and received differs between both users. In a social mediated touch environment, the sender will most probably use a pressure sensor while the receiver feels a sense of touch through actuators such as vibration motors. In a real-life social touch, the means of touch is complementary. Second, social mediated touch has its limits in providing a comprehensive meaningful touch compared to social touch. Third, social mediated touch does not have to occur simultaneously. This means that a social mediated touch does not have to be real-time as the touch can be stored and received at any time. When applied to jogging, social mediated touch can allow joggers to overcome the lack of motivation by exploiting its social aspect through allowing joggers to run over a distance [35]. The haptic technology can enhance the experience of togetherness as users are able to feel and evaluate what they are doing as if they were at the remote site even though the exertion activity is of parallel nature [12], [13]. However, [27] addresses that factors such as context, timing and the communication partner can be of great influence on the potential of applying social mediated touch, and should consequently be taken into consideration when creating the prototype.



(a) Simultaneous haptic stimulation .

(b) Apparent motion.

(c) Subsequent motion.

Figure 2.2: Control space of haptic apparent motion [1].

2.2.2.1 Applying social mediated touch

As elaborated earlier, interpersonal touch plays a significant role in social communication. According to [33], an interpersonal touch such as a gentle touch is able to express

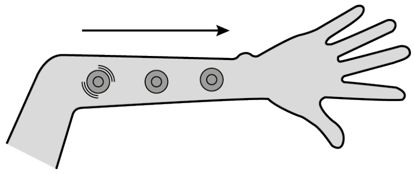


Figure 2.3: Illustration of the experiment conducted by Israr and Poupyrev [1] on the forearm.

social support, which is of high importance for this project. In order to create such a touch, apparent haptic motion can be applied. Apparent haptic motion is defined by [36] as the appearance of real motion through a sequence of vibrations which are detached by time and location but perceived as a single stimulus moving from one position to the other. In other words, a sensory illusion in touch is created through a control algorithm [1]. Research of Israr and Poupyrev [1] state that two variables are of high importance to create an effective apparent haptic motion: the duration (d) of the vibration and the stimulus onset ansynchrony (SOA), which is the time between the start of the stimuli (see Figure 2.2). Stimulus onset ansynchrony is a critical feature for the efficacy of haptic apparent motion. For example, Figure 2.2a shows that when the stimulus onset ansynchrony is too small, one might detect a single motion. This is a result of the overlapping of vibrations. However, when the SOA is too large like in Figure 2.2c, one might feel two or more individual vibrations as if the vibrations appear subsequently. Therefore, a balance should be found between these motion so a continuous directional motion can be simulated where stimuli are integrated in time and space (see Figure 2.2b). Israr and Poupyrev [1] investigated the parameters of applying an effective apparent motion on the forearm and the back by conducting various experiments with participants as can be viewed in Figure 2.3. The results of the research of Israr and Poupyrev [1] showed that duration is a significant factor as the results suggested that a slow continuous moving stimulation can be created because the SOA space between the lower- and upper-thresholds was greater in a higher duration. Furthermore, the study also showed that a higher control range for apparent haptic motion was found on the back. This is a result of the spatial resolution on the forearm being more advanced compared to the spatial resolution on the back. Furthermore, the effect of spacing on the back was also significant but not on the forearm. A reason for this could be due to more advanced spatial resolution on the forearm, enabling participants to locate the actuators on the forearm more easily. In turn, this could result in a higher risk of subsequent motion. Lastly, as the parameters could be applied to various actuation technologies such as coin vibration motors or high-end military actuators, the SOA parameters depicted in the described study highlight some important benefits. The cost of producing products with small margins reduce. Furthermore, the energy consumption, size and weight of the actuators are low while it produces an effective apparent motion.

2.3 Products

Figure 2.4 shows the design space of running technologies can be divided in two axes: the focus axis (y-axis) and the feedback axis (x-axis) [2]. The focus axis focuses on performance vs technique technologies. However, since this project focuses on providing a means of social mediated touch, performance and technique technologies will be neglected. Instead, a focus will be put on the feedback axis which ranges from representative to assistive feedback. Representative feedback is provided in terms of numbers such as running distance. Assistive feedback alerts the runner of inexpedience but also acts as a virtual coach for reaching the best performance. The virtual coach can, for example, keep track of the running schedule, adapt the schedule according to preferences and weekly results, but can also help in assisting the runner during training sessions. A balance between assistive and representative feedback will have to be found as the final system will have to provide a meaningful means of social mediated touch based on the position of the other jogger (see the results of the interview in Section 2.1). In order to find this balance, existing products have to be additionally analysed to understand how current technologies are used for providing a means of social communication in jogging.

2.3.1 Sports watches and SPRA

Since 2000, sports watches have been developed such as Garmin, Polar and Suunto [2]. In these watches, technology, such as GPS or a heart rate monitor, are incorporated,

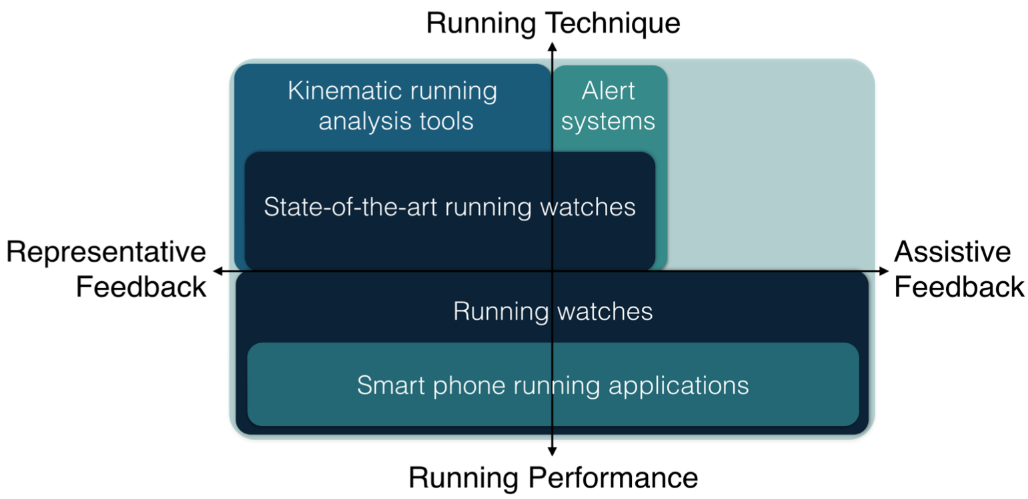


Figure 2.4: The design space of running technologies [2].

aimed at analysing the performance of the run. The information on the performance such as pace or running distance can be viewed on the watch itself or through a detailed overview on a smartphone. Smart phone running applications (SPRA), such as Garmin Connect, Nike Run Club or Endomondo, have adapted the concepts of running watches in order to provide the runner with the same overview, but instead by using the smartphone's GPS and accelerometer. However, these technologies often have a primary focus on running performance, while the social experience of running is neglected. Therefore, applications and watches with a means of social support are highlighted in this section.

2.3.1.1 Garmin Forerunner

A sports watch that contains a social aspect is the Garmin Forerunner 35[2] (see Figure 2.5). The Garmin Forerunner 35 allows for a means of motivation through the Virtual Pacer feature. The Virtual Pacer feature allows the user to run at a set pace to improve performance [37]. Every time the user drops below the targeted pace, the user is notified by a message, and accordingly, a vibration is felt or a beep is heard. A full user test can be found in Appendix B. The results showed that vibrotactile stimulation should not be obtrusive nor distracting. This also means that the use of different types of feedback simultaneously should be avoided as this could cause distraction to the

[2]More watches contain this feature, but for convenience this watch is chosen for analysis.

Figure 2.5: Example of a fitness watch [3].

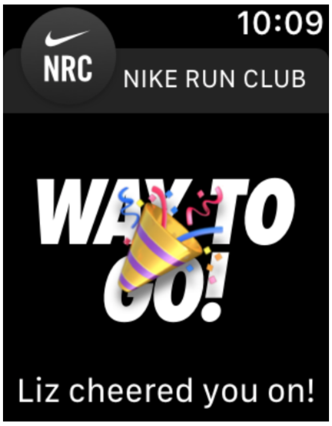


Figure 2.6: Example of an in-run cheer of a friend on a smart watch [4].

jogger. This finding supports the research of Baldi et al. [12] which showed that haptic communication is often preferred due to its intuitiveness, efficacy, intimate nature and because it does not occupy sight or hearing. It is also preferred because the real-time feedback provided by the watch is only effective when the jogger chooses to look at the watch [17]. Furthermore, the Virtual Pacer does not allow for a social support even virtually as feedback is not provided in a motivational way. This way, the social experience of jogging is neglected, which limits any benefits of increasing the user experience as Mueller et al. [13] showed that people joining an exertion activity together can have a positive contribution to the user experience. Although these technologies provide a way of sharing the finished run with friends on social network platforms like Strava to motivate each other, providing social support after the experience often have temporally effects, limiting any benefits of this relationship [13].

2.3.1.2 Nike Run Club

A SPRA that includes a means of social communication is the Nike Run Club application. The Nike Run Club app includes a GPS tracker, pedometer, audio guided runs from athletes and coaches, personalised distance goals and workouts [4]. The app incorporates a social experience in various ways. First, one is able to create challenges with friends and other runners to stay motivated. For example, Figure C.1a shows the ranking in running distance between friends and it also shows challenges and events between runners all over the world that the user can join. Second, one is able to motivate a friend when he or she starts a run by sending cheers. Connected friends will receive a notification when a friend starts a run and are able to respond by sending an recorded audio cheer or a default cheer as a means of motivation as can be seen in Figure 2.6. A detailed overview and user test can be viewed in Appendix C.

For this project, the results showed that no real-time motivation or social support is essential while jogging. However, there should be aimed for real-time feedback as the results of the user test showed that users might miss the notification (no cheers), or users see the notification when the run is almost finished, resulting in cheers to be received after the run. Furthermore, if the sound of the smartphone is muted or if one is not focused on the smartphone, one might not notice that a cheer is received. Since the cheer can only be send once, a jogger might also miss the motivational message during a run. Therefore, it would be interesting to provide a frequent means of social support. However, as Jensen and Mueller [2] state in their research, the feedback should not be provided continuously as this reduces the user experience. Demircan [38] agrees and adds that staggered vibrations are more accurately perceived while running because the cognitive load is less in comparison to continuous vibrations. Because of the incorporated rest periods, the numbness of continuous stimulation is reduced. Therefore, a balance should be found. The missing of messages also makes notifications on sports watches more convenient as an vibration is additionally felt. The preference for vibrotactile stimulation continues in the abrupt clapping sound of a cheer which can be inconvenient and disruptive in a state of focus during a run. For example, distraction can be caused when a cheer is received and one is eager to know who sent the cheer or what type of cheer was send, resulting in an interruption or a decrease in running pace. Jensen and Mueller [2] agree that the continuous look on a smartphone or watch has negative effects as the examination of the effects on movement corrections is unwise and risks of changing to an adverse running style.

2.3.1.3 Zombies, Run!

To understand how games can be of motivation to joggers, the "Zombies, Run!" application was analysed. The story of the game is about the main character, the jogger, who is one of the lucky to survive a zombie epidemic [5]. In the game, the jogger is running to one of humanity's last remaining homes. The people there need help in defence, gathering food and supplies and the rescuing of survivors. There is also another mission which will be explained throughout the game. The aim of the running application is to motivate the user to jog by providing a gamified story about zombies. When the zombies are nearby the game urges the user to increase pace. This way, the narrative and virtual space turn the run in an interval training, highlighting the strength of technology and games to change the nature of jogging [17]. Mueller and Muirhead [17] further elaborate that these type of exertion activities can help to direct the focus of discomfort and fatigue away, contributing to a positive jogging experience. Figure 2.7 shows an overview of interactions with application. The difference in pace as a result of zombies chasing the user motivates the user to run further in order to get the best performance. Furthermore, the application provides different types of motions: jogging, running and walking. The application also has the option to create an own training such as an interval training, has more than 200 workouts, allows the user to run anywhere (outside, inside, in gyms) and tracks the progression for sharing [5]. Appendix D provides an user test on the described application.

The results showed that a gamification element for motivation should be added to the prototype to involve collaboration but also competition for joggers. Moreover, the game also gave insight in how to provide feedback. For example, when the zombies were chasing, no measurement was conducted on whether the user was increasing speed or not. In order words, when one would slow down while the zombies were chasing no penalty or feedback was provided. This way, the chasing was not meaningful and felt numb to the researcher. Therefore, for this project, meaningful feedback and

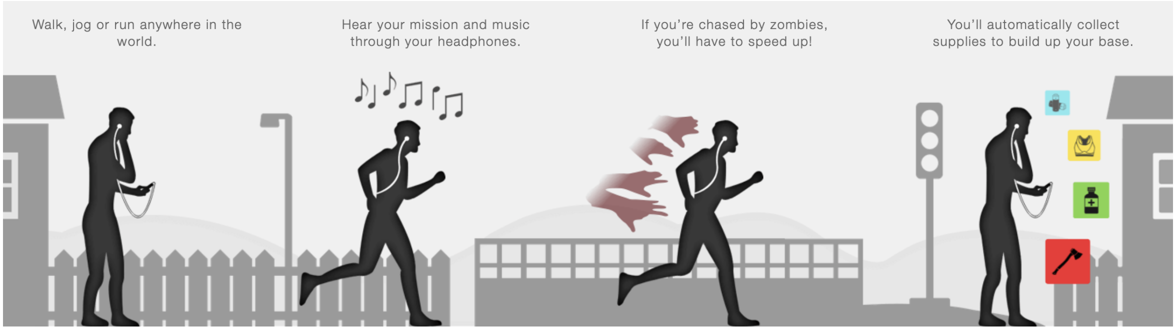


Figure 2.7: Explanation of the Zombies, Run! application [5].

interactions based on the user's location should be provided.

2.4 Research projects

Recent projects and studies have been analysed to provide an overview on inspiring works on how a means of social communication, haptics, social support and jogging are used. Through gaining an understanding of the relationship between the described elements, opportunities and pitfalls for this project can be found.

2.4.1 Jogging over a distance

In the project of Floyd et al. [13], a mobile prototype was created which allowed geographically distant joggers to socialise and motivate each other through spatialized audio in order to convey presence and pace [13]. This was done by tracking and setting a preferred heart rate of each participant to allow participants to specify how much effort they planned to invest in the run according to their physical capabilities. This way, participants of different levels are able to run together in terms of physical effort. The prototype was set up with a head set for each participant as a means of communication in order motivate each other while jogging. During the run, the heart rate of each participant was continuously send to a server. The aim of the spatialized audio was to experience a side-by-side running by positioning the audio according to the heart rate data (see Fig. 2.8). This way, participants are able to determine whether the other jogger is putting more, less, or the same effort in the run based on the set heart rate. The results of the study showed that participants were able to catch up with friends while performing a physical activity. In particular, the prototype allowed participants to save time as one is able to socialise while exercising. This resulted in a shared feeling of "togetherness" as a sense of shared pain was felt, which positively affected the level of exertion for participants. For example, seven participants commented that they would jog further when using the prototype compared to jogging alone [13].

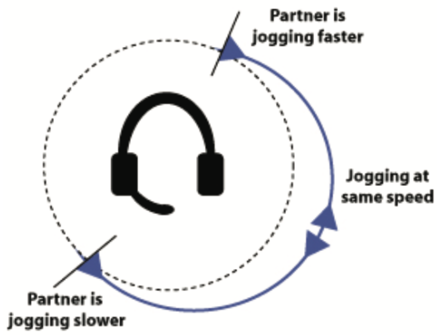


Figure 2.8: Illustration of the spatialized audio according to the heart rate of the participant [6].

However, the results also showed that a competitive element was absent as the majority of the participants would rather wait for the other participant to catch up which would mean that they had to slow down. Nevertheless, when the other participant was increasing speed, the other participant was likely to increase speed as well.

The research illustrated that the resulted collaborative behaviour could have emerged due to a limitation of the technology. In competitive sports such as athletics, the difference in determining the winner is often based on millimetres [39]. However, this reliance is difficult to accomplish in audio spatial environments, because humans have difficulties in identifying the source of sound in outdoor environments [40]. This way, the design of the prototype limited the opportunity of competition, resulting in the collaborative behaviour of the participants.

A limitation to this research is the target group of the study: casual joggers who like to socialise while running. This means that joggers who do not prefer to talk while running are neglected in this study. A future objective could be to include this type of jogger through altering the technology to be able to include preferences for every participant.

2.4.2 Haptic system for guide runners in blind marathon

Another research incorporated haptic feedback to improve guidance for blind runners [29]. In a blind marathon, visually impaired people can run a marathon with a sighted guide. The sighted guide is paired to a visually impaired participant with a stretch rope. Challenges for participants include a clear communication and paying attention to multiple events at the same time such as timing, coaching and how to use a stretch rope. These challenges make it difficult for both the participant and guide runner to maintain a constant running tempo, which can result in anxiety and fatigue for both [29]. Therefore, the aim of the research was to create a system in which both runners are able to match their running tempo without any physical attachment like a stretchy rope. The system holds two independent modules positioned around the ankle: one for the blind runner and one for the guide runner. Once the blind runner's foot hits the ground, a vibration signal is send to the guide runner as a means of communication. This way, the guide runner can adjust the running pace according to the pace of the blind runner.

The research highlighted some significant insights for this bachelor thesis. First, the design of a sports wearable should fulfil the following requirements: ease of use, light-weighted and comfort. Second, various locations for the wearable were considered. The research showed that a tempo-like feedback on the wrist would be difficult to understand. A tempo-like feedback on the knees would be difficult to identify, resulting in the ankle to be the preferred location for positioning vibro-tactile feedback. Yet this research does not comply in a social context, so this has to be tested by the researcher. Third, the research showed some participants felt the vibration too strongly or too little. This also resulted in participants feeling anxious as they expected to feel vibrations also when both runners were synchronised. As this bachelor thesis uses an auto-ethnographic approach, the vibration strength should be set to the researcher's preferences. For further research, one should aim to provide a method in which the user is able to customise the strength and intensity of haptic stimulation.

2.5 Conclusion

This chapter focused on understanding the state of the art through an exploratory interview with potential users, a literature review and the evaluation of existing products and research projects which provide a means of social communication. This way, difficulties and opportunities could be distinguished before the prototype is created.

The aim of the interview was to gain understanding on the motivation of joggers (see Subquestion 1 in Section 1.1). The results showed that all interviewee jog in order to stay fit and, that they use a mobile application or sports watch for support during and after the run. Most participants also take a smart phone during a run, which highlights that the GPS location and Internet connection of the smart phone can be used for Section 4. Notably, participants were interested in incorporating a social aspect to their current running experience in order to stay in touch with friends, for competitive purposes or to be able to jog together in times of COVID-19. However, no agreement could be found how this social aspect would be implemented as it has never been tried before.

Furthermore, the literature review aimed to evaluate the potential of haptic stimulation in jogging and social mediated touch. Social mediated touch can allow joggers to overcome the lack of motivation by exploiting its social aspect through allowing joggers to run over a distance. The results showed that vibrotactile feedback, and especially coin vibration motors, are most safe, non-invasive, cost-effective, small, light-weighted and effective on almost all body parts compared to alternative techniques. This way, vibrotactile feedback can enhance the experience of togetherness while the physical activity is of parallel nature. Most of all, staggered vibrations should be utilised for the ideation phase as these type of vibrotactile feedback is best perceived during jogging. However, the results on the best body location(s) for providing feedback were inconclusive. This shows that more elaborate tests should be performed in Section 4 with coin vibration motors on various body parts to determine what body parts can be used for providing haptic stimulation.

The analysis of existing products and research projects established a preference for vibrotactile stimulation as this did not distract the jogger and a natural means of feedback to the jogger. Subsequently through providing this type of feedback, any negative effects on running style including movement corrections or posture are avoided. Moreover, adding a gamification element, such as a collaborative and/or competitive element, to the prototype would be interesting as this can motivate the jogger when the jogger is unable to meet physically, due to time constraints or when other friends or joggers are unable to meet[3]. The analysis also provided some requirements for the final prototype including ease of use, light-weighted, comfort and the ability to set the intensity of the vibrations according to the preference of the user.

[3]This feature would extend the availability of joggers as people all over the world would be able to join.

Chapter 3

Methods and Techniques

This chapter focuses on the methods and techniques used for this research. First of all, the method used for conducting the interview in Chapter 2 will be elaborated followed by an discussion on the research method used in this thesis: auto-ethnography. After the design process method used in this research for the following phases will be explained.

3.1 Interview

To gain an understanding on the potential of social mediated touch for jogging, an online semi-structured interview with an exploratory approach was conducted with ten participants through heterogeneity sampling (see Section 2.1). This means that the approach is primarily concerned with discovery and does not approach a set theory [41]. The aim of the interview was to understand what motivates joggers and what they miss while jogging (see Subquestion 1). The semi-structured interview approach is, therefore, valuable as it gives the researcher the opportunity to acquire more in-depth knowledge on the discussed topics.

3.2 Auto-ethnographic research

The constraining aspect of this project involves the difficulty of user testing due to the COVID-19 situation in the first stage of the project as well as in later stages such as prototype testing. Therefore, this contributed to the choice to take an auto-ethnographic research approach. Auto-ethnography utilises the researcher as a critical reflexive participant by exploring the act of conducting research of the self which includes analysing personal experiences [42]. Unlike epistemological and methodological approaches, an auto-ethnographic approach engages in contrasting, comparing and contributing critically reflexive examinations of one's personal experience against existing research [43]. Consequently, this approach features qualitative research aspects, but it also tends to go beyond the immediate evidence through the means of critical thinking [44]. This also highlights an advantage of auto-ethnography since the design approach is based on the intrinsic motivation of the researcher [45]. Another benefit of an auto-ethnographic research approach is the accessibility of data. As the research is conducted on the researcher, fast iterations and focused design experiments can be performed without having to wait for feedback or results of user tests, which allows for quick design adaptations [44].

However, utilising an auto-ethnographic perspective for research purposes is challenging. This includes that the degree of generalisability and transferability are questioned as auto-ethnographic research is directed by the personal critique of the researcher [42]. For example, in an auto-ethnography approach one has to describe events thoroughly for the reader to determine whether a correct generalisation has been made [44]. Therefore, to assess and discuss the auto-ethnographic research done in this bachelor project, the requirements below have been set up to support readers to interpret the study as empirical research [42].

- The thesis presents the key claims, study design and methodological approach. This means that the research protocols have to be explicit so others can apply it to their own settings [44].

- The thesis makes critical reflections towards the logic and text design of the researcher. This includes a discussion about the truth of the produced claims.

- The thesis offers a detailed explanation on the collection of data and materials.

- The thesis guides discussion on how the units of study, so the self and potential users in this case, were selected by appropriately describing the means of selection.

- The thesis offers different levels of critique and discusses implications and dilemmas of the position of the researcher as the centre of the project.
- The thesis highlights practical features of auto-ethnography such as ethics and confidentiality issues.

This way, the auto-ethnographic research can be compared to the 2006 AERA Standards of Publication and the relationship between the research and contributions to the particular field can be more easily determined [42]. For this bachelor thesis, all experiments are set up according to a protocol. This means that the goal is stated followed by honest observations and a conclusion. Based on the conclusion, the next experiment is conducted. When specific settings or data is used, a table will be provided accordingly.

For finalising the research, prototypes have to be tested. As this research follows an auto-ethnographic research approach, all prototypes and experiments will be tested by the researcher. In order to provide a valid conclusion, a consistent protocol is followed including the goal, observations, logs and a final conclusion. Lastly, as a means of social mediated touch is incorporated in the final prototype, the researcher has to test the prototype with another user. This way, the personal experience of the other user should be evaluated in the user tests. The other tests are, however, tested and evaluated by the researcher.

3.3 Creative Technology Design Process

Figure 3.1 depicts the design process of creative technology. The process consists of four phases. The first phase called *Ideation* focuses on defining the problem and its solution through generating various possibles ideas. As this bachelor thesis has a clear focus on creating a haptic wearable for jogging which allows for social mediated touch, this phase will be less focused on developing and generating ideas. Instead, this phase will focus on user scenario's, a stakeholder analysis and possible events when, what, where how and why a social touch should be received and send based on the results of the literature and the interview elaborated in Chapter 2.

In the next phase called *Specification*, project requirements will be defined as a result of the knowledge gained in the previous phase. The phase will also focus on specifying the main components by creating small prototypes used to explore the design space [7]. This will be done by the researcher through a short evaluation followed by the previously described protocol of goal, observations, conclusion. In this phase, prototypes will be discarded, improved and (partly) combined into new prototypes until the desired goal is reached.

In the third phase called *Realisation*, the starting point will be the specification of the product. The product will be decomposed to see how the realised components of the previous phase have to be combined to create the haptic wearable. Again evaluation will be used to see if the end prototype meets the specifications. When the desired realisation cannot be met, the specifications will be changed accordingly. This will be an iterative process resulting in a prototype and improved specifications.

Lastly, the prototype will be evaluated by the researcher and another user to test whether the intended user experience is reached in the *Evaluation* phase. This will be done through a functional evaluation to see whether the prototype meets the functional requirements and the requirements set in the *Ideation* phase, followed by a critical reflection on the personal and academic process [7].

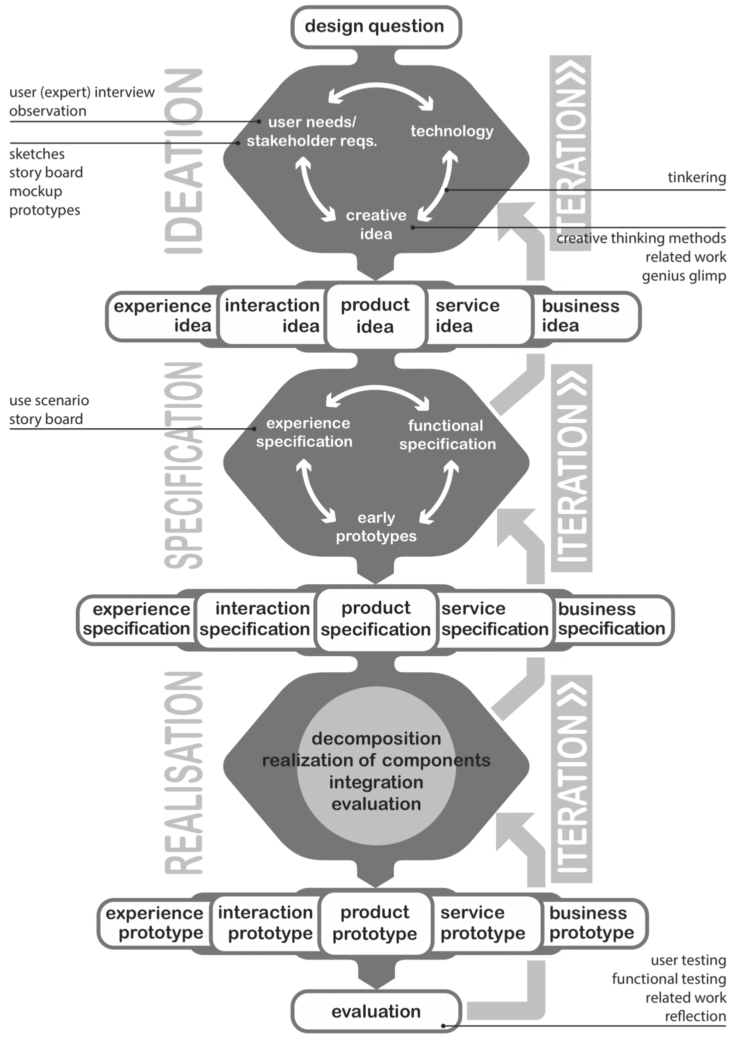


Figure 3.1: A creative technology design process [7].

Chapter 4

Ideation

This chapter focuses on exploring the user group including needs and goals. First, a mind map was created to formulate the initial idea. This is followed by user scenarios to understand how different potential users might interact and use the system. Lastly, a stakeholder analysis is conducted in order to discover and eliminate possible barriers in releasing a successful project through understanding the influence and importance of stakeholders in this project [46].

4.1 Initial idea

Based on the results of the state of the art and the mindmap, a wearable for joggers will be developed in which geographically distant joggers can motivate and challenge each other through a means of social mediated touch. Because haptic stimulation was found to be intuitive and non-distracting, a choice is made to use haptic stimulation for receiving the social mediated touch and to provide feedback on the location of the other jogger. In order for joggers to provide a meaningful social communication, the travelled distance of joggers will be tracked. For example, when two joggers are jogging over a distance and the system notices that the first jogger is falling behind through calculating the travelled distance of both joggers, haptic stimulation is provided to the second jogger in order to notify the second jogger that the first jogger is falling behind. Subsequently, the second jogger can send a means of social mediated touch such as a pat on the back to motivate the first jogger.

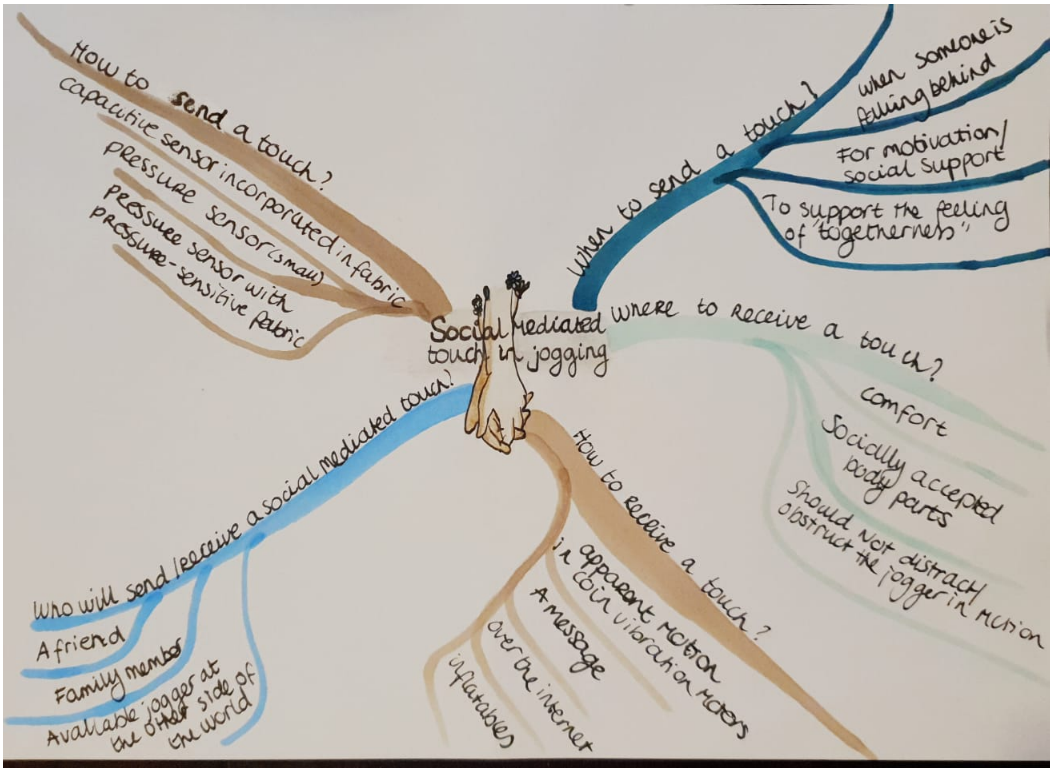


Figure 4.1: Mindmap.

4.2 User scenarios

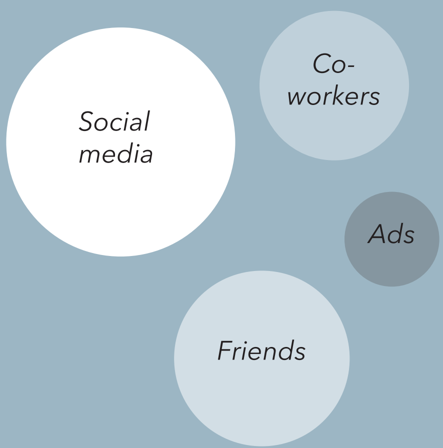
Based on the results of Chapter 2 including the literature review and interview, user scenarios were created in order to show how users might interact with the system. This way, the goals, needs, contexts and barriers of potential users can be shown and tackled in order to improve the design process of ideating and iterating.

REBECCA
Performance jogger

PERSONAL INFORMATION

Age:	25
Occupation:	Salesmanager
Online locations:	Online and work
Technology use:	iPhone 10 and Apple Watch
Internet usage:	8-9 hours a day

WHO INFLUENCES REBECCA?



CASUAL JOGGER — HARDCORE JOGGER

TECHNOPHOBE — TECH WIZ

REBECCA'S SITUATION

Goals , motivations:

- Jogs before work to regulate her energy level throughout the day
- Sports a lot including fitness
- Uses a smart watch to keep track of her stress level, sleeping cycle, hydration etc.
- Interested in analysing her results after every run
- Shares her runs on various social media channels

Keywords: performance, fitgirl, marathon runner, international running challenges, influencer

OBSTACLES REBECCA FACES

- Too busy to go jogging with friends
- Hard to find a jogging partner

HOW WILL REBECCA INTERACT WITH THE SYSTEM

Questions Rebecca will ask:

- How can I compete with a stranger at the other side of the world?
- Will the battery's life span hold for one hour?
- How do I know I am leading the run?

HOW WILL REBBECCA USE THE SYSTEM?

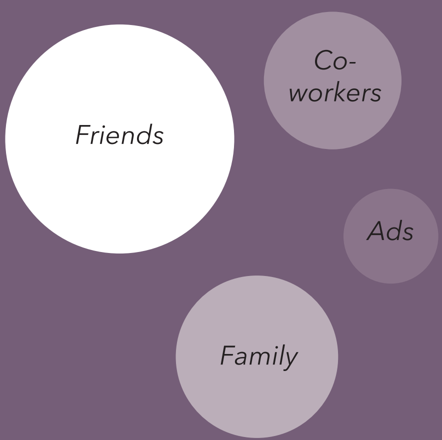
As Rebecca is too occupied to run with friends, she will use the system to find an available runner at times it suits her. Since she often runs during lunch breaks and she is often on business trips, she is unable to find a jogging partner. Therefore, she would love to have a medium in which she is able to compete with other available joggers over a distance. She is always in for trying out the newest technology in order to show off at social media and because it enables her to improve her results. She does not want to be distracted while jogging and, therefore, she likes the idea of involving haptic stimulation. Furthermore, the system should be intuitive because she wants to fully focus on the competing with other joggers. She also likes the idea of sending a cheer or motivational touch as it can support the other jogger to keep going, which is something that she is missing in current jogging technology.

LISA
Social jogger

PERSONAL INFORMATION

Age:	27
Occupation:	Secretary
Online locations:	Online and work
Technology use:	Samsung Galaxy S10
Internet usage:	5 hours a day

WHO INFLUENCES LISA?



CASUAL JOGGER — *HARDCORE JOGGER*

TECHNOPHOBE — *TECH WIZ*

LISA'S SITUATION

Goals , motivations:

- Jogs to stay fit
- Sees jogging as a way to socialize
- Jogs with a jogging association or with friends
- Sometimes uses a jogging application for analysing if she has improved

Keywords: social support, running events with friends, fun, relax

OBSTACLES LISA FACES

- Misses running with friends due to COVID-19
- Staying motivated without physical social support

HOW WILL LISA INTERACT WITH THE SYSTEM

Questions Lisa will ask:

- How can I send a means of social support to a friend when he/she is falling behind?
- Will the system be data-efficient?
- Is the system intuitive?

HOW WILL LISA USE THE SYSTEM?

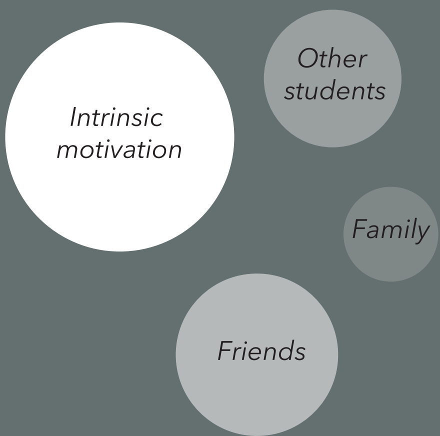
Due to the COVID-19 situation, Lisa will use the system to have a means of jogging together but over a distance. This way, Lisa and her friends can support each other without being physically present. Therefore, she only uses the system with friends and not with other online available runners. She especially likes the social and collaborative aspect of the system as the system allows for motivation through social mediated toch. This way, she and her friends can push each other to keep running. She also likes the idea of knowing how far the other runner is, so she can provide a meaningful motivational social touch. Lastly, she would not use the system while jogging with the association as this might distract her from the workout.

NICK
All-rounder

PERSONAL INFORMATION

Age:	23
Occupation:	International student
Online locations:	Online and study
Technology use:	iPhone 12 and Garmin Forerunner 745
Internet usage:	8 hours a day

WHO INFLUENCES NICK?



CASUAL JOGGER *HARDCORE JOGGER*

TECHNOPHOBE *TECH WIZ*

NICK'S SITUATION

Goals , motivations:

- Jogs to stay fit but fitness and soccer are his priority
- Uses his sports watch for fitness and jogging
- Currently he jogs by himself but he would like to jog with others
- Uses Strava and Garmin connect for analysing and sharing the run

Keywords: new student, friends, sports fanatic

OBSTACLES NICK FACES

- Misses running with his friends from home
- Finding new friends in a new country

HOW WILL NICK INTERACT WITH THE SYSTEM

Questions Nick will ask:

- Is the system expensive?
- Can I jog at any time when a friend is unavailable?
- Can the system be connected with the sports watch?

HOW WILL NICK USE THE SYSTEM?

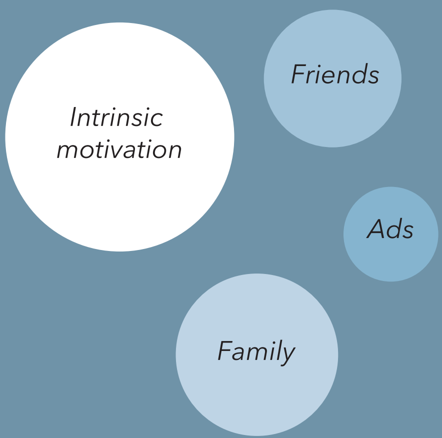
Nick recently moved to the Netherlands for his masters. He likes sports and, for this reason, just joined a student soccer team and a fitness center. Next to this, he also jogs but his priority is with soccer and fitness. He sees jogging as a collaborative sport as it is a means of exercising together. This means that he never jogs by himself, but only with friends. Therefore, he likes the system because he is able to jog together with his friends from home. His friends also like the system as they see it as a way of staying connected. He likes that he is still able to exercise together even though they are far away from each other. Furthermore, the ability to run with unknown joggers motivates him as well, as this allows him to compete but also to run together.

ANNA
Mountain runner

PERSONAL INFORMATION

Age:	33
Occupation:	Professional mountain runner
Online locations:	Online
Technology use:	Samsung s8 and Fitbit smartwatch
Internet usage:	2 hours a day

WHO INFLUENCES ANNA?



CASUAL JOGGER — *HARDCORE JOGGER*

TECHNOPHOBE — *TECH WIZ*

ANNA'S SITUATION

Goals , motivations:

- Jogs for relaxation or to blow off steam after a long working day
- Currently jogs by herself but would like to jog with others
- Uses Strava for analysing and sharing the run

Keywords: mountain running, hiking, off-road, introvert

OBSTACLES ANNA FACES

- Misses the ability to run with other mountain runners

HOW WILL ANNA INTERACT WITH THE SYSTEM

Questions Anna will ask:

- Can the system be used at any location such as in the mountains or off-road?
- Is the system sustainable?
- Can the system be connected with the smart watch?

HOW WILL ANNA USE THE SYSTEM?

Anna loves to wander through the mountains to discover new places in the pristine nature. As she is a professional mountain runner, it is difficult to find a consistent jogger partner as friends might not have the required running level, are scared of the heights or the unknown that the run might bring. Since running in the wild can make Anna disappear for hours without seeing anyone, she would love to have a medium in which she is able to socially interact with someone without being distracted from the run. Therefore, she likes the system as she is able to run together with others mountain runners without being physically present; something which could otherwise not be achieved. This way, she is able to compete with others, but is also able to practice mountain running together over a distance at any given time.

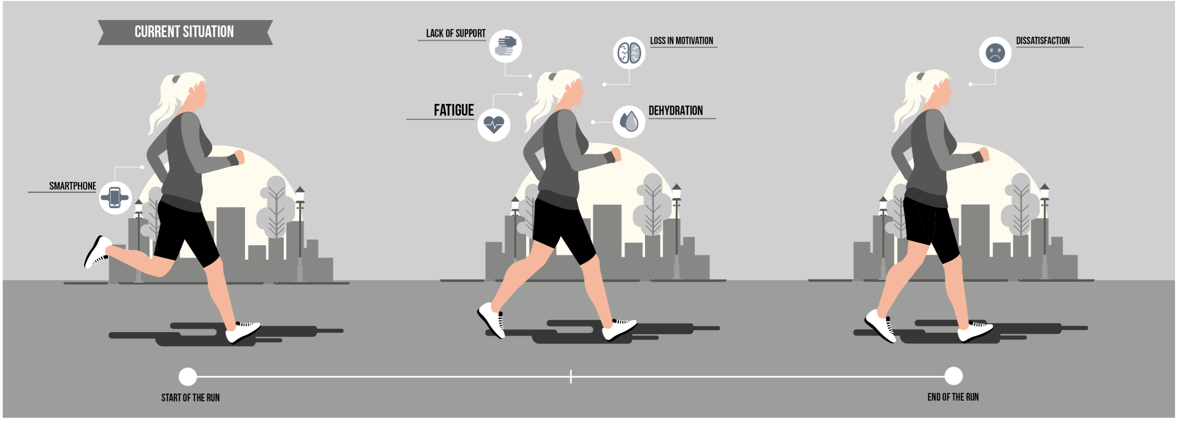


Figure 4.2: Current situation without the system.

4.2.1 Conclusion

Based on the user scenarios, required interactions for the prototype can be established. The current situation as depicted in Figure 4.2, shows the current situation of joggers. Most joggers start the run with a smartphone or sports watch. During the run, joggers encounter various impediments such as fatigue, lack of motivation, dehydration and a lack of support, making the runner feel dissatisfied after the run. In the new situation when the system is used, haptic feedback is provided when someone is leading, catching up or falling behind (see Figure 4.2). To accommodate social joggers like Lisa, a meaningful social mediated touch has to be provided by the prototype. This can be done by providing haptic feedback based on the compared travelled distance. The importance of the compared travelled distance is also seen in performance joggers as they want to compete with other joggers. To do so, haptic feedback on the location is necessary to determine whether the other jogger is falling behind, catching up or leading the run. Therefore, an illustration is created with possible types of haptic feedback based on the compared travelled distance depicted in Figure 4.4. The first interaction occurs when there is a difference of +100 meters between jogger 1 and jogger 2. This means that jogger 2 is 100 meters in front of jogger 1. At the fourth interaction, the difference is changing as jogger 1 is catching up with jogger 2, and at the fifth interaction, jogger 1 caught up with jogger 2. This means that the difference has changed and now jogger 1 is leading the run. Based on these findings, a requirement can be set up used in the upcoming phases. The requirements involves that the travelled

Figure 4.3: New situation with the system.

distance of all joggers should be precise. This means that the tracking of the GPS location should be accurate. To indicate the position of the other jogger, different body locations (front or behind) as well as different vibration patterns (increasing or decreasing pace) have to be examined to indicate if someone is catching up or falling behind. Experiments will be done in the next chapter to study the best possible way of providing haptic feedback regarding compared travelled distance.

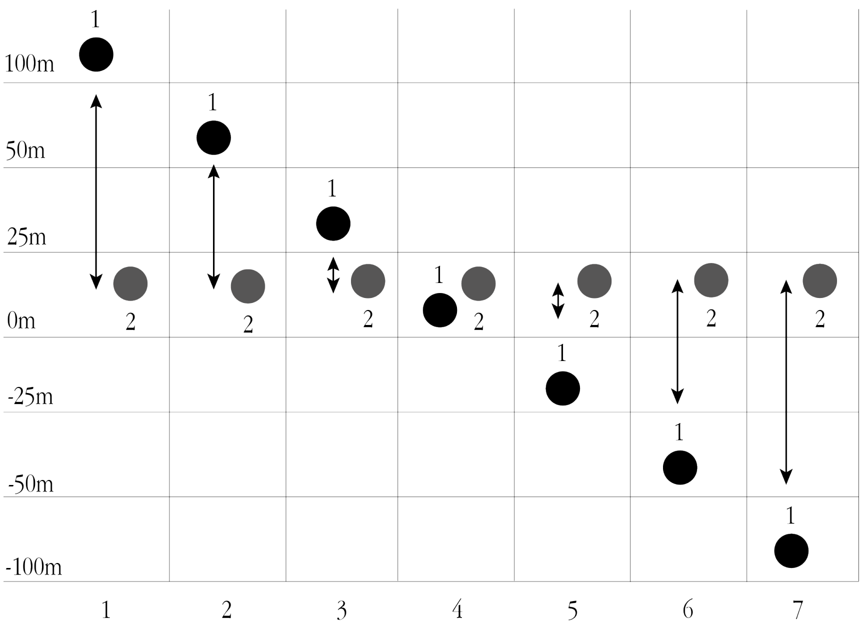


Figure 4.4: Possible types of haptic feedback based on compared travelled distance. The numbers on the vertical axis show the compared travelled distance between jogger 1 and 2. The horizontal axis illustrates the number of the possible interaction.

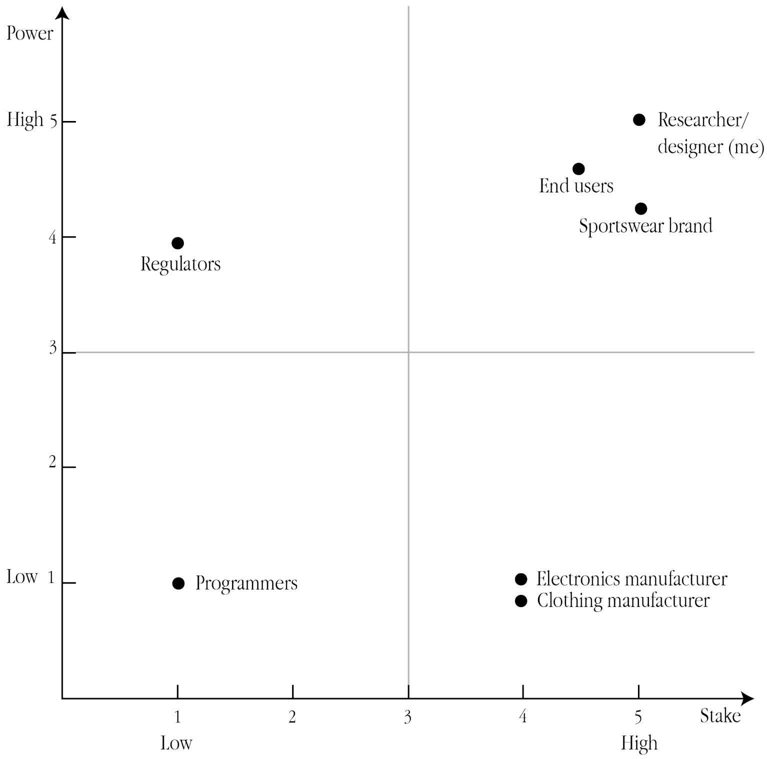


Figure 4.5: Stakeholder analysis matrix.

4.3 Stakeholder analysis

For this bachelor thesis, only end users and the researcher are considered as stakeholders. However, a stakeholder analysis is performed in order to identify potential stakeholders from a product development perspective. This was done in Figure 4.5 by arranging them according to participation level, interest and influence in a matrix.

Regulators include governments and international law such as data privacy regulations. To allow worldwide running over a distance, the tracking of the location of the user might involve different law regulations. This highlights that regulators have high power as they might deny the use of the system when requirements are not met. For example, when data privacy regulations are not satisfied, a government is able to refuse the utilisation of the Yet they do not have a deep interest in the creation of the project. Therefore, the regulators are positioned with high power and low interest.

Programmers comprise the people who will create the software required for the functioning of the system. As the programmers will make what is required for a well-functioning system. They will most likely not be interested in the progress of the project.

Researcher/ designer has the most power and interest in the project as the research is conducted from an auto-ethnographic perspective. Therefore, the researcher/ designer is prioritised as the most important stakeholder.

End users involve the users who will use the final product. For the success of the project, it is important to keep them fully engaged throughout the progress of the project.

Sportswear brand is defined in this project as the company that will sell the end product cost-effectively. As they will promote and be responsible for the marketing of the product, it is important to satisfy the brand in order to maintain a valuable collaboration. Therefore, the brand is of high-power and high-interest.

Electronics manufacturer is responsible for the development of the electronic components. As it is important that they deliver the required components to the appropriate safety regulations, it is important to maintain a good collaboration in order to check if the manufacturer is experiencing any complications such as problems in delivering on time.

Clothing manufacturer is responsible for the creation of the garment. As it is of high importance that the wearable is assembled, it is important to keep the manufacturer informed in order to check if the manufacturer is experiencing any problems such as an incorrect or uncomfortable fitting.

Based on the stakeholder analysis, requirements can be set up. From a product development perspective, it is important that the system is **cost-effective** to increase revenue and improve profitability. Furthermore, the system should also meet the demands of the end users and the researcher/designer depicted in the stakeholder analysis and State of the Art. These requirements involve **comfort**, **ease of use**, **compactness**, **cost-effectiveness**, **light in weight**, **robustness** and **safety**. These requirements will be utilised in the coming phases.

Chapter 5

Specifications

Based on the concept created in the previous chapter, small experiments will be conducted to explore the design space. This means that technologies have to be identified and small prototypes have to be created in order to gain an understanding on how to compare the travelled distance and how to send and receive a means of social mediated touch. Therefore, this chapter is separated in the following sections: *Comparing the travelled distance of joggers*, *Sending a social mediated touch* and *Receiving a social mediated touch*. Based on the results of the experiments and the previously gained knowledge, project requirements will be formulated.

5.1 Comparing the travelled distance between joggers over a distance

To compare the travelled distance, a pedometer was first considered. However, this was found to be inaccurate as each user's footstep might not be identical to another user's footstep, the measured travelled distance might be inaccurate to indicate if someone is leading the run or falling behind for example. Therefore, using the GPS location of the smartphone was examined as the results of the interview showed that most joggers take their smartphone during a run. The technique includes that the travelled distance between joggers can be compared over a distance by using the GPS location of the smartphone to continuously track the location of the joggers. This way, no additional modules are required nor additional costs are made. The smartphone will also accompany a WiFi connection for the microcontroller to be able to provide meaningful haptic stimulation based on the location of the other jogger.

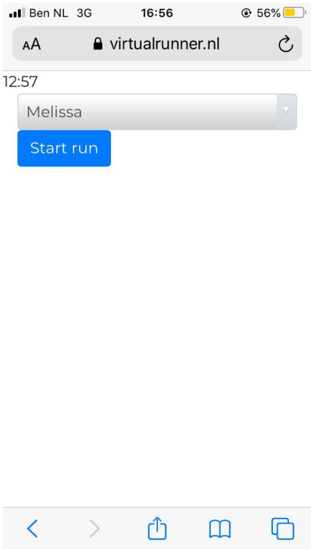


Figure 5.1: Screenshot of the start screen of the website.

To process the data, a web server will be used in combination with a website. As requesting the location of the smartphone compromises privacy, the user is asked to provide his or her location by approving to proceed when the website is loaded. This way, the position of the user is only provided when the user approves and privacy requirements are met.

To calculate the travelled distance, the website uses the HTML Geolocation API to return the current position of the user and continues to do so as the user moves [47]. According to the Haversine formula, the distance d travelled by the user is given by

$$d = 2r\, arcsin\sqrt{(\frac{\varphi_2 - \varphi_1}{2}) + cos\varphi_1 cos\varphi_2 sin^2(\frac{\lambda_2 - \lambda_1}{2})}\,, \tag{5.1}$$

where:

- d is the distance between two points on a sphere,
- r is the radius of the sphere,
- φ_1 and φ_2 are the latitude of point 1 and 2 provided by the API,
- λ_1 and λ_2 are the longitude of point 1 and 2 provided by the API [48].

The formula is managed in the web server to obtain the distance travelled in real-time while the user is moving. The location is send every 10 seconds and stored on the web server. This method was tested by the researcher outside. The goal of this experiment was to determine whether the GPS of the smartphone connected to a web server is accurate enough to use while jogging. The researcher selected a user on the website and the run was started (see Figure 5.1). The researcher waited one minute before she started jogging for 50 meters. When analysing the location log, the location would jump at the start of the run for a few seconds before fixing to the exact GPS location as illustrated in Figure 5.2. This shows that in stationary position, the system thinks that the user already started jogging, resulting in an incorrect increase in travelled distance. This in turn hampers determining the proper leading position during a run. Therefore, the method was changed to resolve this problem. The method was changed in such a way that when starting the run, the user is asked to run for 10 meters before the tracking will start. This way, the system is able to determine the precise GPS location of the user before the run starts and does not estimate the GPS resulting in an increase in travelled distance. This was again tested by the researcher. The results showed that the interval of 10 seconds is too long to provide constructive feedback as the system will miss when someone caught up and instead start the fast pace haptic feedback that someone is nearby. Since the system would be less precise, less interactions can be provided. Therefore, the interval was changed to 4 seconds. The concept of integrating 10 meters before the run starts allowed the GPS to calibrate properly.

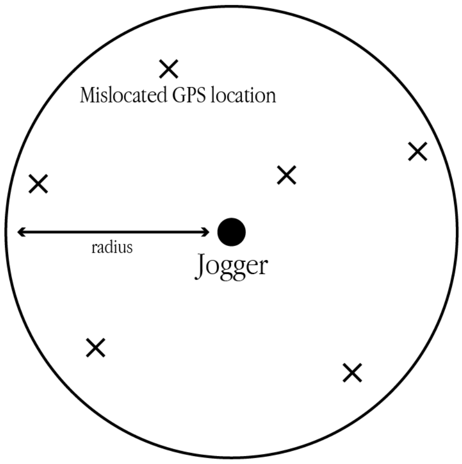


Figure 5.2: Illustration of the dislocated GPS locations before the jogger started running.

5.1.1 Conclusion

The use of the GPS on the smartphone show the solution to research sub-question 3: *How can a smartphone and its network be used to compare the travelled distance of joggers and to provide haptic stimulation?*. By utilising the Haversine formula on travelled distance and the GPS of the smartphone, one is able to provide an accurate travelled distance for comparison with other joggers. The internet connection of the smartphone can be used for sending the GPS location to the web server. This can subsequently be used for receiving the travelled distance of another jogger on a microcontroller. As one is able to access the website and web server at any time and any location, this set-up allows for international available joggers to run together over a distance. Therefore, these results will be used for realising the product.

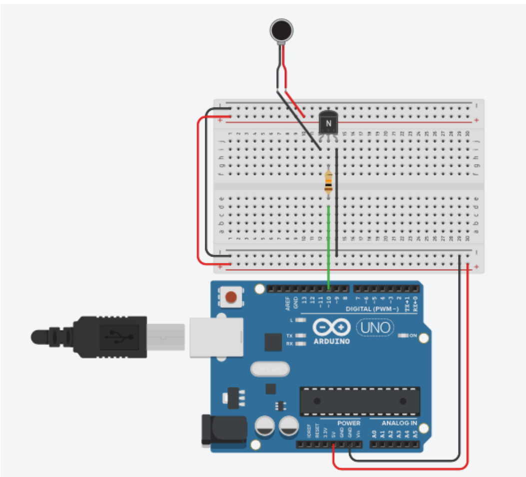
5.2 Receiving haptic stimulation

To provide social mediated touch and GPS location-based feedback to users accordingly, coin vibration motors are used because this type of vibrotactile feedback is most safe, non-invasive, cost-effective, small, light-weighted and effective on almost all body parts as compared to alternative methods as elaborated in Section 2.2 in Chapter 2. However, before fully integrating this in the project, various topics have to be studied including the position of the vibration system on the body, how to provide a social mediated touch on the body, and how to provide meaningful haptic feedback according to the compared travelled distance. First, research will be done on the preferred position of the vibration system on the body. Second, experiments will be conducted on how to successfully create apparent motion with a specific amount of vibration motors, which is important for creating a social mediated touch. Third, more experiments will be run on what will be the best technique to provide feedback on the body with respect to the location of the joggers. Lastly, textiles will be tested in order to integrate the components successfully into a haptic wearable.

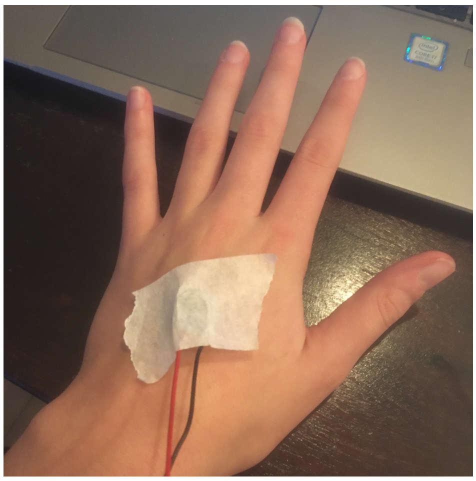
5.2.1 Position of the vibration system

To understand what body parts are most preferred by users of wearable vibration systems and especially jogging, an experiment is conducted in order to determine the most comfortable body locations.

As most studies analysed in Section 2.2 did not conform in a social context, an experiment with coin vibration motor on the body was conducted to allow the researcher to determine preferred body location for haptic stimulation. The set-up of the experiment can be viewed in Figure 5.3a.



(a) Documentation of the set up of the experiment with an Arduino UNO.



(b) The results of the run.

Figure 5.3: Setup of the experiment on the hand.

The procedure of the experiments was as follows. A coin vibration motor was placed directly on the skin of the researcher with a tape on various body parts (see Figure 5.3b). Then, a vibration was released every second. After receiving the vibrations for three cycles, the researcher rated the degree of comfort between comfort and discomfort (see Table 5.2.1 for the results).

Vibration position	**1) Most uncomfortable**	**2) Uncomfortable**	**3) Neutral**	**4) Comfortable**	**5) Most comfortable**
Shoulder tip	x				
Shoulder blade	x				
Spine	x				
Back					x
Neck	x				
Chest		x			
Waist					x
Clavicle	x				
Wrist				x	
Ankle	x				
Foot		x			
Shine	x				
Knee	x				

Table 5.1: Observations on the degree of comfort.

Figure 5.4 represents the results of this experiment on the researcher's body. One should note that the results of preferred body locations on a female body are constrained to social acceptability. For example, Figure 5.5 shows that the chest is socially accepted for men but placing a wearable on the breasts is socially unaccepted for

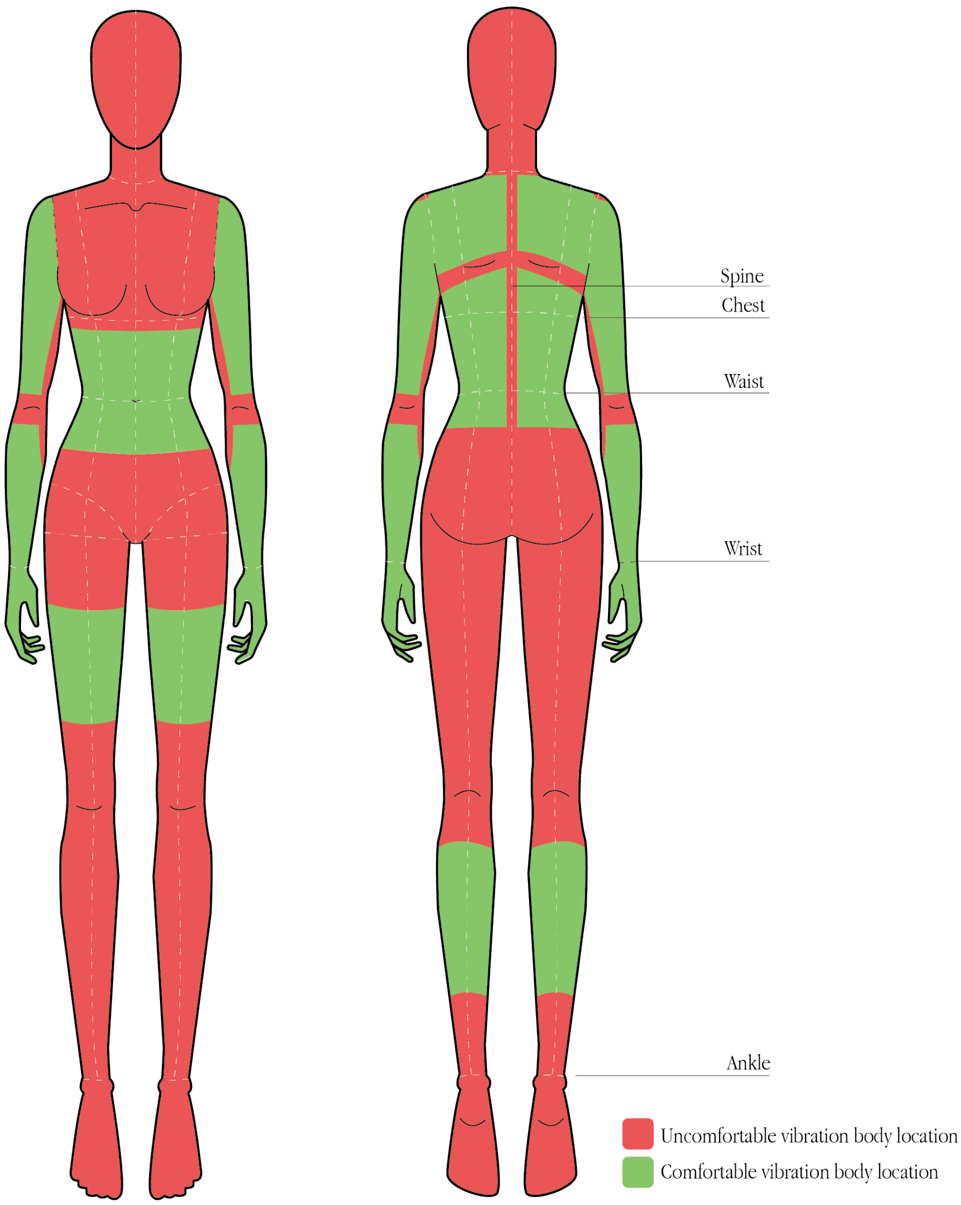


Figure 5.4: Body map on preferred body locations for vibrotactile stimulation.

women. However, to involve both women and men as potential end users, the results of the female body are prioritised. Moreover, the results of this experiment are similar to the research of Zeagler [8] as positions for movement were not preferred and that bony areas such as the spine should be avoided, since the bones seem to transfer the vibrations deeply through the body. Other significant unpleasant observations were:

- Neck: Similar to the research of Machida et al. [30], the neck is perceived as unpleasant and somewhat painful as the vibration is felt through the whole spine and head.

- Shin and knee: The vibration is felt deeply through the whole leg, making this location unpleasant and obtrusive while jogging. The knee is especially used for running so this location should also be avoided as this might hamper the posture of the jogger.

- Clavicle: The vibration perceived as too intense as the vibration transfers through the chest.

- Shoulder blade: The vibration is unpleasant as it is partly also felt through the spine.

- Shoulder tip: The vibration is too intense as it feels like a shock when applied to the bony shoulder tip.

- Ankle: Unlike [12], [29], the ankle is perceived as unpleasant, painful and obtrusive as the bony area causes the vibration to be transferred through the lower leg, which could perhaps result in undesirably changing the posture of the jogger.

5.2.1.1 Conclusion

The results in Figure 5.4 show that the upper body has the largest area for comfortable vibrotactile stimulation. Therefore, the green parts on the upper body are used for further experiments.

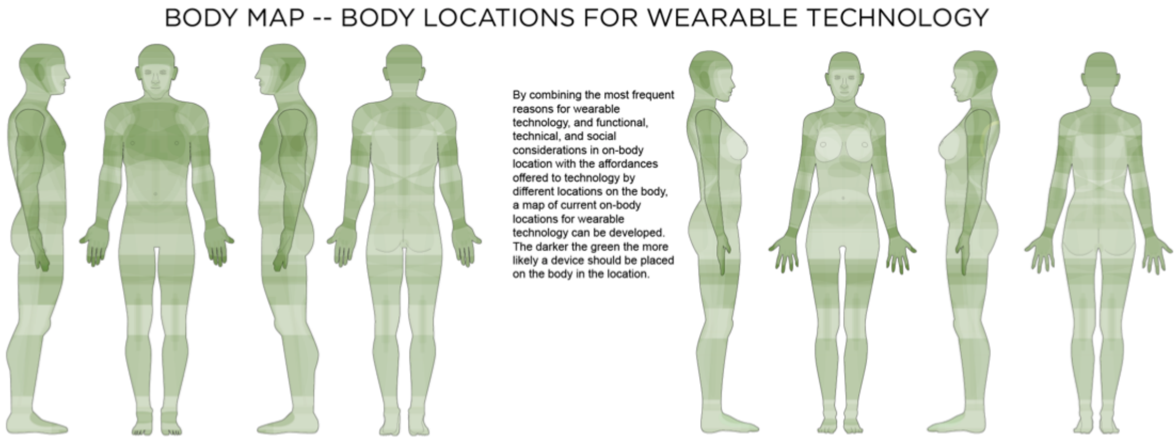


Figure 5.5: Most likely body locations for wearable technology including social acceptability [8].

5.2.2 Apparent motion

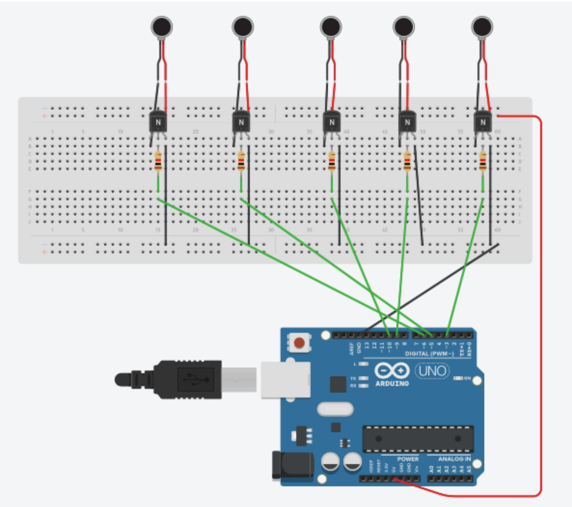
This section focuses on creating apparent motion on the body in order to simulate a social mediated touch. As the results of the previous section showed that the arm and back are preferred vibration locations, these body parts will be tested in this section. First the arm will be tested.

5.2.2.1 Experiment 1: Apparent motion on the arm

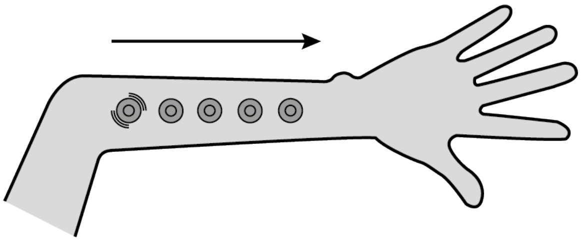
Apparent motion was first tested on the arm with five coin vibration motors. Figure 5.6b shows the set up of the vibration motors on the arm and Figure 5.6a shows the set-up of the Arduino. The application of apparent motion was based on the theory of [1] in Section 2. The settings of the apparent motion were tested regarding duration and location to indicate whether the arm is a good position for applying apparent motion. The vibration pattern was looped three times with a 3 sec. pause in between. The results can be viewed in Table 5.3.

Conclusion

The results of the first experiment, including five vibration motors, indicate that the first vibration motor should be removed as the location on the arm of the vibration motor might have caused the vibration to be felt too intensely. Therefore, the next experiment should include four vibration motors.



(a) Set up experiment to emulate apparent motion with 5 vibration motors.



(b) The results of the run.

Figure 5.6: The set-up of the experiment on the arm.

5.2.2.2 Experiment 2

The goal of this experiment is to create apparent motion with four coin vibration motors on the arm. The set-up of the experiment is similar to the previous experiment but without the first vibration motor. The observations of the experiment can be viewed in Table 5.2.2.2.

Duration	**Observations**
500 ms	Subsequent motion.
400 ms	Subsequent motion.
300 ms	Two individual vibrations are detected.
200 ms	Same as above.
100 ms	1-2 individual vibrations are detected.
90 ms	Almost apparent motion, but the vibration motor at the wrist is too intense.

80 ms	Same as above.
70 ms	Too fast so feels like simultaneous haptic stimulation.

Table 5.4: Observations on the second experiment with 4 coin vibration motors.

Conclusion

The results of using four vibration motors indicate that the vibration motor at the wrist should be removed. Hence, the next experiment should include three vibration motors.

5.2.2.3 Experiment 3

The goal of this experiment is to create apparent motion on the arm with three coin vibration motors. The same set-up is used as the previous experiment, but with one coin vibration motor removed at the wrist. Table 5.2.2.3 show the results.

Duration	**Observations**
500 ms	Subsequent motion.
400 ms	Subsequent motion.
300 ms	Two individual vibrations are detected.
200 ms	Same as above.
100 ms	1-2 individual vibrations are detected.
90 ms	Almost apparent motion.
80 ms	Same as above.
70 ms	Too fast so feels like simultaneous haptic stimulation.

Table 5.5: Observations on the third experiment with 3 coin vibration motors.

Duration	Observations
500 ms	Subsequent motion.
400 ms	Subsequent motion.
300 ms	Fast subsequent vibrations.
200 ms	The first vibration (most left) is too intense, so suggestion is to remove this vibration motor. Still subsequent motion.
100 ms	Three distinct vibrations are felt.
90 ms	Two vibrations are detected.
80 ms	Two vibrations are still detected, might be the result of the location of the vibration motor on the arm.
70 ms	Same as above.

Table 5.3: Observations on the first experiment with 5 coin vibration motors.

Conclusion

The results show that apparent motion might be hard to simulate on the arm. As stated in [1], this could be due to the spatial resolution on the arm which is richer compared to the back. Therefore, the next experiment will position three coin vibration motors on the back.

5.2.2.4 Experiment 4: Apparent motion on the back

The aim of this experiment is to create apparent motion on the back with five vibration motors. The vibrations were initiated at the lower back up to the upper back. The set-up of the coin vibration motors can be viewed in Figure 5.7 and the results in Table 5.2.2.4.

Duration	Observations
500 ms	Subsequent motion.

400 ms	Subsequent motion.
300 ms	Subsequent motion.
200 ms	Subsequent motion.
100 ms	A direction motion is detected which is almost similar to apparent motion.
90 ms	Lower back feels as apparent motion. The second vibration motor on the upper back is too intense.
80 ms	Apparent motion is indicated under the waist. The second vibration motor on the upper back is too intense.
70 ms	Too fast to feel like apparent motion.
60 ms	Too fast to feel like apparent motion.
50 ms	Too fast feels like a tick.

Table 5.6: Observations on the fourth experiment with 5 coin vibration motors on the back.

Conclusion

Based on the observations in Table 5.2.2.4, apparent motion is achieved in below the waist and lower back. However, the vibrations are felt too intensely on the upper back. Therefore, the next experiment will focus on creating an effective apparent motion below the waist with five vibration motors.

5.2.2.5 Experiment 5

The aim of this experiment is to create apparent motion on the lower back with five vibration motors. Figure 5.8 shows the set-up of the experiment on the lower back and Table 5.2.2.5.

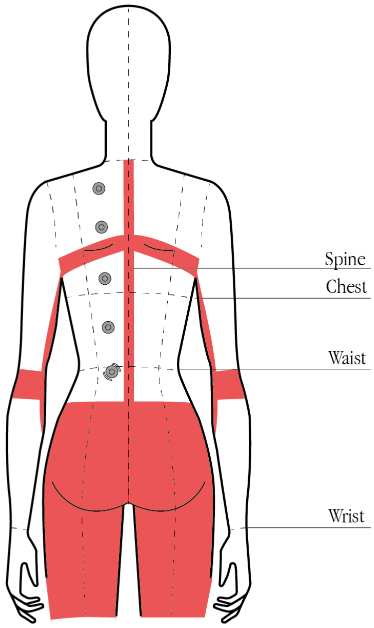


Figure 5.7: The set-up on the back of the experiment. The red areas indicate uncomfortable body locations for vibrotactile stimulation.

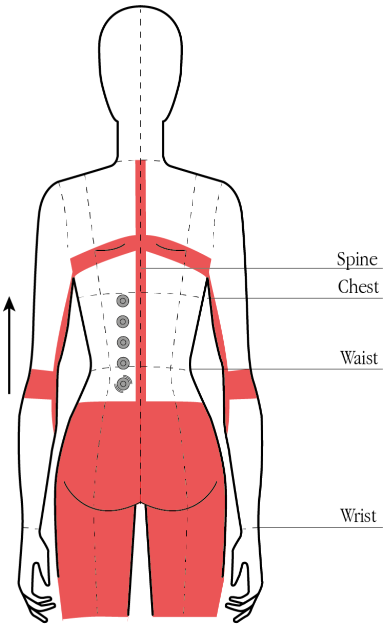


Figure 5.8: The set-up on the lower back of the experiment with five vibration motors. The red areas indicate uncomfortable body locations for vibrotactile stimulation.

Duration	**Observations**
500 ms	Subsequent motion.

400 ms	Subsequent motion.
300 ms	Subsequent motion.
200 ms	Direction motion is clear but still subsequent motion.
100 ms	Almost apparent motion, but the last vibration motor around the waist is felt individually.
95 ms	It feels as if too many vibration motors are applied for an effective apparent motion.
90 ms	Too fast to indicate apparent motion.

Table 5.7: Observations on the fifth experiment with 5 coin vibration motors on the lower back.

Conclusion

The results of the experiment showed that apparent motion is almost achieved but it still feels as subsequent motion. Therefore, the next experiment will focus on changing the intensity and overlap of the vibration motors to see if apparent motion can be achieved.

5.2.2.6 Experiment 6

The goal of this experiment is to generate a push or stroke on the back by using four vibration motors on the lower back. To determine if the results of the previous experiment could be improved in terms of apparent motion, a different vibration set-up was used to ultimately remove the intensity of the last vibration motor. The set-up was the same as the previous experiment on the lower back but with four vibration motors. The vibration pattern differs compared to previous experiments as the actuating of the motors comprised an overlap. This is contradictory to the results of the literature review in Chapter 2 as this would create a simultaneous haptic stimulation (see Figure 2.2a in Chapter 2). A delay of 2000 ms, different intensities, duration of 200 ms and an overlap of 80 ms were used. The vibration pattern was looped five times before observations were written down.

Intensity	**Observations**
250 ms	Too intense.
200 ms	Too intense.
150 ms	Too intense.
100 ms	Still a bit too intense. A direction is detected but it feels as if the vibrations are more intense at some places and it also feels as if the last vibration is going down. By changing the intensity of the vibration motors during the overlap, the direction of the motion does not feel homogeneous.
50 ms	No vibrations are detected.

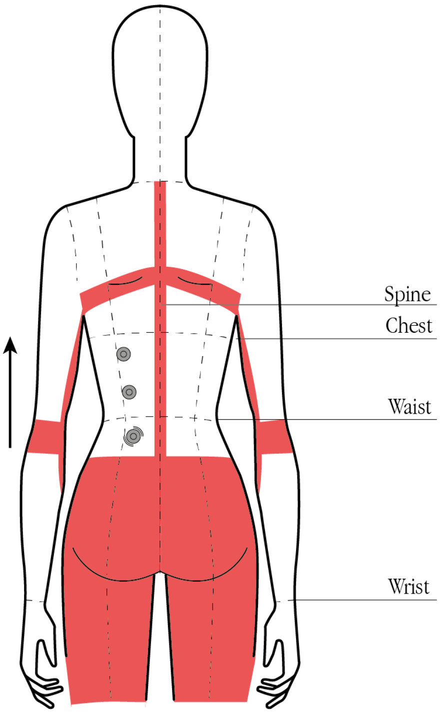
Table 5.9: Observations on the seventh experiment with 4 coin vibration motors on the lower back with a different vibration pattern.

Conclusion

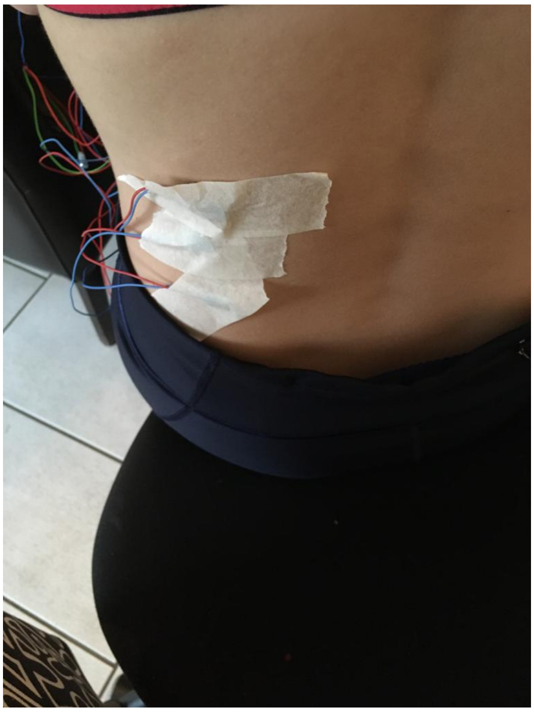
The results of the experiment showed that integrating overlaps between actuating the motors is less related to apparent motion compared to the previous experiment. Particularly, the overlap causes a more intense vibration feeling, resulting in a chaotic haptic feeling. Therefore, the results of the previous experiment will be used in the next experiment. This way, the next experiment will involve three instead of four vibration motors.

5.2.2.7 Experiment 7

The goal of this experiment is to create apparent motion on the lower back with three vibration motors to simulate a push in the back for motivation. Figure 5.9a shows the set-up of the experiment on the lower back, Figure 5.9b shows the set-up of the experiment on the body of the researcher and Table 5.11.



(a) The set-up on the lower back of the experiment with three vibration motors. The red areas indicate uncomfortable body locations for vibrotactile stimulation.



(b) The results of the run.

Figure 5.9: The set-up on the lower back of the researcher.

Conclusion

The results of the experiment showed that apparent motion is best achieved with three vibration motors on the lower back. Therefore, this knowledge will be used for realising the prototype in terms of applying social mediated touch through apparent motion.

5.2.3 Location-based haptic feedback

In order to provide meaningful feedback on the location of the other jogger, a method has to be found which allows the user to know that someone caught up. In other words, when the system detects that the distance is 0 and someone caught up, a particular vibration or vibration pattern should be felt. During jogging, one visually

Duration	Observations
500 ms	Subsequent motion.
400 ms	Subsequent motion.
300 ms	Subsequent motion.
200 ms	Direction motion is clear but still subsequent motion.
150 ms	Almost subsequent motion.
120 ms	Almost subsequent motion.
110 ms	Almost apparent motion.
105 ms	Best related to apparent motion. However, the last vibration motor is felt too intensely.
100 ms	Related to apparent motion.
95 ms	Too fast to indicate apparent motion.
90 ms	Too fast to indicate apparent motion.

Table 5.11: Observations on the sixth experiment with 3 coin vibration motors on the lower back.

sees someone passing by. Figure 5.10 shows how it looks like when someone is catching up. One hears footsteps going faster and harder until the point when someone passed by and the sound of the footsteps will go softer. This shows that two means of haptic feedback are required: knowing when someone is coming closer and the exact point when someone passed by. Experiment 1 will focus on the first type of feedback and Experiment 2 on the second type of feedback.

5.2.3.1 Experiment 1

The goal of this experiment is to give haptic feedback to the jogger when the other jogger is coming closer or moving further away. This will first be tested on the researcher by applying one vibration motor on the front with various paces to indicate if a vibration pace would represent the idea of a user coming closer or moving further away (see Figure 5.11). After testing on the front, the same procedure will proceed on

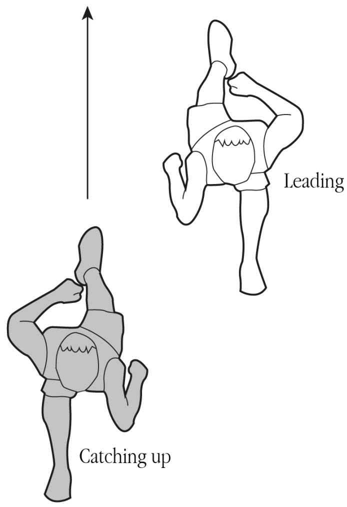


Figure 5.10: Illustration of what happens when someone is passing by during jogging.

the back with two vibration motors as positioned on the right in Figure 5.11. Lastly, for testing different haptic paces the Adafruit DRV2605L Haptic Controller Breakout[1] is used. The 117 effects provided by the library were looped three times before any observations were written down.

Observations

The position of the vibration motor on the centre of the body is perceived as unpleasant. The middle vibration motor feels unpleasant. It is suggested to provide haptic stimulation on the centre of a muscle for a comfortable experience. Therefore, the feedback provided on the front was changed to two vibration motors but with the same set-up as on the back. This resulted in a consistent and intuitive way of providing feedback on the location of the other user. The increase in pace of the vibrations resembles that someone is coming closer and the decrease in pace resembles that someone is falling behind. The duration of the vibrations should not be too long and consistent as this causes distraction and is unpleasant. As a result, short vibrations such as a click should be used for determining pace.

Conclusion

By using two vibration motors on the front and the back like shown in the right part of

[1]Source: https://learn.adafruit.com/adafruit-drv2605-haptic-controller-breakout/arduino-code

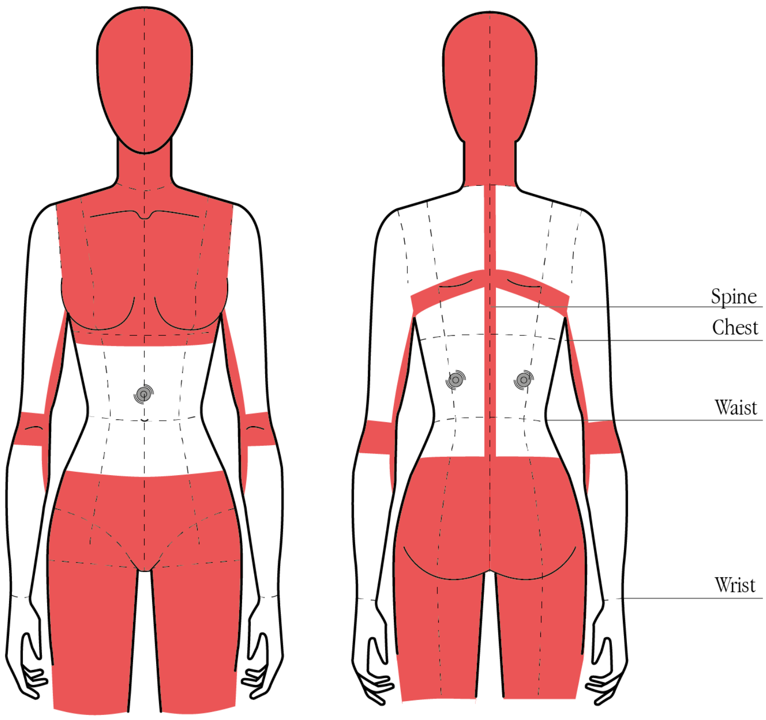


Figure 5.11: Set-up of the experiment on the body.

Figure 5.11, a vibration pace can be generated to provide feedback to the user whether the other user is nearby, coming closer or catching up. The duration of vibrations should be short and consistent as this causes distraction and is unpleasant.

5.2.3.2 Experiment 2

The goal of this experiment is to simulate the motion when someone caught up (distance between the runners is 0). In real-life jogging, one sees that someone is catching up as one sees the runner coming from behind. This indicates that a similar motion should be generated in which haptic stimulation is moved on the body from the back to the front. Therefore, for this experiment, apparent motion is used by initialising the vibrations motors on the back to the front in order to simulate the motion of the jogger coming from behind and catching up with the other jogger. The apparent motion set up is looped three times before observations were written down. After looping the apparent motion from the back to the front, the apparent motion is looped three times from the front to the back to indicate to the other jogger that he has caught up and is now leading the run.

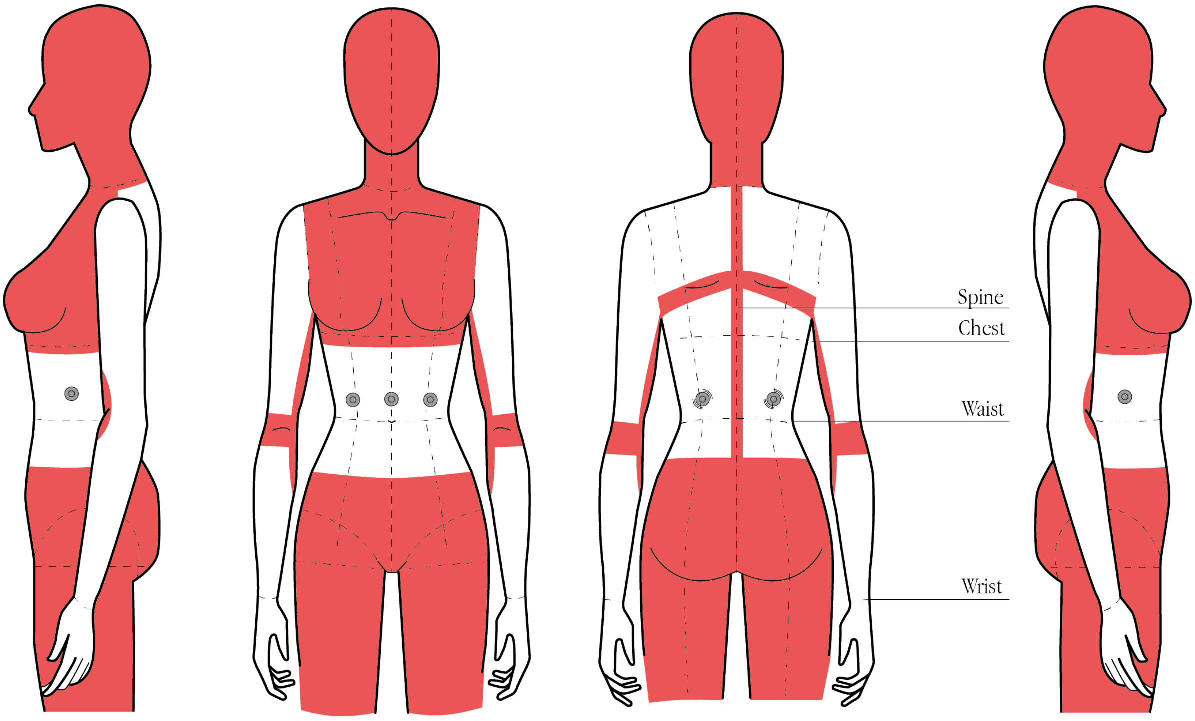


Figure 5.12: Set-up of the experiment on the body.

Observations

The vibration motor on the front applied to the centre of the body feels unpleasant as it is felt too intensely. By changing the intensity and duration of the vibration motor, it is still unpleasant. The inconsistency in vibration motors (three vibration motors on the front and two on the back) generate a perception of a fast apparent motion in the beginning but slower at the front. After removing the vibration motor on the front and spacing the two vibration motors on the front of the body, the vibration pattern is dispersed and clear.

Conclusion

Based on the observations of this experiment, two vibration motors on the front should be used with two vibration motors on the side and two on the back. The generated apparent motion simulates the change in run leader.

5.2.4 Materials

Since research of Machida et al. [30] has shown that users tend to feel discomfort when wearing a vibration motor directly on the skin, a choice was made to integrate the vibration motors in the garment or accessory [30]. This way, any direct contact was avoided. Furthermore, to create a wearable for jogging, one has to fulfil some specific requirements set for active sportswear. According to [49], general requirements should be met including functionality (light-weighted, stretchable, high tenacity) and aesthetics (softness, comfort, colour, texture). For jogging, more specific requirements should additionally be met: perspiration absorption and release, fast drying and cooling. Therefore, fabrics that include these properties can be used for further analysis. These materials include nylon, polyester, cotton, polypropylene, merino wool, spandex, econyl. Polyester will first be tested as this is the most common light-weighted fabric used in sportswear because of its durability, wrinkle-resistance, fast dryness and non-absorption of moisture which results in a fast drying of perspiration. Figure 5.13 displays the tested materials with the vibration motors. The goal of this test was to investigate what material would be most appropriate for applying constructive haptic stimulation. Table 5.2.4 shows the observations of the experiment.

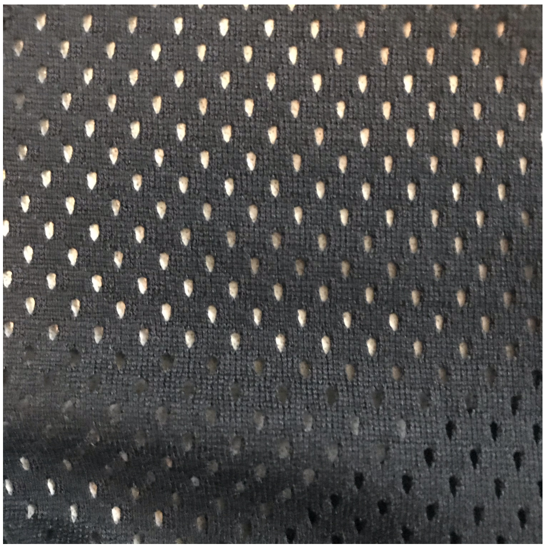
Type of fabric	**Observations**
Warp knit (100% polyester)	No noise. It feels pleasant and is breathable. The fabric should be tight-fitting for the most efficacy. Yet while moving, apparent motion can be well indicated.

Jersey knit (100% polyester)	No noise. Warmest fabric compared to the other fabrics. It is also not really breathable and would, therefore, most likely be used in autumn or winter. The fabric should be very tight-fitting for the most efficacy. It feels pleasant but apparent motion is hard to indicate on the back. However, haptic stimulation from the back to the front can be indicated.
Bird's eye knit (100% polyester)	No noise. Second warmest fabric compared to the other fabrics. It is less breathable than the first fabric. The fabric should be very tight-fitting for the most efficacy. Apparent motion is hard to indicate on the back but haptic stimulation from the back to the front can be indicated.

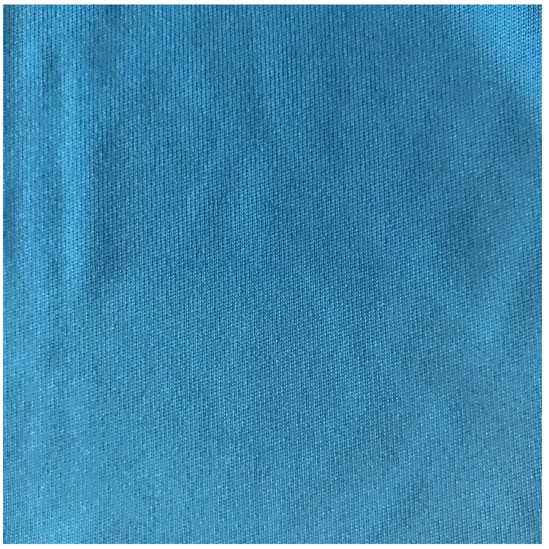
Table 5.12: Observations on the testing of different types of sportswear fabrics. One should note that the vibration motors were tested with tape and should be positioned on the fabric with velcro or press studs.

Conclusion

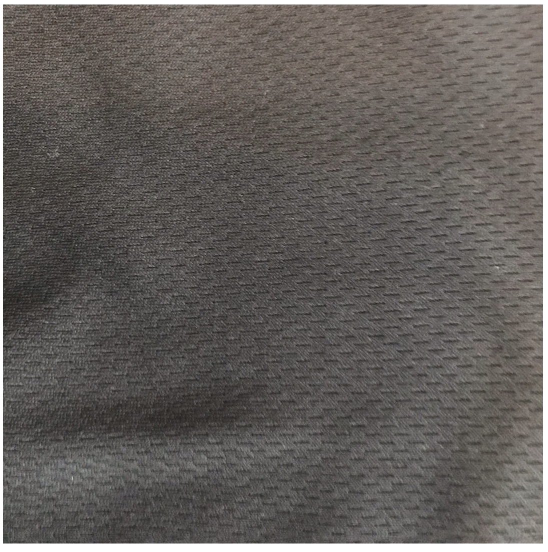
The warp knit is most suitable for applying apparent motion on the back. However, the other types of fabric can also be used for other types of haptic stimulation. It is important that the final shirt is tight-fitting for the best efficacy.



(a) Warp knit made of 100% polyester.



(b) Jersey knit made of 100% polyester.



(c) Bird's eye knit made of 100% polyester

Figure 5.13: Fabrics for testing the efficacy of the coin vibration motors.

5.3 Sending social mediated touch

To send a social mediated touch to the other jogger, a way has to be found to be able to send it without being obstructive or distracting to the sending user in motion. Therefore, a simple and intuitive way of interaction has to be found through conducting small experiments to determine the best way to send a social mediated touch to another user. First, capacitive sensors were used to detect the presence of a hand.

5.3.1 Experiment 1

The first experiment holds to investigate how conductive thread can be used on the arms to detect the presence of a hand in order to send a social mediated touch. The arm is used in this experiment, because [1] showed that the back is preferred to apply apparent motion because of its poor spatial resolution, which results in a better perception of apparent motion and because the back is used for receiving haptic feedback and a social mediated touch. Since the arm is easy to touch while jogging, the capacitive sensor has been applied on the arm. A black piece of cotton was used in which the conductive thread was sewn according to a particular pattern to see whether a pattern would have a different effect compared to a regular line (see Figure 5.14b). The set-up of the experiment depicted in Figure 5.14a was used on various places on the arm to determine what would be preferred for detecting the presence of a hand.

Observations

The fabric is very sensitive to the presence of the hand. This means that when the fabric is positioned on various places of the arm, the output of the sensor slows down or even stops when moving the arm. When placing an additional piece of cotton between the skin and the conductive thread, the fabric is still to sensitive. This results in the output of the sensor to stop when the arm is moved too much. When an additional piece of cotton is positioned on top of the fabric in which the conductive yarn is incorporated, the sensing of the presence of the hand is insignificant. In other words, the detection is inaccurate as it generates irregular values.

(a) Set up of the capacitive sensor in a piece of cotton.

(b) Conductive yarn pattern.

Figure 5.14: Results after the run.

Conclusion

This experiment shows that sewing conductive thread in a piece of cotton this way is not applicable to the project. Sensing the presence of the hand is too sensitive in this set-up due to the direct application on the skin. Therefore, to solve this problem, isolation material between the skin and fabric could be used in order to make the sensor less sensitive to the skin. However, this would create a multi layer fabric on the arms, which is not preferred in jogging. Subsequently, another idea was to use a pressure sensor on the arm. However, this would eliminate the convenience of pressing anywhere on the arm to send a social mediated touch while jogging. Therefore, this idea was excluded and, instead, a pressure-sensitive conductive material such as Velostat was used for the next experiment to indicate the presence of the hand on the arm.

5.3.2 Experiment 2

The goal of this experiment is determine whether pressure on the arm can be detected by using a pressure-sensitive conductive material (Velostat) in order to easily and intuitively send a social mediated touch while jogging. A resistor of 1k Ohm was used for this experiment. Figure 5.15 depicts the set up of the experiment.

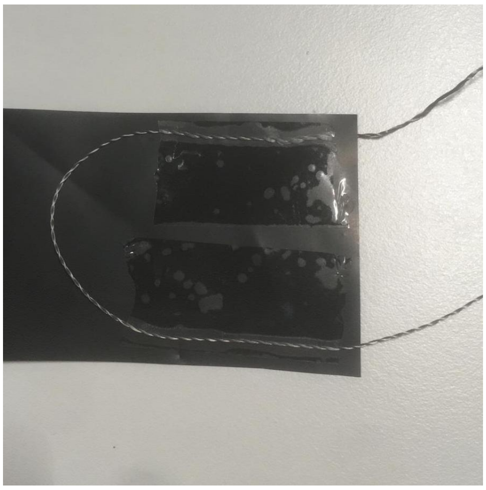


Figure 5.15: Set up of Velostat with conductive thread taped to both sides.

Observations

The set up of the Velostat acts as a resistor, which signifies that the value changes when pressure is applied to the Velostat. However, in this set up it only senses a pressure when a rather large force is applied. This means that a gentle stroke or touch is not defined, but only when one presses on the Velostat. By changing the value of the resistor, the same applies. The conductive threads should be well-positioned, otherwise, inaccurate or no values are given.

Conclusion

The observations highlight that a pressure or rather large force is required and that the threads should be well positioned without moving for accurate values. Therefore, this is not applicable for this project, because sending a social mediated touch should not require a large force while jogging as this can be obstructive to the user. As the user is jogging, it might also occur that the threads will move, making the sensor useless. Subsequently, the next experiment will involve using Velostat with an aluminium sheet to create a more consistent pressure sensor.

5.3.3 Experiment 3

The aim of this experiment is to create a consistent pressure sensor with Velostat and an aluminium sheet. A resistor of 1k Ohm was used for this experiment. Figure 5.16 shows the set up of the Velostat.

Figure 5.16: Set up of Velostat with an aluminium sheet and conductive thread taped to both sides.

Observations

The aluminium allows for more accurate and consistent values Yet a gentle stroke can not be defined as the sensor acts as a momentary switch. This also occurs when the value of the resistor is changed. Furthermore, only the aluminium can sense a pressure.

Conclusion

The observations indicate that this set up is best for detecting a key-press, but the detection of a fast gentle stroke on the arm is too difficult. The inclusion of aluminium results in an additional layers on the arm. To protect the sensor, a fabric on top and below are required, resulting in five individual layers. This is inconvenient as for jogging it is important that the wearer is comfortable throughout the entire jogging experience, meaning that the wearable should enable sweat to absorb and dry quickly [49]. By providing multiple layers, this is inconvenient. Therefore, the next experiment will focus on removing additional layers by changing the resistance behaviour of the Velostat to a capacitive behaviour.

5.3.4 Experiment 4

The goal of this experiment is to create a sensor that detects the presence of a hand to send a social touch to another jogger. The goal is that few additional layers are required for a well-functioning sensor. A resistor of 1M Ohm was used for this experiment. However, different values were tried as the resistor effects the sensitivity. This means that a range of 50K to 50M Ohm was conducted during this experiment. Figure 5.17 shows the set up of the experiment.

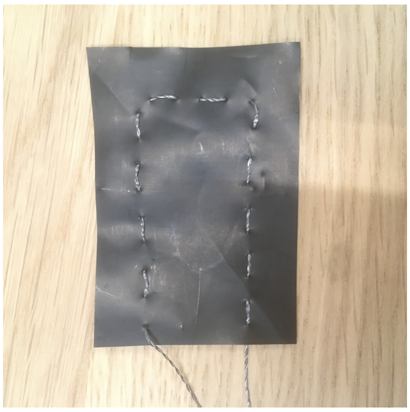


Figure 5.17: Set up of Velostat with an aluminium sheet and conductive thread taped to both sides.

Observations

The whole Velostat sheet senses the presence of the hand. However, 1M Ohm only detects small differences which means that it might be hard to detect a fast gentle touch. Therefore, a resistor of 10M Ohm was used. This set up senses a fast gentle touch. By applying a piece of jersey (cotton) on the top and the bottom, it still detects a fast gentle touch. This result was also seen when the experiment including the cotton pieces was placed on the arm. Placing two resistors of 10M Ohm in parallel or series did not affect a more effective result. As Velostat is a conductive fabric, the need for sewing in the Velostat might be redundant.

Conclusion

The observations indicate that this experiment create an effective means of sending a social mediated touch. Yet this has to be tested on a larger piece of Velostat. Since it might be redundant to sew through the Velostat, the next experiment will incorporate a larger piece of Velostat with less conductive thread.

5.3.5 Experiment 5

The goal of this experiment is to create a capacitive sensor that senses a fast gentle stroke on the arm with the use of a conductive fabric: Velostat. Figure 5.18 shows the set up of the experiment. A 10M Ohm resistor is applied as the previous experiment showed that this value would provide the best sensitivity.

Figure 5.18: Set up of Velostat with conductive thread.

Observations

The same sensitivity is detected as in the previous experiment. The sensitivity does not change when placing the hand anywhere on the Velostat. Placing two resistors of the same value in parallel or series does not improve the efficacy of the sensor. When placing the Velostat between two pieces of jersey (cotton) and on the arm, the efficacy is slightly changed but still effective for detecting a gentle touch. However, when used on the elbow, a touch can not be defined.

Conclusion

The observations showed that this set up can be used for the next phase, because the sensor shows to be effective on the arm when positioned between jersey (cotton). Yet the sensor should not be placed on moving body parts, as this eliminates the ability to sense a touch. Therefore, the sensor should not be placed around the elbow. To eliminate multiple layers, the final product can include woven conductive fabric to meet the requirements of sportswear to be sweat absorbing, fast drying and cooling.

5.3.6 Experiment 6

The goal of this experiment is to create a capacitive touch sensor that senses a fast gentle stroke on the arm with the use of a woven highly conductive fabric.

Observations

The fabric is highly sensitive to touch and more sensitive compared to the Velostat. Therefore, a plastic tape was placed on one side of the fabric to act as isolation. When cutting the fabric into smaller pieces, the act of sensing touch is more accurately received. Placing two resistors of the same value in parallel or series does not improve the efficacy of the sensor.

Figure 5.19: Set up of Velostat with conductive thread.

Conclusion

This set-up is most accurate compared to previous experiments. Since this set up is more highly sensitive compared to the Velostat, a proper isolation material has to be chosen to be placed between the skin and the garment. However, placing a fabric on

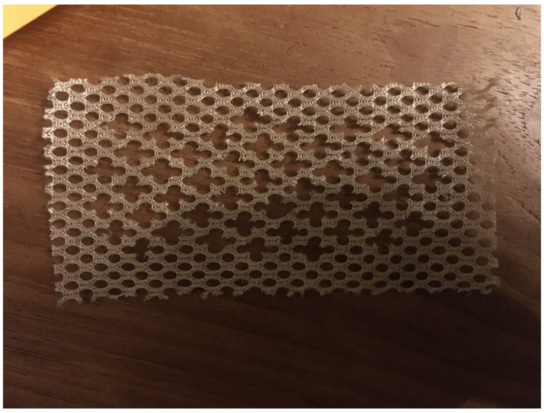


Figure 5.20: Fabric positioned between the conductive fabric to create a touch sensor.

top is not required. However, when testing this set-up the NodeMCU used in this project permitted the use of the capacitive sensor library. Therefore, the analog pin was instead used to create a touch sensor with the conductive fabric and a thicker fabric with small holes in between (see Figure 6.4a). Both sides were connected with a press stud and kept separately so no touch could be contrived.

5.4 Conclusion

The experiments in this chapter showed that the travelled distance of joggers can be compared by using the GPS of the smartphone and its network. The Haversine formula can be used to calculate the travelled distance on a web server. This will be returned to the micro controller to provide haptic stimulation to the user. This way, joggers can guide the performance of other joggers during the run.

The results also showed that the upper body is most appropriate for providing haptic stimulation as it acquires the largest area for comfortable vibrotactile feedback. Therefore, the vibration motors and touch sensor will be positioned in a shirt. Particularly, the social mediated touch will be provided on the lower back with apparent motion. The change in run leader, so catching up, will be done by generating an apparent moti on from the front of the body to the back of the body or the reverse. When a jogger is falling behind and instead now becomes the run leader, the apparent motion is generated from the front to the back. However, when a jogger was the run leader and is now falling behind, the apparent motion is generated from the *back* to the front.

The haptic feedback based on the travelled distance will be provided by two vibration motors on the back and two vibration motors on the front. The pace of the haptic stimulation will increase once the runner is getting closer. The pace will decrease when the runner is falling behind.

To continue, the sending of a social mediated touch will be done through creating a touch sensor connected to the analogue pin. The touch sensor consists of two conductive fabrics with a thicker fabric with holes in between. Press studs will be added to the separate pieces of conductive fabric and will be connected to the micro controller with flexible cables. With this set-up, the micro controller is able to read whether the touch sensor has been touched. When the touch sensor is touched, the bottom two vibration motors will be activated so the user knows that a touch is sent.

The combination of the results of the literature review, interview, *Ideation* phase and the experiments conducted in this chapter resulted in the following requirements for the haptic wearable:

1. Ease of use [12]
2. Light in weight[2]
3. Comfort in wearing of the wearable and the haptic stimulation[2]
4. Cost-effective[2]
5. Compact [12]
6. Tight-fit (for efficacy of the vibration motors)
7. Robust [12]
8. Battery life span of 45 minutes (average running time of a jogger based on the interview)
9. The travelled distance should be accurate. This means the tracking of the GPS location should also be accurate[2].

[2]Created in the *Ideation* phase

10. Safety[2] including waterproof (important for sweating and external weather influences)

11. Designing the wearable with a modular approach to incorporate sustainability in the project. This means that the wearable will consist of various separable parts in which individual pieces can be purchased, collected or assembled in different ways over time by the user [50]. This way, users can, for example, buy larger coin vibration motors when they desire a larger vibration area or the user can separate all parts to wash the shirt.

The requirements in combinations with the results of the conducted experiments combined will be used for realising the wearable in the next chapter.

Chapter 6

Realisation

To understand the user experience of the system, two prototypes have to be made. One prototype will be used for the researcher and the other will be utilised by participants in the Evaluation phase. This chapter focuses on designing the prototypes.

Figure 6.1: Image of the digital design created in CLO3D[1].

For the efficacy of the vibration motors, it is important that the shirt is tight-fitting. As one prototype is primarily used by the researcher, a shirt is created especially for the researcher's body. The digital design was created in CLO3D based on the measurements of the researcher (see Figure 6.1). Based on the results of the *Specifications* phase, Figure 6.2 shows the set up of the ten coin vibration motors on the body. A modular

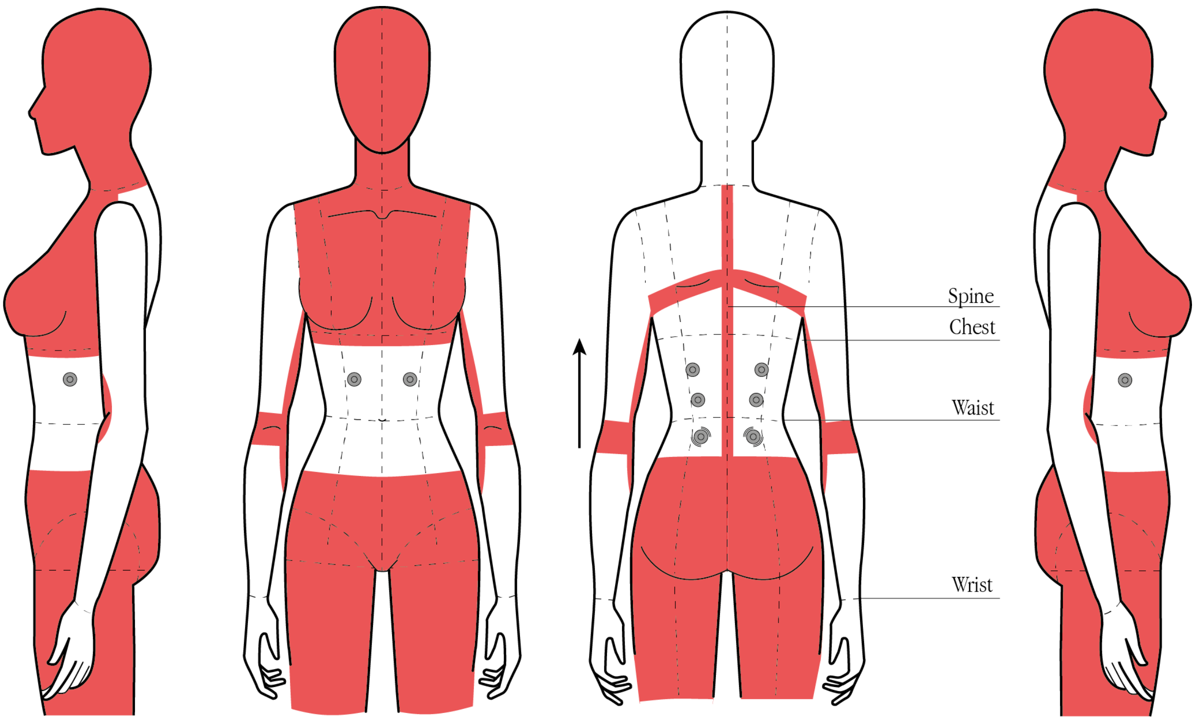


Figure 6.2: Positioning of the coin vibration motors on the body.

touch sensor, that acts as a switch, is incorporated on the sleeve of the shirt (see Figure 6.4a). Conductive yarn was used on one side of the touch sensor. As can be viewed in Figure 6.4b, this was sewn in the shirt of the researcher to connect the touch sensor with the Node MCU. An isolated cable was used to connect the other side of the touch sensor to the Node MCU. The touch sensor could be removed by press studs. A choice was made to include conductive yarn as this would be more comfortable on the skin. One side of the press studs were sewn on the allocated body parts as depicted in Figure 6.2. The other side were soldered on the vibration motors. Press studs were chosen for convenience and to be able to meet the requirement of modularity. Furthermore, to meet the requirement of a 45 min battery lifespan, a lipo battery of 3.7V was used. This way, the battery life span is over 5 hours which allows for an easy use of the system as joggers can decide any running distance.

The final result can be viewed in Figures 6.3. The other prototype was modular as well, however, no addition shirt was made. Instead, the press studs will be sewn inside a tight-fitting shirt for every participant. This way, the efficacy of the vibration motors is ensured.

(a) Outside front.

(b) Outside back. The pink bag is used for storing the micro-controller and the battery.

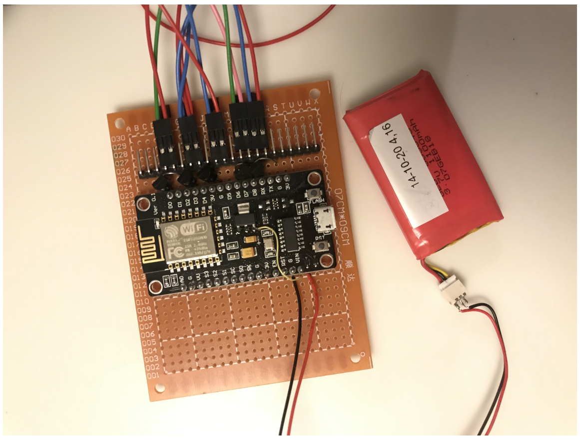
(c) Inside front.

(d) Inside back.

Figure 6.3: Images of the final prototype for the researcher.

(a) Touch sensor on the sleeve.

(b) Detail of the touch sensor sewn in the shirt. This way, the movement of the arm is not hampered.



(c) Hardware set-up.

Figure 6.4: Details of the final prototype.

6.1 Set-up of the prototype

Based on results of the previous chapter, the prototype consists of three parts: a micro-controller (Node MCU ESP8266), a smartphone and a website connected with a server (see Figure 6.5). The hardware set-up with the coin vibration motors can be viewed in Appendix E[2]. The smartphone is used to start and end the run but is also used while running to continuously send its GPS location to the server. The server in turn will calculate the compared travelled distance and send the data to the Node MCU. The server also manages the runs, poules, runners and is responsible for saving earlier runs. The acquired data is received by the micro-controller, which uses the data to provide haptic stimulation to the user. Subsequently, the micro-controller uses the WiFi connection of the smartphone to stay connected to the server. A Node MCU ESP8266 is used because a WiFi module is integrated inside the micro-controller. A Bluetooth connection between the smartphone and the micro-controller is particularly not used, because this set-up requires no additional application or platform as the micro-controller has direct access to the server. This also means that this set-up is universal to all devices. This way, no additional module was needed (**compact**) and no additional costs were made (**cost-effective**), which fits the requirements.

The users that want to start a run both open the website: `www.virtualrunner.nl/app/run`. The user selects a name and presses *start run*. To provide real-time data as the user moves, a website is used which is connected to a web server managed by phpMyAdmin which runs on MySQL. The web server is set up in different entities. To clearly show the relationships of the entities stored and the overall structure, an Entity Relationship Diagram is provided (see Figure 6.6). The entity *pool* stores the set goal for a particular run connected to an id, so 5 kilometres for example. The entity *runner* stores the name of the runner and connects this to an id. Furthermore, the entity *runner pool* saves to which pool a runner belongs. As runners are able to join different friends and so different pools, a many-to-many relationship is found between the entities *pool* and *runner*. With this set-up, multiple joggers are able to join a run or pool at once. This means that the system can be extended to more than two people

[2] One should note that in this stage two prototypes were created with the set-up of Figure E.3. In the Evaluation phase, the prototype of the participant was altered

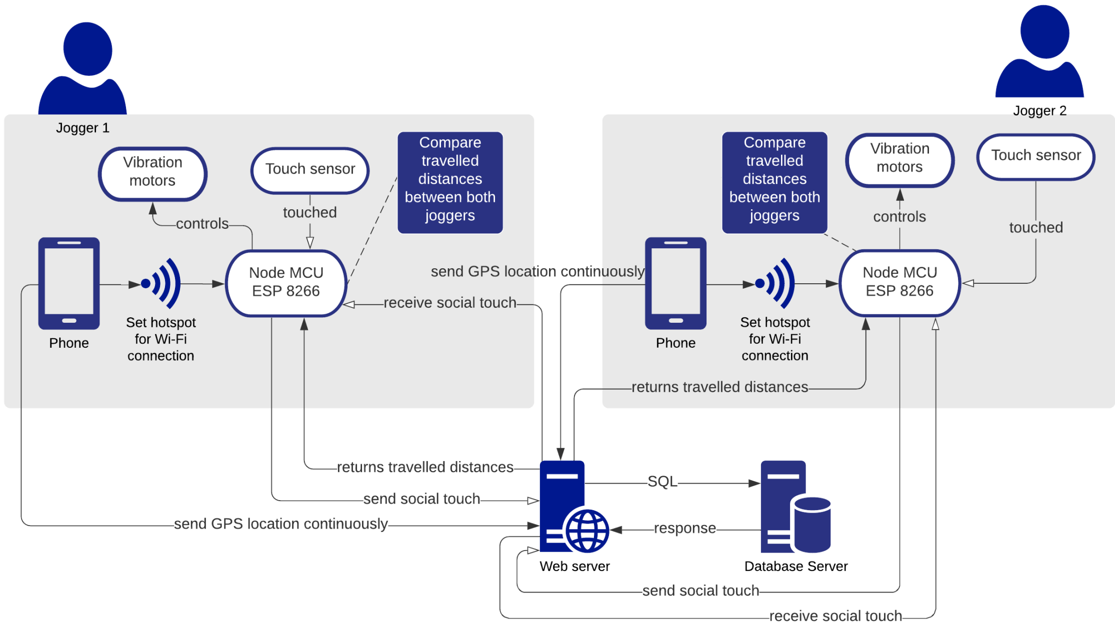


Figure 6.5: Flow diagram of the setup of the prototype between 2 joggers.

which includes the benefit of group dynamics for motivation [12]. However, for this bachelor thesis, the system will be tested between two users.

To continue, the entity *run* saves every individual run connected to an id, by saving a start time and end time, linked to a particular pool and runner. The id of the entity *run* is used in the entity *location log* which saves the distance every 4 seconds for every run. The entity *broadcast* stores the sending of a social touch. This will be activated by the micro-controller when the touch sensor is pressed. To remove the continuous sending of a social touch, the incoming values are grouped every 20 seconds. This way, a social touch can be send every 20 seconds. The entity *broadcast read* will be used to read if a social touch has been received every 4 seconds. Furthermore, one particular location log is connected to one runner, run and pool. However, the location log can have multiple objects of runners, runs and pools as it continuously tracks the travelled distance. This means that the entity *location log* tracks how much a runner has run so far, which is used to determine who is leading the run or who is falling behind to provide haptic feedback.

Based on the compared travelled distance, interactions are be defined with possible scenarios as depicted in Figure 6.8. The received social touch is based on apparent

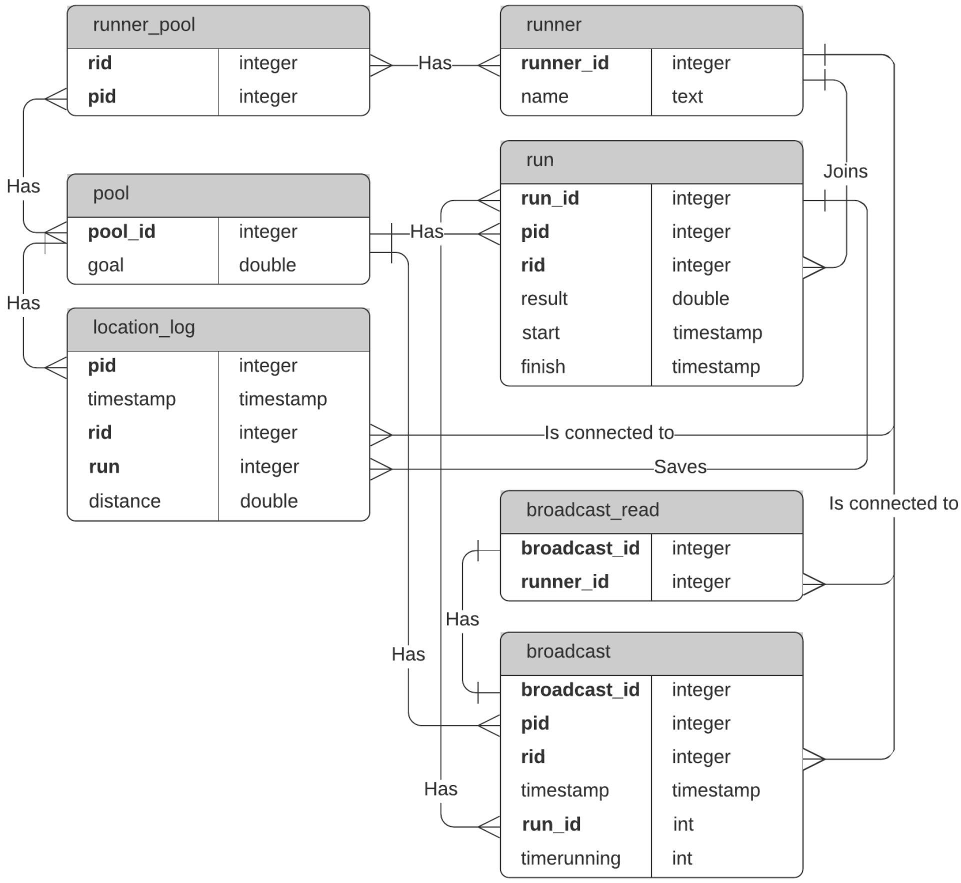


Figure 6.6: The figure represents the ER diagram showing the relationships between the different entities stored in the server.

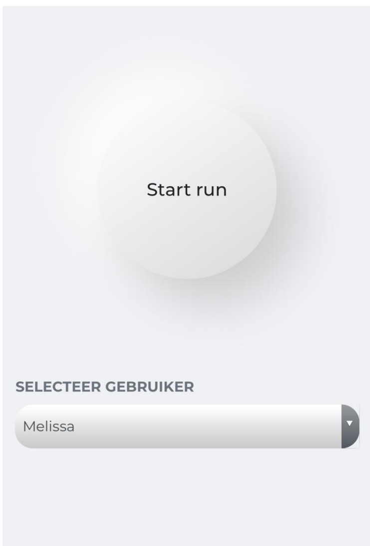


Figure 6.7: Screenshot of the website.

Type of interaction (runningState)	Scenario	Front	Side	back_top_motor	back_middle_motor	back_bottom_motor
awayRunningFront	*Other person is jogging very far in front of you*	on: 300ms, off: 900ms, pause: 1 min				
closeRunningFront	*Other person is jogging close in front of you*	on: 100ms, off: 600ms, pause: 1 min				
veryCloseRunningFront	*Other person is jogging very close in front of you (Keep going! You can catch up!)*	on: 50ms, off: 50ms, pause: 20 sec				
iCaughtUp	*You caught up with the other person*	1. on: 100ms	2. on: 100ms	3. on: 100ms		
runnerCaughtUp	*Other person caught up with you*	3. on: 100ms	2. on: 100ms	1. on: 100ms		
veryCloseRunningBehind	*Other person is jogging very close behind you (Watch out! He is catching up!)*			on: 50ms, off: 50ms, pause: 20 sec		
closeRunningBehind	*Other person is jogging close behind you*			on: 100ms, off: 600ms, pause: 1 min		
awayRunningBehind	*Other person is jogging very far behind you*			on: 300ms, off: 900ms, pause: 1 min		
sendSocialTouch	*I want to send a social touch for motivation*	on: 30ms	on: 30ms	on: 30ms	on: 30ms	on: 30ms
receiveSocialTouch	*I received a social touch*			3. on: 100ms	2. on: 100ms	1. on: 100ms

Figure 6.8: Table of all possible haptic stimulation based on compared travelled distance or social mediated touch between runners.

motion studied in chapter *Specifications*. This vibration pattern will be felt once to simulate the idea of a pat on the back. A short vibration is felt when the user sends a social touch. When a user is in a particular range and far from the other user, a slow pace is felt. When the user is coming closer, this pace increases and when the user is very close, this pace is fast. To exclude numbness because of continuous haptic stimulation, a pattern is felt once with a pause in between when the user is still jogging within the specified range. Moreover, when a user caught up apparent motion is felt from the back to the front or from the front to the back, to indicate that the leading position has changed. The intuitiveness of these interactions will be tested in the next phase. A more detailed elaboration of the system can be found in Appendix E.

Chapter 7

Evaluation

This phase focuses on evaluating the prototypes to test whether the intended user experience is reached. This will be done by evaluating the functionality of the system through critical observations and reflections. The chapter will conclude with a requirement analysis to indicate whether the requirements set in Chapter 5 are met.

The two prototypes will be tested with the researcher and potential users. The convenience sampling method was used because of the nature of the study: a user test aimed to understand the usability and user experience of the system. This way, a complete representation of the population is not required and the participants can be easily recruited. Participants were though recruited based on their jogging experience. This means that only intermediate to expert joggers were invited to participate as they will most likely use the system as discusses in Section 2.1. This resulted in a selection of five female participants who have been jogging for more than two months.

7.1 Set-up of the user test

The user test and evaluation consists of a run in which the researcher and participant run a specified distance determined by the participant. The researcher and user will wear their own prototype and test the system according to the following protocol:

1. The press studs were sewn in a tight-fitting shirt for the user. The researcher wore her own shirt. The vibration motors were attached to the shirt.

2. The prototype of the user was tested by the user beforehand. This was done to

check if there were any malfunctions and whether something was uncomfortable. The different types of interactions were not explained to test if the use of the system was intuitive.

3. The prototypes were connected to the mobile hotspot of the user and the researcher, then the website was opened. Both the researcher and user accepted the continuous GPS tracking and selected a fictional user.

4. The battery was connected to the micro controller and the system was tested if a consistent connection between the server and wearable was established.

5. The run was started. The researcher chose "Melissa" and the participant would chose the pseudonym "Vincent" to track the travelled distances. The researcher and participant were jogging over a distance and did not see each other during the run.

6. After the run, an interview was conducted to gain a better understanding of the user experience and usability of the system. The observations of the researcher were first written down without the interference of the participants to eliminate any interviewer bias. The participant was asked to evaluate the haptic wearable in terms of improvements, intuitiveness and usability in a semi-structured interview (see Appendix F for more details). The participant was also asked whether the different vibration patterns were intuitive and useful, and whether he or she had any recommendations or improvements.

7.2 User test 1

The goal of the user test was to test the efficacy of the system and whether the requirements were met. The first participant chose to run a distance of 1 km. The hardware components were put in a small bag, positioned around the hips (see Figure 6.3b in Chapter 6).

Both the participant and the researcher perceived the vibrations as pleasant and intuitive. The small bag was not disturbing. The participant highlighted that the interaction of catching up is easy and clear while jogging. It also motivates to keep on running. The other interactions were also clear, however, the participant did not always feel the vibrations on her back. When she was walking, she could feel them more distinctly. She recommended to change and test the intensity of the vibration motors beforehand in motion as she did not feel the vibrations that well on some parts of her back while jogging. However, this could also be caused by the fitting of the shirt which could be too loose while jogging.

During the run, the haptic feedback that a jogger was falling behind and running far away from the other jogger was not sensed. She also liked the idea of sending a motivation through haptic feedback as it pushes one to keep on running without thinking too much about it; changing one's mindset. The researcher agrees that the system supports directing the focus of fatigue away as fatigue is shared over a distance, which contributes to a positive jogging experience. It is particularly motivating as the sending of a motivation permits no distracting as one does not have to look at a watch or a phone. In other words, one can keep on jogging without changing one's posture or changing aspects in one's jogging style.

Furthermore, the participant highlighted that she especially likes the idea of incorporating feedback in a shirt since provide haptic stimulation on other body parts might be too disruptive. She explained that she does not use the haptic feedback on her sports watch because it is too intense and annoying during a run as the looking on the watch changes her style of jogging. The arms would also not be preferred, as during jogging, the arms are moved continuously resulting in haptic feedback to become disruptive. Furthermore, the amount of vibration motors should not be changed as the different types of interactions are intuitive with this specific amount of motors. Less vibration motors could hamper intuitiveness of the system as one has to remember during the run what different vibration patterns are allocated to what interaction. She recommended to integrate a virtual coach if friends or running buddies are unable to join. The virtual coach could help in accomplishing run goals.

7.2.1 Improvements

After the run, it became apparent that the described interaction was not felt due to problems with the GPS of the researcher's smartphone. The travelled distance of both joggers showed that the participant ran 1 km and the researcher ran 1.4 km. This shows that the GPS was not accurate enough as it was jumping regularly to estimate the GPS location. As a result, the travelled distance increased while the jogger was not moving. For future user tests, this smartphone should not be used again and the interval of applying haptic feedback should be increased. However, the researcher and participant did not perceive it as a problem during the run as the interaction and motivation were still apparent, because one did not physically see each other. From a product development perspective, it is though important that the travelled distance is accurate when joggers would be interested in viewing and analysing the run.

7.3 User test 2

The prototypes were tested between the researcher and the participant before the start of the run. A distance goal was set to 5 km. During the run, the participant noticed that it was very windy. This made her focus completely on the run in order to clear her mind. She thinks that this was the reason that she did not perceive any haptic stimulation during the run as she was focusing on the run and not on receiving the haptic stimulation. Similar to the first participant, another reason could be that the vibration intensity was not high enough in motion to be well perceived. However, she likes the idea of staying motivated during the run through haptic stimulation and social mediated touch on the body. The researcher did not encounter any problems with the vibration motors. She experienced the haptic stimulation as pleasant. She also received several social mediated touch interactions from the participant.

7.3.1 Improvements

Since the researcher received several social touches, the WiFi connection was not considered to be the cause for the numbness of the system. Based on the results of this user test and the previous user test, the intensity of the vibration motors seems to be a recurring issue for participants. As can be viewed in the set up of the prototype in the previous chapter, one transistor was used for two vibration motors. To determine whether the intensity of the vibration motors is caused by using a single transistor[1], the voltage and current of one vibration motor were measured to examine whether one transistor is sufficient for two vibration motors.

Measured voltage	**Measured current**
3V	60mA[2]
3.77V	77mA
4V	83mA

Table 7.1: Measurements of one vibration motor with a multi-meter.

Table 7.1 shows the results of the measurements. The measurements indicate that using one transistor is insufficient for two vibration motors parallel. To validate this finding, the voltage and current were measured over two vibration motors parallel, depicted in Table 7.2. Based on the measurements, the current of two vibration motors is above 120mA, while the transistor is not capable of switching 100mA. Therefore, the transistors were changed to MOSFET BS170 as it can be used in applications requiring up to 500mA DC. A low drop out regulator was added and a series diode was bypassed to enable the lipo battery — 3.7 Volts — to be used as power source, since the minimum voltage for Node MCU is specified at 4.5. Volts. After testing this set up, the vibration intensity was increased. For the other user tests, this set up was used for the participants (see Figure E.2 in Appendix E for the schematics). The researcher's prototype remained the same, because she was comfortable with the current vibration intensity. This means that the set-up with the transistors was used (see Figure E.3 in Appendix E for the schematics).

Measured voltage	**Measured current**
3V	120mA

[1]See Figure E.3 for the old setup of the prototype.

[2]Retrieved from the datasheet of 1034 coin vibration motors: https://www.vibrationmotors.com/wp-content/uploads/2018/05/BVM1034-C4701X50-1TU.pdf

3.7V	135mA
3.96V	150mA

Table 7.2: Measurements of two vibration motor parallel with a multi-meter.

7.3.2 Repeated user test 2

After the prototype of the participant was improved, the user test was repeated with the same participant to determine whether the issue was resolved. The participant evaluated the new setup with a higher vibration intensity as pleasant and easy to perceive. The positioning of the vibration motors on the body were also perceived as pleasant and she would not alter the positions. There were no problems during the run, which means that all interactions were perceived during the run. However, sometimes she did not feel the haptic feedback on her back when she was touching the touch sensor. This caused her to stop running to remove the touch sensor to see whether it was malfunctioning. She also did not feel the short vibrations on the front and back. After the run, it was shown that this was caused because the participant was unable to catch up with the researcher. Yet she liked the social mediated touch as it motivated her during the run:

> 'It felt as if the researcher was watching me when I was walking instead of running, because I received a social touch at that exact moment. This pushed me to keep running.'

Furthermore, the system was non-obtrusive. The cables and vibration motors did not bother her during the run. Instead of motivating herself, the system especially motivated her when she had periods of lacking motivation during the run. She recommends to explain and try out the different types of interactions before the run so the participant understands every interaction. Now she did not intuitively understand whether she was leading the run or not.

The researcher encountered an issue with the touch sensor. Because the conductive yarn used for the touch sensor was not isolated, the system was closing the circuit continuously when conductive yarn touched the Node MCU while the researcher was running. This resulted in intermediate stops of the run.

7.3.3 Improvements repeated user test 2

The improper functioning of the participant's touch sensor could be caused due to curling up of the touch on the arm while jogging. For the next user test, the touch sensor will be relocated to a body location that encounters as little movement as possible. The touch sensor of the researcher will be adjusted by isolating the conductive yarn with tape so no short circuit can be evoked. The use of the small bag will be eliminated as this might have caused the malfunctioning of the touch sensor due to cables getting stuck while jogging. Therefore, the system will be placed in a back pocket in the sports leggings in future user tests. Lastly, since the participant did not intuitively understand the different interactions, the researcher decided for the upcoming user tests to explain the interactions beforehand to improve learnability. This way, participants do not have to think while running what the specific interaction intended.

7.4 User test 3

The goal of the run was set to 3 km. The participant perceived the haptic stimulation as pleasant and intuitive. However, sometimes she could not indicate the different types of interactions. She thinks this was caused due to the positioning of the small bag around the hips. While running, the small bag was pressing against her back and moving. This resulted in the shirt to curl up and the vibration motors on the back to overlap. However, she could understand the different haptic feedback when she caught up or when someone was catching up or running in front or behind her. When she was sprinting, she did not properly perceive the interactions. The interactions were too short for her to perceive what type of interaction was provided. Nevertheless, the difference between the social touch and the other haptic feedback interactions were clear as they felt very differently. She also explained that the implementation of a social mediated touch and haptic feedback based on compared travelled distance gave her remarkably more motivation during the run. The haptic stimulation was in particular stimulating as one did not have to look at something or change posture while running. She added that while jogging one does not want to think of the technology, instead one wants to focus on the run. This system notably does not distracts the jogger while it *does* motivate the jogger to keep running. The concept of running over a distance especially functions because one does not physically see each other. She also expects that if joggers would be jogging in sight, the joggers might focus on receiving the interactions and social touch real-time instead of focusing on the run. This could negatively influence the user experience. Therefore, she thinks that the system should mainly be used over a distance as it is highly motivating this way.

Furthermore, the participant made some recommendations for future use of the system. She thinks that it might be interesting to run against the jogger's ghost. This means that the run will be saved and when the jogger decides to run the same distance again the jogger will run against his own saved track. This way, the jogger can, for example, improve his run as he knows when he is slowing down. The researcher added the use of heartbeat instead of the GPS location. By using the real-time heartbeat, joggers with different levels could run together. This could be interesting when running with friends is difficult due to differences in physical capabilities.

A problem emerged with the compared travelled distances. Near the end of the run, the travelled distances of the researcher and participant had a vast difference in which catching up was considered to be impossible (see Figure 7.1). Although it was near the end of the run and the participant received all the intended interaction, the problem had to be solved for future user tests. After analysing the run, the problem became evident. Near the end of the run, the participant had put her phone in her pocket, resulting in the smart phone to stop the tracking of the GPS.

Lastly, the researcher did not encounter any problems with the functioning of the system. Therefore, the use of the current set-up — in which the small bag is not used — will be continued.

7.4.1 Improvements

For the next user tests, the participants will be asked to hold their smartphone in their hand will jogging without letting the phone go to sleep mode. Although this approach

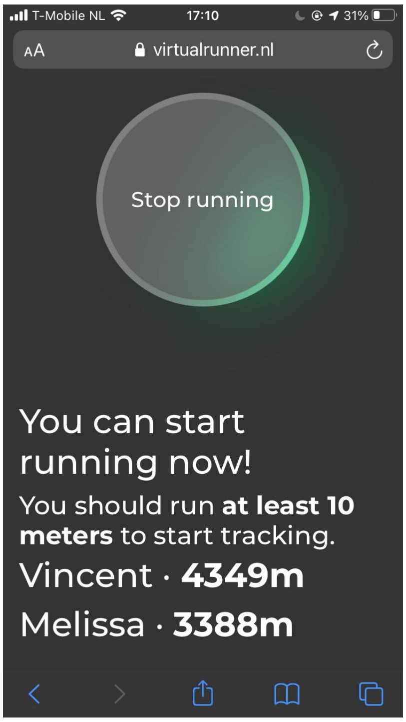


Figure 7.1: Screenshot of the compared travelled distances of the researcher and the participant.

is inconvenient, it will allow for a complete user experience. Furthermore, participants will be asked to wear a sports leggings with a back pocket so the small bag does not have to be utilised. This way, the efficacy of the vibration motors can be retained. If the participant does not possess the described garment, the small bag will still be used.

7.5 User test 4

The goal of the run was set to 5 km. She perceived the haptic stimulation as pleasant. While she was walking, the vibration intensity was adequate and sometimes too much. However, she would like to increase the vibration intensity to improve perception while jogging. As one is jogging, the vibration motors move and do not remain at the right position. Consequently, she suggests to incorporate a auto-pause option. This way, the vibration intensity will be altered according to the running pace. To increase intensity, another way of would be to use an elastic band instead of implementing the system in a shirt. The elastic band would hold the vibration motors in place while jogging.

The front vibration motors were better perceived than the back vibration motors.

Although she was satisfied with the positioning of the vibration motors on the front and side, she would recommend to extend the length between the vibration motors on the back. This way, the different vibration patterns would be better perceived in motion. She did though perceive the difference between receiving a social touch and the location-based haptic feedback.

When she wanted to send a social touch, she liked the provided haptic feedback. This way, she was assured that the social touch was send. Furthermore, the interactions were clear but during the run she had to think considerably about the meaning of the received haptic stimulation. Therefore, she recommends to develop an application in which the user is able to add visual or audio notifications. In the beginning, this could be helpful in understanding and remembering the different interactions. However, she thinks that the system is easy to learn. The application could also be used for choosing the appropriate vibration intensity.

Lastly, she considered the haptic feedback to be more motivating than the social mediated touch. She highlighted that she runs to improve so the social mediated touch is not really interesting for her. However, when she was walking, she like the idea of sending a social touch to the other jogger, but during the run she did not think of using the touch sensor. She also liked the idea of receiving a social touch while other passing joggers were getting tired and did not receive such motivation. She would also use the system more often if the cables would be incorporated in the shirt. The cables constricted her from running like she used to.

7.5.1 Improvements

For the next user test, the space between the vibration motors on the back will be extended. Instructions will be provided so the participant knows what to expect.

7.6 User test 5

The running goal was set to 3 km. After the run, she felt as if she did not get the full experience. She struggled with differentiating the social touch and other types of haptic feedback on the back. The vibration pattern on the front was too short to understand its full meaning. She thinks that she encountered the struggles because the vibration motors were tickling on her body. She assumes that when the vibration motors would not tickle anymore, the haptic stimulation would be better perceived. She adds that the system would be more motivating when the small bag would not be incorporated in the design. In her view, the small bag caused the shirt to curl up, resulting in vibration motors to overlap which hampered the efficacy of the interactions. She suggests to exclude the use of the small bag to maintain the intended vibration intensity. Moreover, when one is running at the same pace as the other jogger, various interactions are received at a fast pace. Sometimes the participant differentiate the wind from the haptic feedback due to the fast amount of interactions. She suggests to measure pace instead of travelled distance. Hence when one is slowing down, the system will notify that one has to speed up.

She also struggled with the touch sensor. The cables that connected the touch sensor to the Node MCU appeared to be too tight in the sleeve. This resulted in the set-up to break during the run. However, the participant did not notice this during the run. Subsequently, she had intermediate stops during the run once the set-up was broken as she did not feel the haptic feedback when pressing the touch sensor. This way, she was not really focusing on the run. She thinks she would have used it more when it was functioning properly and not distracting her from the run.

The GPS of the participant showed to be inconsistent. The travelled distance was larger than the absolute travelled distance. When the participant took intermediate breaks during the run to allow the researcher to catch up, the travelled distance was still increasing. This way, the researcher was unable to catch up and not all interactions were perceived. As a result, the participant did not feel the system was motivating her as it did not feel like a race. However, she suggests that the system could be motivating when the use of the small bag is excluded, the GPS tracking is working properly and the intensity of the vibration motors is increased.

7.7 Requirements analysis

Based on the findings of the researcher and the results of the interviews, this section will focus on determining whether the requirements established in Chapter 5 were met through a small reflection.

Ease of use

The NodeMCU sometimes had difficulties connecting to the mobile network, resulting in the NodeMCU to keep searching for available networks. However, this set-up was only required once. When the battery was removed from the set-up, the micro controller would remember the settings for future use and once the micro controller was connected with the mobile network, the WiFi connection was consistent. Furthermore, the website is easily accessible by users and easy to use as only a few tasks are required by the user: choosing the appropriate user and starting the run.

Light in weight

The prototype can be considered light-weighted as it only requires the micro controller, lipo battery, vibration motors and the touch sensor. As the results of the interview discussed in Section 2.1 showed that most joggers take their smartphone with them during a run, no additional modules are required. This also signifies that the requirement of **cost-effectiveness** is met.

Comfortable

The haptic stimulation was perceived by the researcher and all participants as pleasant. Some participants indicated that the use of the small bag hampered the experience of interactions and should therefore be avoided in future use and that the cables could be constricting while jogging. Therefore, the cable management should be improved through e.g. incorporating the cables in the shirt.

Tight-fit

The shirt created for the researcher was designed based on her measurements in order for the shirt to be tight-fitting. The participants were used to use a tight-fitting shirt during the user tests. Therefore, one can conclude that this requirement is met.

Robust

During one user test, the touch sensor was malfunctioning because the press stud got disconnected during the run. Throughout the other user tests, the touch sensor did not break but *did* occasionally got disconnected from the micro controller. Therefore, a housing for the system should be developed.

Battery life span of 45 minutes

The 3.7V lipo battery allowed for a battery life span over 45 minutes.

Accuracy

The accuracy of the travelled distances showed to be inconsistent. The accuracy of the GPS location proved to depend on the type of smartphone. This frequently resulted in peculiar travelled distances. When a smartphone could not find the exact GPS location due to sleep mode or temporally shutting down the operating of the GPS, the smartphone started to estimate its exact location by jumping from location to location, which in turn increased the travelled distance [3]. Nonetheless, the user tests still provided a profound experience of the system even though in some user tests not all interactions were met. As jogger do not physically see each other during the run, it can be said that the travelled distance does not have to be real-time.

Safety

The system is safe except from the conductive thread incorporated in the prototype of the researcher. The yarn was not isolated, resulting in hampering the use of the system. Therefore, only isolated cables and yarn have to be used for future work or an isolated set-up has to be used.

Modularity

[3] This could be resolved by developing an application. The application will request the GPS location of the smartphone every X seconds. This way, the GPS will not be accidentally turned off or put to sleep. However, the improvement and testing of this improvement is outside the scope of this study.

Since the components of the participant's prototype can be separate from the shirt, the shirt of the participant is completely washable. Although the conductive yarn is specified as washable, the prototype of the researcher is not washable as one cable is incorporated in the shirt. The prototypes are though modular as the components of the haptic wearable can be separated from the shirt, battery and micro controller.

Compact

The developer board is relatively small and can be put in a small bag. Although the cables were sometimes inconvenient for the participants, most participant did not struggle with the haptic wearable. However, smaller cables could be used for future work. The cables could also be incorporated in the shirt or tuck away in a more efficient way.

Chapter 8

Discussion

The results of the *Evaluation* phase showed that social as well as competitive joggers can be addressed with the use of the haptic wearable and its system. The haptic feedback based on compared travelled distance and the social mediated touch created a feeling of togetherness as it allowed joggers to interact with each other over a distance. Unlike current social communication technologies for jogging, this is the first technology that allows joggers to gain an understanding of how other joggers are performing throughout the run. Moreover, the jogger can interact with other joggers during the run by sending a social mediated touch or change pace based on received location-based haptic feedback for competitive purposes. Unlike [13], joggers did not slow down to wait for the other jogger to catch up, instead the joggers motivated each other through sending a social mediated touch as the run felt as a race. In particular, the combination of haptic feedback based on compared travelled distance and a social mediated touch showed to be crucial. Competitive joggers were motivated through the increasing pace of the haptic feedback, and social joggers were notably motivated through sending and receiving a social mediated touch. Although the user evaluations show promising results, these findings have to be validated by a larger sample size.

Furthermore, the requirements analysis showed that the following requirements depicted in Chapter 5 were met: ease of use, light-weighted, comfortable, cost-effectiveness, tight-fit, battery life span of 45 minutes, safety, accuracy and modularity. Yet the analysis also indicates that the prototype can be improved. The protocol to connect the ESP8266 to a mobile hotspot is inconvenient as it can take a while for the Node MCU to connect. However, once the connection is established, the system will remember the settings and will connect to the network after restarting, resetting or turning the device on or off.

Furthermore, an important benefit of the use of the website is that this set-up is universal because any device with a GPS can connect to it. Nonetheless, a LED, vibration pattern or other type of notification should be provided for the user to know that the system connected successfully to the internet. As mentioned before the accuracy of the GPS and this issue can be tackled by developing a mobile application. The application will notify the user with a sound, visual or a haptic notification when the system has a malfunction. The application will also connect the micro-controller to the internet without user interference. Yet this was beyond the scope of this study.

8.1 Recommendations

The results of the user evaluations also suggest that personalisation should be incorporated, because different users prefer distinctive vibration intensities, lengths or timing of the haptic stimulation. In addition, future work could enable different types of touch for different users. For example, when jogging with multiple users simultaneously, one would not know the sender of the social touch. This could be resolved by adding personalised vibration patterns.

However, the results of the user tests also signify future research directions. First, the system allows the possibility of integrating a personal trainer or virtual coach. This way, the user can jog at any time while the coach is guiding, pushing or motivating the jogger to get the most out of the run. When integrating a posture improvement ability, the system can also support the jogger to maintain a good posture during the run. This also shows the potential of rehabilitation purposes.

Furthermore, the system stores every run. This way, a jogger is able to run against his ghost, or in other words, himself. During the run the jogger will get haptic feedback based on the results of the previous run. As a result, the jogger experiences the spots in the run to improve. The set-up of this system also allows joggers to run by themselves when a partner is unavailable at a particular time. This holds that one user first goes jogging. The run will be stored on the server and the partner can run at another time as available online joggers can be asked to join a run. This extends the range of available joggers at a particular time as any available jogger can join the run. Subsequently, joggers of different but also similar physical capabilities can run together, something collocated joggers have difficulty with. Hence in this application, the social mediated touch feature will be discarded.

Lastly, the system can be integrated in other sports such as cycling or walking. Different vibration patterns can be investigated to display information through vibrations specified to a particular sport.

8.2 Reflection on the auto-ethnographic research approach

In order to interpret this study as empirical research in terms of generalisability and transferability, this section focuses on whether the requirements set up in Chapter 3 are met.

In Chapter 3, the study design, key claims and methodological approach are discussed. In the *Specifications* phase, the auto-ethnographic research approach showed to be an effective tool to make fast iterations and quick design adaptions. Throughout the study, the same protocol was used for examining experiments and user tests. The protocol consisted of a goal followed by honest observations and a conclusion with further recommendations for the next experiment or user test. Results of experiments were compared with existing research whenever possible. For example, the experiment conducted to understand preferred body locations for vibrotactile feedback (see Figure 5.4 in Chapter 5) was compared with research of research of Zeagler [8]. Raw data was provided in a table and observations were discussed in greater detail. Figures were used for visualising the experiments or results of the experiments and/or user tests. As the same protocol was used throughout the project, the study can be replicated.

The collection of data was elaborated including the audio recording of the interviews and the tracking of the GPS data. Privacy concerns were elaborated in provided information brochures and informed consent forms for participants. The participants for the interview and user tests were selected based on their jogging experience. The chosen sampling techniques were also elaborated (see Section 2.1 and Chapter 7 for more details).

To evaluate the user experience of the implemented social mediated touch thoroughly, two people are required. However, the auto-ethnographic research approach does not support this, as the approach takes the position of the researcher as the centre of the project. Subsequently, it does not allow to test the effectiveness of social mediated touch between two people. In order to test the interaction, potential users were asked to participate in this project in order to get more insight in the user experience. The combination of testing with the researcher/designer and participants enhanced the understanding of the user experience as it allowed the researcher to sympathise with the observations of the participants more effectively. By involving potential users in the *Evaluation* phase, the researcher was given more insight in the user experience of joggers which otherwise could have been missed. For example, the vibration intensity was considered to be comfortable, while most participants considered the vibration intensity to be too low. Before the interviews were conducted, the findings of the researcher during this phase were first written down and kept separate from the participant for the researcher to stay as objective as possible to prevent bias. During the evaluation interviews — when the participants were asked to reflect on their experiences — the researcher did not interfere in the reflection process to prevent interviewer bias.

Chapter 9

Conclusions

The aim of this bachelor project was to develop a haptic wearable that incorporates the act of sending and receiving a meaningful social mediated touch for distant joggers through haptic feedback based on the compared travelled distance. To validate whether this has been achieved, this chapter focuses on answering the main research question "*How to design a wearable that allows for real-time social mediated touch during running from an auto-ethnographic perspective?*". First, the sub-questions will be answered.

> *How do joggers motivate each other while jogging? How can social mediated touch enrich the experience of jogging?*

Based on the results of the interview in Section 2.1, joggers miss a social support due to several factors. These were found to be COVID-19 regulations, distance between jogging partners, time or availability constraints or a difference in physical capabilities. They keep motivated through using a sport watch or running application. As joggers appreciate the use of technology to support their jogging experience, social mediated touch can be used to incorporate a social aspect (competitive or collaborative) in the current jogging experience. This way, joggers can have an experience of jogging together but over a distance.

> *What is the state of the art of technology and social communication incorporated in sports, and in particular in jogging?*

In Section 2.3, current running technologies such as sports watches and mobile applications were tested and analysed. The analysis showed that the purpose of the running technologies was to provide the user an analysis of the performance of the run, and a way of sharing the run with friends. This showed to have temporary effects, because the interaction was only provided after the run. Although the Nike Run Club application did incorporate a way of sending cheers during the run, issues emerged when friends did not see the notification in time to send a cheer, or a notification was not received or seen by the runner, making this feature less effective. Other analysed running technologies did not involve support during the run, which highlights that a means of jogging together over a distance was not incorporated. Therefore, a social support during a run is yet missing in current technologies.

> *How can a smartphone and its network be used to compare the travelled distance of joggers and to provide haptic stimulation?*

The GPS of the smartphone can be used to send the location of the user to the web server as studied in Section 5.1. A website can be used as a user interface that asks the user to give permission to the continuous tracking of the user's location through the GPS of the smartphone. The web server calculates the travelled distance through utilising the Haversine formula and returns this to the haptic wearable. The web server stores the runner, location log, travelled distances, pool and run. It is also responsible for storing the sending of social touches and informing the micro controller that a social touch is received. The haptic wearable is connected to the internet by using the mobile hotspot of the smartphone. Subsequently, the haptic wearable will compare the travelled distances of the users to provide haptic feedback accordingly.

> *Which body parts are most preferred by users of wearable vibration systems and especially in jogging?*

The results of the literature review in Section 2.2 showed that kinesthetic feedback, and in particular vibrotactile feedback, is the most safe, non-invasive, cost-effective, small, light-weighted and effective on almost all body parts in order to accommodate a sense of touch. Vibrotactile feedback can also be well perceived while running, especially through providing staggered vibrations. Figure 5.4 in Chapter 5 showed that the upper body has the largest area for comfortable vibrotactile stimulation. Bony areas, body parts allocated to movement and socially unaccepted body parts should be avoided. This resulted in the design of a shirt with regards to the described limitations. Figure 6.2 shows the final set-up of the vibration motors on the body utilised in this research.

> ***How to design a wearable that allows for real-time social mediated touch during running from an auto-ethnographic perspective?***

This bachelor project followed the Creative Technology Design Process and was executed according to an auto-ethnographic research approach, which signifies the act of conducting research of the self. This research approach allowed for fast iterations and quick design adaptations in the specifications phase as the research went beyond the immediate evidence through critical thinking of the researcher/ designer (see Chapter 8 for a critical reflection).

Finally, two modular prototypes have been developed in which ten coin vibration motors were incorporated on the inside of a tight-fitting shirt and a touch sensor on the outside of a shirt. These vibration motors allowed for haptic feedback based on the compared travelled distance between two joggers by using a web server, a smartphone and its network. The haptic feedback was designed in such way that the relative distance of joggers was translated to an appropriate sensory feedback through haptic stimulation. As a result, the current jogging experience was transformed through adding a feeling of togetherness. For example, when a jogger was falling behind, a particular vibration pattern was felt at the other distant jogger. Another feature is that the jogger could send a motivation or social support through sending a social mediated touch by pressing the touch sensor on the shirt. The social mediated touch was created through apparent motion. The prototypes were tested between the researcher and potential end users to validate the intended user experience. After every user test, the prototype was evaluated and improvements were made accordingly. Despite these adaptations, the results of the interviews showed that personal calibration is of high importance for the best positive user experience. The results of the *Evaluation* phase showed that the combination of a social mediated touch and haptic feedback based on compared travelled distance, can be an effective way of sending social support between distant joggers during a run. The system also showed to be easy to use, comfortable, cost-effective, light-weighted, safe and accurate (see Section 7.7 for more details).

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Appendix A

Interview

A.1 Information brochure

My name is Melissa van Schaik, and I am a third-year Creative technology bachelor student at the University of Twente. I am inviting you to participate in a research study for my thesis. Participating is voluntary, so you may choose to participate or not. I am now going to explain the study to you. Please feel free to ask any questions that you may have about the research. I will be happy to explain anything in greater detail.

I am interested in learning more about the motivation of joggers. In order to do so, a semi-structured Skype interview will be conducted with open questions. This will take approximately 15 min of your time. The interview will be recorded (only audio) and transcribed for analysis purposes. All information will be kept anonymous. This means that your name will not appear anywhere and no one except me will know about your specific answers. In any articles I write or any presentations that I make, I will use a made-up name for you, and I will not reveal details nor will I exchange any personal information.

The benefit of this research is that you will be helping me to understand what motivates joggers and how joggers are motivated. There are no risks involved for participating in this study. However, if you do not wish to continue, you have the right to withdraw from the study, without penalty, at any time. If you decide during the interview that you do not want to participate any more, please notify the interviewer.

The interview will be stopped and your data will be deleted. If you decide after the interview that you do not want to participate anymore and want to delete your data, you can mail m.e.vanschaik@student.utwente.nl with a request for deletion. Your data will be deleted. The link between your name and the anonymous data will be carefully, securely and separately stored in a document locked in a desk drawer. This document will be deleted after the research is finished.

Data

The audio footage will only be watched by researchers directly involved in this study. It will never be made public and/or shown to a third party. All the research material will be used and stored according to the rules and guidelines of the AVG. The audio will be deleted after transcription. The complete transcribed interviews are only accessible to the researcher directly involved in this research. Parts of the transcribed interviews can be quotes in the thesis, this will be in such a way that the quote is not traceable to the participant.

More information

If you have any questions regarding this research, you can contact Melissa van Schaik (m.e.vanschaik@student.utwente.nl). For advice of an independent expert or the submission of a complaint, please contact Petri de Willigen, secretary of the Ethics Committee (053-489 2085, ethics-comm-ewi@utwente.nl). This is a committee of independent experts at the University of Twente. They are available for questions or complaints regarding the research.

A.1.1 Informed consent

You will be asked to verbally give consent for being recorded, before any recordings have started and before the start of the online interview. If you consent, the recording will start and the statements below will be read to you, you will be asked to consent to each statement. Your consent will be recorded and stored separately from the interview data.

- I am fully informed about the research. The goal of the research and the methods are clear. Questions after reading the explanatory text were answered.

- I understand that I can withdraw from the research at any time without any consequences or reasoning for doing so.
- I give permission for participating in the research and for collecting and using my data as described above.
- I give permission to record audio for research purposes.

A.2 Questions asked during the semi-structured interview

The online interview will consist of multiple open-ended questions to allow for discussion, which can be viewed in Table A.1. The aim of the interview is to obtain a better understanding of the motivation and social experience of joggers.

Focus of research	**Subfocus of research**	**Questions**
Opening of the interview	Provide details on the study including the study's objectives and ask for consent	Read exploratory text and provide verbal informed consent
Experience in jogging	Determine the degree of experience in jogging	How long have you been jogging?
	Same as above	How often do you run on average per month?
	Understanding the motivation to run	How do you stay motivated when you do not want to run?
	Measuring user's opinions for the necessity of introducing social mediated touch	Do you miss anything while jogging?

	Understanding if there is a need for guidance or social support for motivation and encouragement	Who is in your running network? Are you currently running under the guidance of a trainer or coach?
Motivation of jogging	Understanding why people engage in jogging	Why do you jog?
	Understanding if there is the need of technology	How long does a running session take on average?
Use of technology while jogging	Understanding if providing a route is essential for the system	How do you usually determine the route you will run?
	Evaluating what additional technologies or devices can be used for creating the system	What do you take with you for a run?
	Technical aspects of running technologies	Are you interested in viewing the results (data) of your running sessions?

Table A.1: Questions asked during the interview.

A.3 Results

Ten subjects were interviewed according to the described method above. The participants were divided into three categories based on their jogging experience according to [29].

- Beginner: Less than 2 months to no previous jogging experience.
- Intermediate: Running experience of less than 1 year.

- Expert: Experienced runners (more than 1 year).

The first participant was a beginner as the participant had been jogging for six weeks in the summer, three times a week. The participant started jogging because the participant's basketball coach demanded the players to run 5 kilometres in 24 minutes. Although the participant followed a running scheme for 5 kilometres in 8 weeks, the participant quit running because of an injury and returned to the practice of jogging because basketball started again. While jogging, the participant missed a comprehensive means of feedback. Audio feedback in terms of that the jogger knows that one kilometre has been run, would be appreciated for motivational purposes. Haptic feedback would be an idea for adding different means of feedback. However, she has never tried this before. Furthermore, the participant runs with her boyfriend and is guided by the application on her smartphone. However, the participant adds that she does not perform running for communication purposes and that she would not appreciate non-stop audio messages or music. The participant normally runs for approximately 3 kilometres and the route is determined beforehand. The participant, in particular, runs by signs provided in the park which highlight a particular route with corresponding kilometres. The participants always takes her smartphone with her while jogging and her keys. Lastly, she would like to see her results after the running session.

The second participant was an expert as she has been jogging for more than 10 years, two times a week. A running session takes about half an hour. She stays motivated through setting goals and running with friends. In a way, her friends give feedback and motivate and push her to run further. She does not particularly miss something but she would like to get feedback during her run and after the run. Therefore, she bought a sports watch. Although many features are incorporated in the watch such as the Virtual Pacer or interval workouts, she uses the main function of the watch and just starts running after she pressed start on the watch. The participant also used the Strava application, but she stopped using the application because the tracking and recording of the run did not work properly anymore. Another reason why she decided to buy the sports watch. She connects the sports watch with the Garmin Connect application to analyse the results after the run. Furthermore, she runs to stay fit and because she likes the social aspect of jogging with friends. Sometimes she jogs with music and sometimes she jogs to stay focused. The jogging route is not really set before the run. Mostly friends determine where to go. Lastly, she takes her smartphone and keys when she goes jogging.

The third participant was also an expert as she has been jogging for more than 11 years. She tries to jog twice a week but prefers three times a week. Now she jogs one time per week, because of health problems. She has little motivation to jog at the moment, because of the COVID-19 situation. She misses the social aspect of jogging and she misses jogging with her running friends. However, some running friends do not want to jog together because of the COVID-19 situation which means that they prefer to run alone, or because they have injuries. She stays motivated through her friends and the running association. She is guided by a coach who gives her running training, tips on respiration and a scheme for jogging individually. She likes jogging because you get energetic after a run and you feel fit and happy afterwards. A running session at the association takes 1 hour and 15 minutes. An individual run takes 45 minutes but she would like to increase this to 1 hour and 15 minutes. Furthermore, she always runs around a lake and sometimes she runs to another city. If she runs alone, she takes her mobile phone because if something happens, she has her phone to call someone. If she runs for more than 10 kilometres, she takes water. For every run, she takes her sports watch with her which is connected to the Garmin Connect application and the Strava application to analyse and share results after the run. She stopped using the RunKeeping application because it was not accurate enough.

Furthermore, the fourth participant is an expert runner as she has practised jogging for years, but with intermediate stops. For example, she started running when hockey practices stopped and she stopped running when hockey practices would start again. So she was mostly jogging in the summer. She tries to jog a few times a week, but she mostly jogs one time per week because of time constraints or bad weather. She stays motivated to jog because she wants to stay fit and wants to challenge herself to improve her performance every single run. Moreover, she always jogs by herself and uses the Samsung Health app every run. This application allows the jogger to choose interval workouts, long distance workouts etc. The application also shows results for further analysis such as burnt calories. A running session mostly takes around one and a half hour, because she includes a warming-up, cooling-down and stretching workout in the running session. She always runs in a park next to her house. This means that she always runs the same route. She takes her smartphone, keys and sunglasses. Lastly, if there would be an application that adds a means of running together, she would be interested in the collaborative aspect and not the competitive aspect of such an application. This means that the social aspect would include that friends jog together as a means of motivation and not against each other because she thinks that this could be demotivating.

The fifth participant is an expert jogger as she has been jogging for more than 4 or 5 years, two or three times a week. She stays motivated because she sees after every run on her smart watch that her stamina improved, that she can run longer etc. She does not miss anything, because she usually runs by herself and likes it that way. However, if there would be a way of jogging together without being physically present, she would be interested. She is, in particular, interested because she is from a foreign country, and this way, she would be able to run together with friends over a distance. She thinks that she will prefer to run through an audio communication, but she is not sure as she has never tried it before. Furthermore, she uses her smart watch in combination with the Samsung Health application for analysis after the runs. She does not want to be guided during a run. She wants to jog on her own pace without any pressure of reaching goals and, therefore, she jogs for fun. She really likes that she sees that she improves every run, which is highly motivating and gives joy to the practice of jogging. Every time she goes for a run, she knows that it will be longer than 4 kilometres so a running session takes around half an hour. She jogs in the park and decides the distance and time beforehand.

The sixth participant has been jogging for three months, two times a week. This means that she is a intermediate jogger. She stays motivated because she wants to stay fit and sees that her stamina is improving after every run. She also sees the improvements of staying fit in daily life. Furthermore, she always runs by herself, and takes her keys and smartphone for music and tracks her run through the RunKeeper application. She is especially interested in the average pace. For every run, she does not want to lower her average pace and aims to go improve her pace every run. She does not miss anything while jogging. However, she would be interested in joining run challenges with friends. A running session takes approximately 30 minutes. She uses a fixed running route.

The seventh participant is also a intermediate jogger, because she has been jogging for 4 months, two to three times a week. A running session takes between 20 to 30 minutes. She does not miss anything while jogging and jogs by herself. She stays motivated because of the same reasons as the sixth participant. She does not have a fixed scheme but does different interval workouts. She uses a fixed route for jogging so she knows that she will reach the set goal. She is interested in analysing the results after the run. She would also be interested in running together over a distance.

The eight participant is a beginner as he had been jogging for a few weeks, one to two times a week. He stays motivated because he wants to stay fit for another sport he practices. Once the other sport will start again, he most probably quits jogging because of time constraints. He does not miss anything while jogging because he always goes jogging by himself. He jogs according to a running scheme retrieved from the Internet. He has a sports watch but has not been using it actively because he just started jogging. A running session takes around one hour. He only uses the sports watch to watch the time for e.g. interval workouts. He does not analyse his results after the run, but that might change because he just started. He decides the route through Google Maps. He only takes the sports watch and his keys. He would be interested in a gamification of jogging. He would especially be interested in the competitive aspect not a collaborative aspect.

The ninth participant is an intermediate jogger as she has been jogging for 7 months, 2 to 3 times a week. She stays motivated as it is a means of losing energy and to stay fit, especially now when she cannot go to basketball practices. However, when the practices start again, she will keep on jogging next to the practices. She mostly runs by herself and sometimes with friends. She prefers to run by herself because, this way, she can go jogging without having to consider someone else. She does not miss anything, but prefers to run when it is less cold. When it is too cold, she runs less. She follows a 5km scheme, because without a goal she cannot jog. While jogging, she takes her sports watch and sometimes her smartphone so she is able to call someone

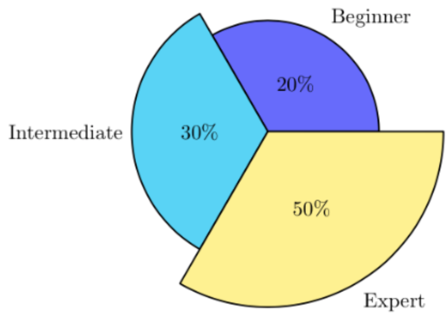


Figure A.1: Demographics on the degree of jogging experience.

in need. However, she does not use her smartphone so most of the times she does not take the smartphone with her. Her sports watch is connected with the Garmin Connect application. This way, she is able to view the results after the run on her smartphone and analyses if she has improved, her average heartbeat, pace etc. A running session takes max. 25 minutes. She has some fixed routes, but when she is somewhere she has never been running before, she determines the route by using the Garmin Connect application. The application will choose a random route based on a preferred settings such as distance or time. However, one has to memorise the route because the sports watch or smartphone will not act as a means of navigation during the run. Lastly, she does not use special functions such as the interval practice or the Virtual Pacer. She presses on her sports watch that she starts a run and starts jogging afterwards.

The tenth participant is an expert jogger as he has been jogging for 12 years, two times a week. He misses jogging with the jogging association as this is not allowed anymore due to the current COVID-19 situation. He normally stays motivated through his friends at the jogging association. He runs according to a running scheme provided by the trainer of the jogging association. He jogs to stay fit. The route is determined by the trainer beforehand. If he jogs with the association, it takes one hour and 15 minutes. He runs with a sports watch and sometimes uses the interval practice feature of the sports watch. He connects the sports watch with the Garmin Connect application for analysis after the run.

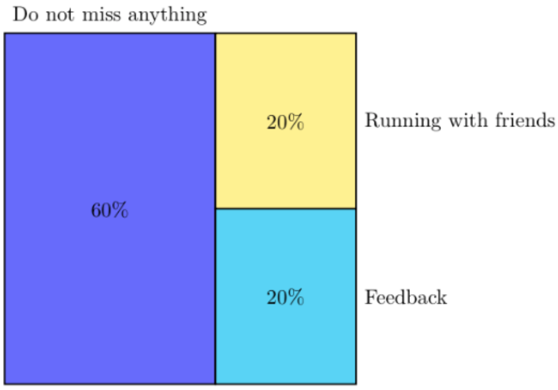


Figure A.2: What do joggers miss during a run?

A.4 Conclusion

The results of the interview showed that all participants jog to stay fit and use technology such as a mobile application or a sports watch in order to track and analyse the run or to help set a route. The average running session takes around 45 minutes. This means that the final prototype should have a minimum battery length of 45 minutes. As can be seen in Figure A.2, two participants miss running with friends because of the current COVID-19 situation, and two participants miss a comprehensive means of feedback during and after the run. One participant sold this problem by buying a sports watch for analysis after the run. Although six of the interviewee do not miss anything while jogging, five interviewee would also be interested in incorporating a social aspect in jogging through a means of running together over a distance or through participating in run challenges with friends. The participants have different opinions about how this should be achieved. Some agree that audio would be interesting for communication over a distance, but they are not sure if they would really appreciate it because they have never tried it before. Others do not want to be distracted while jogging so propose a haptic feedback system. Yet they are also not sure if they would appreciate it as they have not tried it before. All participants agree that they like jogging because they see that they improve after every run and the majority of the participants take their smart phone and keys with them during a run for analysis or in order to call someone in need. This means that the final prototype can utilise the Internet connect and GPS location of the smart phone. It also shows that the potential target group would be intermediate to expert runners as they will most likely use a smart phone for tracking and analysing the run. Lastly, all participants are interested in viewing the results after the run for analysis.

Appendix B

Virtual Pacer, Garmin Connect and Strava

To get familiar with existing running technology and to get insight into haptic stimulation, the Virtual Pacer feature of Garmin was tested together with Garmin Connect application and the Strava application (social network for runners). The goal of this test is to gain understanding of how technology is currently used in jogging, and what could be improved or integrated in this project. The Virtual Pacer feature is a training program that can improve performance by encouraging to run at a set pace [37]. The Strava application is additionally used to get an understanding of how social network is used for motivation and social support. This appendix depicts the results of the research on the Garmin Virtual Pacer feature combined with the Garmin Connect application and Strava application.

B.1 User test

For testing purposes, the test was constrained to using the described feature as this would best represent a way of running together. This means that other features were neglected in this test. The Garmin Forerunner 35 was used together with the Virtual Pacer feature (see Figure 2.5). Before starting the running, the set pace was set to 5:00 (12km/h). The Virtual Pacer was tested for 11:55 minutes. The test was conducted twice to be able to get used to the system. After the runs, the runs were synchronised with the Garmin Connect application for analytical purposes. The synchronised runs were automatically uploaded to the Strava application.

Protocol

The first run was used to order to get used to the system. This way, different paces were tried in order to understand when feedback was provided. The second run was used to get used to the system to get more insights and to focus more on the feature itself while running. During both runs, when the pace would be too slow compared to the set pace, a sound and vibration would be heard and a text message would pop up with a notification that the pace was too slow (see Figure B.1c). When the pace would be too fast, again a different sound, longer vibration and the jogger was notified through a text pop-up (see Figure B.1d). Lastly, when the pace was the same as the virtual pacer, a different sound, short vibration and a text notification were provided as feedback to the jogger (see Figure B.1b). Figure B.1a shows the screen when no feedback was given.

After finishing the runs, the runs were synchronised from the watch to the Garmin Connect application through a Bluetooth connection. The two runs were presented at the start screen of the application (see Figure B.2a). The application shows pace, heartbeat (maximum and average), cadence (average and maximum), height, time in heart rate zones, average pace, calories, rounds and a detailed overview in graphs per minute for every measurement (see Figure B.2b). Through these measurements, the runner can evaluate the run in greater detail.

Simultaneously while synchronising the runs to the Garmin Connect application, the runs were also uploaded to Strava. The application provides feedback on runs, walks, bicycle tours or workouts of friends which users can like, comment on or share. Users are also able to set goals, start runs for tracking or start challenges with others. The analysis is similar to the analysis provided by the Garmin Connect application.

Observations

The first run was used to understand how the Virtual Pacer worked. So I tried out different running paces to see when feedback and what kind of feedback would be provided. The purpose of the second run was, therefore, to run at a set goal of around

1 kilometres along with the Virtual Pacer. During both runs, I felt that the feedback was obtrusive in the beginning as I had difficulties in finding the set pace. This was probably the result of distraction caused by too many different types of feedback. It would be most useful and convenient to provide one type of feedback so either visual, vibrotactile or audio. I prefer the use of the haptic notifications as the sound of the watch might not be noticed when running with music, and a visual notification might be missed when focused. It is also distracting when only visual notifications are provided as you might want to look continuously on the watch instead of focusing on the run. After a few minutes, it was easier to run without distraction as less feedback was provided, but this also results in waiting for feedback (so there was still a degree of distraction). This was frustrating when the feedback of the set pace did not accurately match the current pace, resulting in no feedback. This can be viewed in Figure B.1a in which no feedback was provided while the running pace was too high.

Furthermore, the analysis of the Garmin Connect application and the Strava application showed that one application would be enough for analytical purposes. However, when exclusively using the Strava app, you are required to take the phone with you, resulting in an extra device to be carried along.

Conclusions

For this project, the user test of the Virtual Pacer showed that vibrations should not be obtrusive nor distracting. The observations also showed that vibrotactile feedback on a set pace should be real-time. Moreover, the designer should also avoid to use different types of feedback together as this could cause distraction to the runner. This finding supports the research of Baldi et al. [12] which showed that haptic communication is often preferred due to its intuitiveness, efficacy, intimate nature and because it does not occupy sight or hearing. Furthermore, the Virtual Pacer does not allows for a social support even virtually as feedback is not provided in a motivational way. Althought the Strava application provides a means of social communication, it would be interesting to add more social aspects to the application or the system in general.

(a) Screen shown while running without any feedback given.

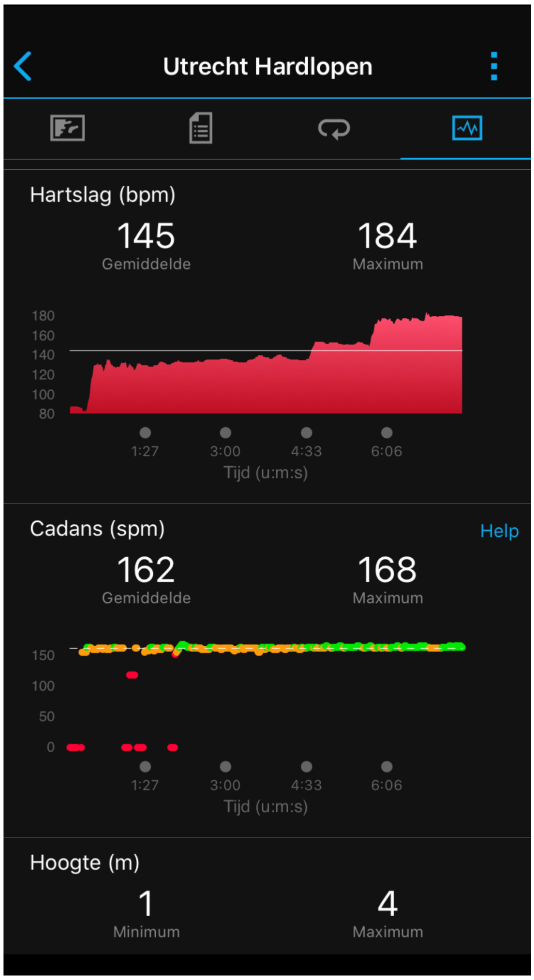
(b) Visual feedback provided when the user is running at the set pace.

(c) Visual feedback provided when the user is slower than the virtual pacer.

(d) Visual feedback provided when the user was faster than the virtual pacer.

Figure B.1: Interactions with the watch while running.

(a) Start screen of the Garmin Connect application. The two runs processed by the watch were synchronised with the application after the runs.



(b) Part of the analysis of the results of the first run.

Figure B.2: Analysis of the first run on the Garmin Connect application.

(a) Start screen of the Strava app. The runs were uploaded to the feed of Strava.

(b) Part of the analysis of the results of the first run.

Figure B.3: Analysis of the first run on the Garmin Connect application.

Appendix C

Nike Run Club Application

To get familiar with existing running technology and to get insight into social communication in running, the Nike Run Club application (NRC) was tested. The goal of the test was to gain understanding on how joggers stay motivated to run and how technology can be of any support. This appendix depicts the results of the research on the Nike Run Club app.

C.1 Profile

In order to use the application, a profile needs to be created including various types of personal information (see Table C.2). The values marked with an asterisk were asked to provide accurate results on running distance, pace and calories burned. These were, however, not compulsory. After providing the required information, the application asked permission to access the tracking of your location. This was compulsory as NRC needs the exact location to keep track of outdoor runs and to provide additional services and features.

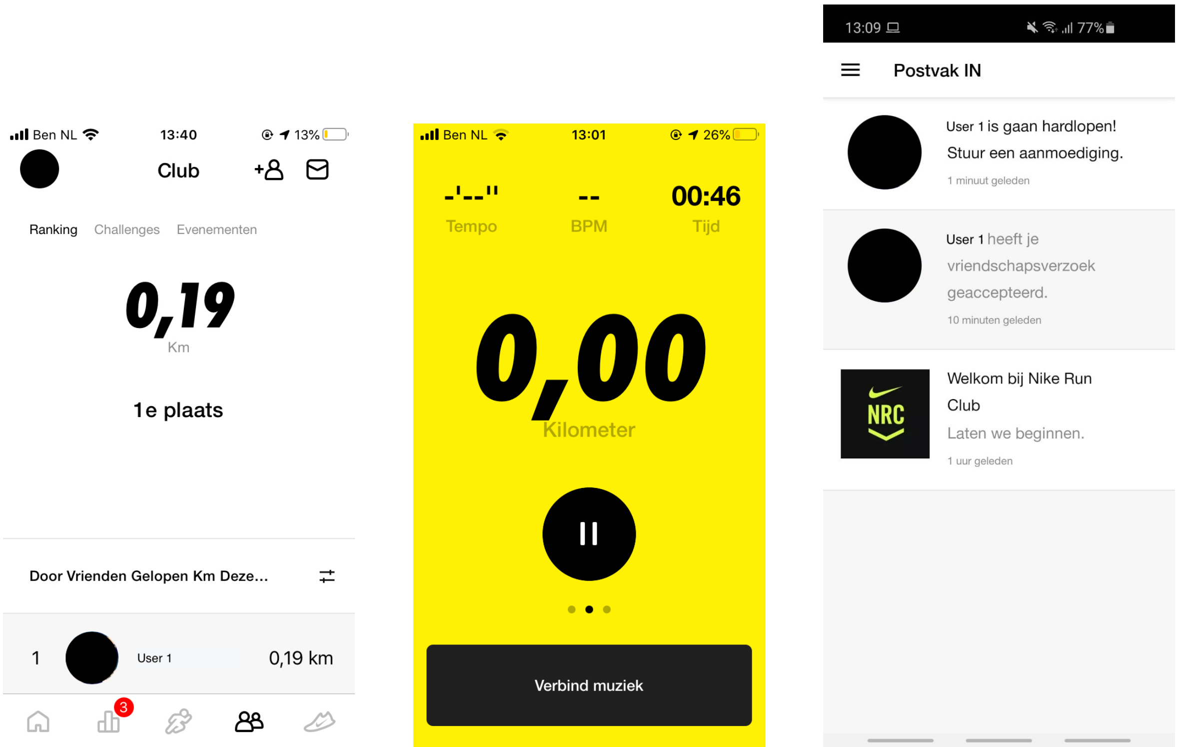
Type	**Data**
E-mail	m.e.vanschaik@student.utwente.nl
Password	-
E-mail	m.e.vanschaik@student.utwente.nl
First Name	Melissa
Last name	van Schaik
Birthday (used for sending a discount)	24-06-1997
Country	the Netherlands
Gender*	Female
Height*	1.73m
Weight*	58kg

Table C.2: Personal information required to set up a profile.

NRC is an application that focuses on providing a means of motivation through personalised runs and schedules, challenges with other runners all over the world and friends, means of sending cheers when a friend starts a run and audio controls from Nike athletes and coaches to get the most out of your run. For example, Figure C.1a shows the ranking in running distance between friends and it also shows challenges and events between runners all over the world that the user can join.

C.2 User test

To understand how NRC provides feedback and motivation while running, a user test was performed in which thoughts and opinions about the application were depicted. The application was tested with two smartphones (iPhone SE (User 1) and Samsung Galaxy s10e (User 2).



(a) Screenshot of the club tab.

(b) Start screen when a run starts (user 1).

(c) Screenshot of the notification in the mailbox of NRC (user 2).

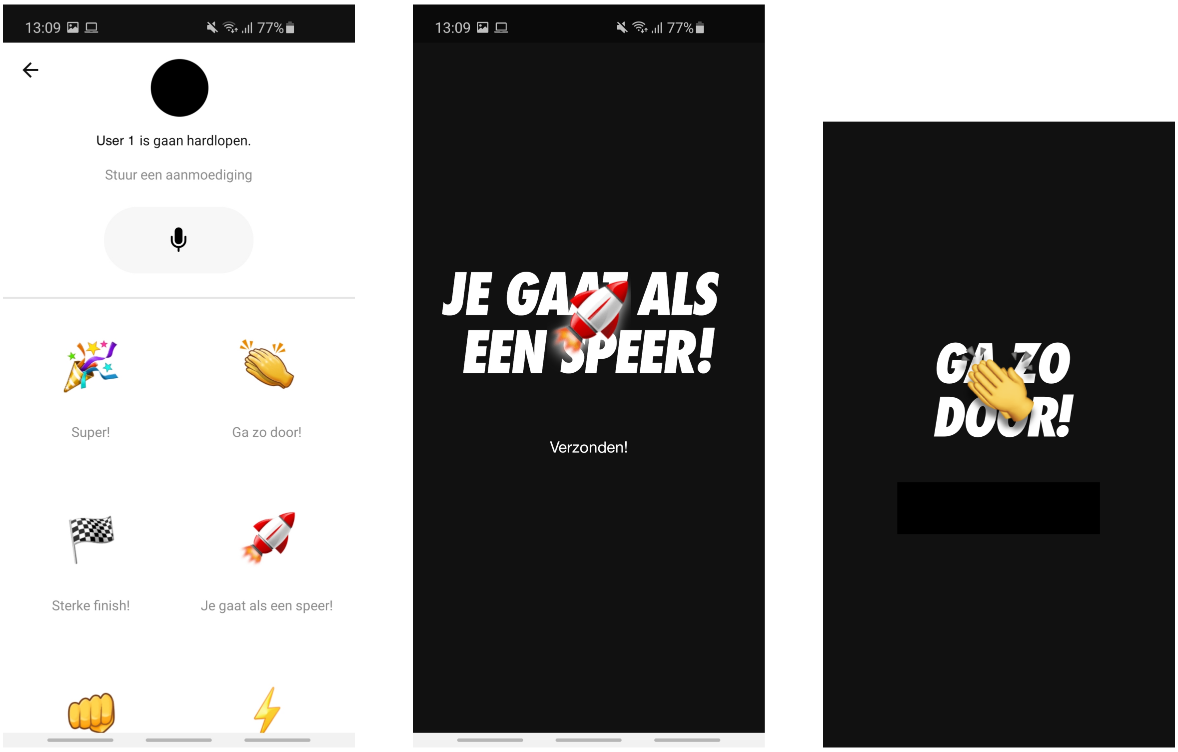
Figure C.1: Interaction with NRC.

Protocol

User 1 starts a run (see Figure C.1b). The other phone was notified that User 1 started a run (see Figure C.1c). While User 1 was running, the other user was able to send a cheer or an own audio cheer (see Figure C.2a). After User 2 sent a cheer, User 1 received the same cheer on screen and a clapping sound was heard. When sending a recorded audio message, this was received the same way. However, a cheer or audio message could only be sent once during a run. This experiment was repeated three times, switching between users that would start the run.

Observations

During a run, it is motivating that friends can send cheers especially when running alone. This type of motivation shows that no real-time motivation or cheer is required while running. Although the application allows geographically distant participants to



(a) Screen that is shown when a friend wants to send a cheer (user 2).

(b) Sending a cheer (user 2).

(c) Receiving a cheer (user 2).

Figure C.2: Interaction with NRC.

be connected, a means of real-time feedback is though useful as sometimes the message might be missed or is send when the run is finished. Friends could also miss the notification that one has started a run, resulting in no motivational messages at all. This can be disappointing especially when the cheer was received after the run. While running, if one is not focused on the smartphone or if the sound is not on, you might not notice that you received a cheer. This makes notifications on a smartwatch or fitness watch more convenient as you receive a small vibration when you receive a cheer. Furthermore, the abrupt clapping sound can be inconvenient and disruptive when one is focused. When receiving the cheer, one can get eager to know who sent the cheer, resulting in distraction or a decrease in the running phase. Lastly, as only one cheer can be send, the social support is only there for a while. It would be interesting to add more continuous motivational cheers, so that there is a feeling of support.

Conclusion

For this project, the results showed that no real-time motivation or social support is essential while jogging. However, there should be aimed for real-time feedback as the test showed that users might miss the notification (no cheers), or users see the notification when the run is almost finished, resulting in cheers to be received after the run. Furthermore, if the sound of the smartphone is muted or if one is not focused on the smartphone, one might not notice that a cheer is received. Since the cheer can only be send once, a jogger might also miss the motivational message during a run. Therefore, it would be interesting to provide a more regular means of social support, and this also makes notifications on a sports watch more convenient as an vibration is additionally felt. The preference for vibrotactile stimulation continues in the abrupt clapping sound of a cheer which can be inconvenient and disruptive in a state of focus during a run. This is a result of when a cheer is received one can get eager to know who sent the cheer and what type of cheer was send, resulting in distraction or a decrease in the running pace.

Appendix D

Zombies, Run!

To get familiar with existing running technology, the "Zombies, Run!" application was tested. The goal of this test is to gain understanding on how games can be motivating for joggers, and what could be improved or integrated in this project. The story of the game is about the main character, the jogger, who is one of the lucky to survive a zombie epidemic and has to help other remaining cities (see Figure D.1) [5].

(a) The aim of running to another city is to help a remaining city.

(b) The user is able to perform a jogging, running or walking activity in the game to reach the other city.

Figure D.1: Explanation in-game of the "Zombies, Run!" application.

D.1 User test

Before starting the run, a time constraint was set to 21 minutes and the first mission was used. The option to provide "chases" was enabled in order to get chased by zombies and to speed up during the run (see Figure D.2a). The tracking of the run was set to GPS as an outdoor run was performed (see Figure D.2b).

Protocol

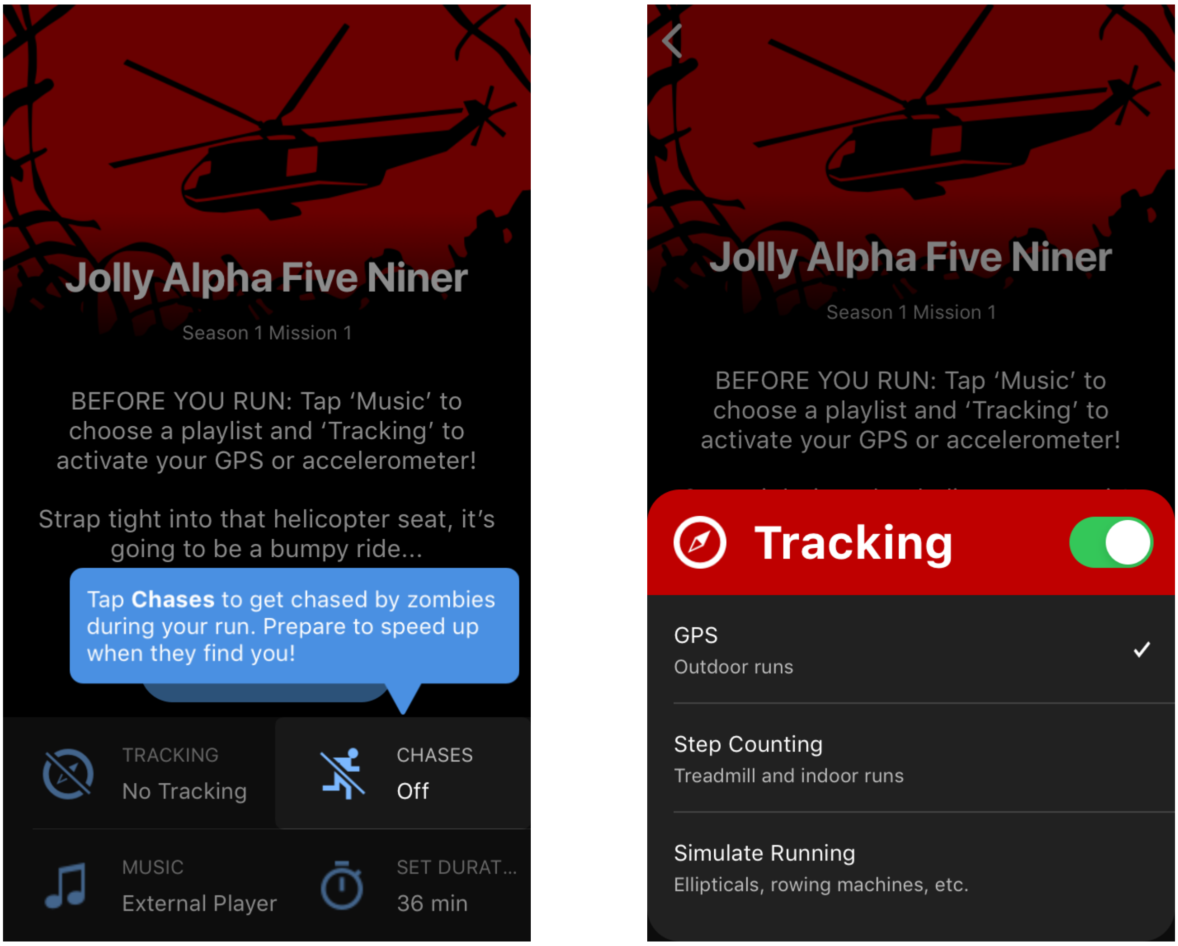
The run started and a story was heard about the main character, the jogger, who had to run to another city to provide support. No external music was used during the run, so primarily the story was heard. During the run, the jogger collected supplies in order to rebuild the city. The chasing was heard twice in which the narrator said that the zombies were close up to 20 metres, 15 metres etc. and the jogger had to increase speed. This was also heard when the zombies were chasing the jogger for the second time. After the run was ended, results were showed including time, average pace, time line, steps, distance and collected supplies (see Figure D.3b and Figure D.4a). An option to share the mission was also provided (see Figure D.4b).

Observations

The introduction took around five minutes in which I was unsure if I should start running or not. During the run, the narrator was sometimes silent for a few minutes and suddenly spook that a supply was collected. As this sometimes took too long, I did not know whether to speed up or to slow down. The chasing of the zombies appeared twice. The first time I increased my speed because the narrator said that the zombies were 15 metres behind but they slowed down during the run. However, the second time I did not speed up and the same audio was heard including that the zombies were 15 metres behind. As the application is tracking the pace, it would have been more engaging and motivating if the zombies would move according to the speed of the jogger (see Figure D.3a). Overall, I felt that the audio was distracting me from the run. However, if the interaction or the story line would be more compelling, it could be have a motivational purpose.

Conclusions

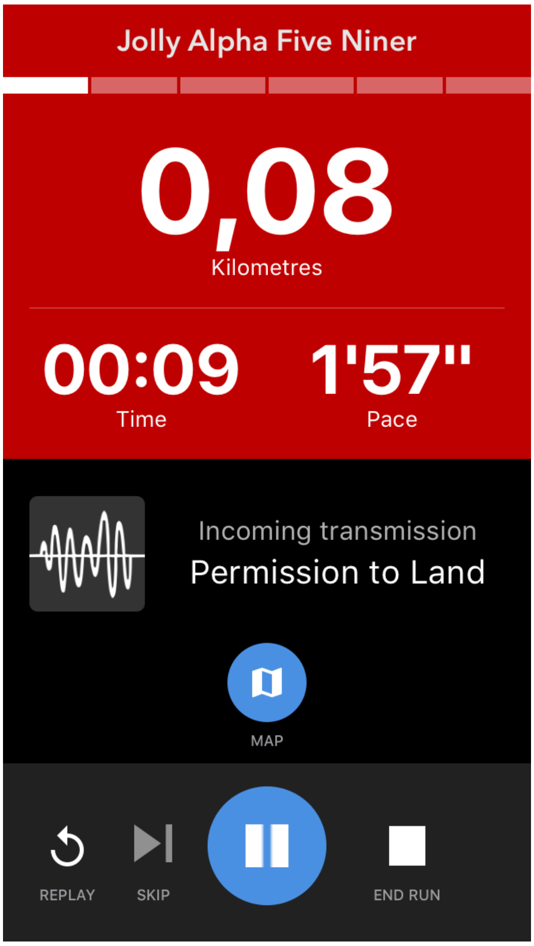
For the final prototype, a gamification element for motivation should be added to the prototype in which a collaborative or competitive element is provided. Furthermore, the feedback should be meaningful. No real-time interactions might feel numb to the user.



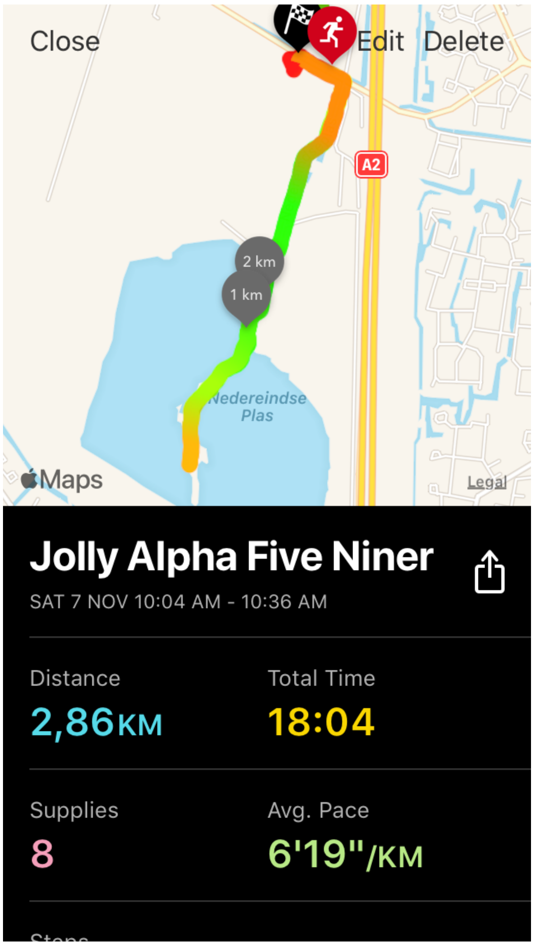
(a) The user can chooses to enable "chases" in order to get chased by zombies and to speed up.

(b) The tracking can be done through the GPS location of the smart phone, step counting and simulate running.

Figure D.2: User settings before a run initialises.



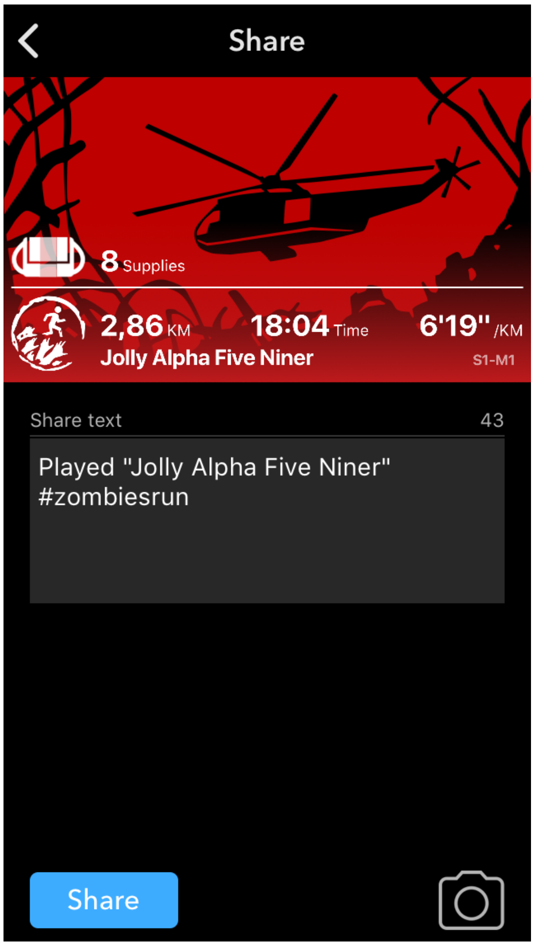
(a) Screen shown while jogging.



(b) The results of the run.

Figure D.3: During and after the run.

(a) Results on pace and the timeline of the game.



(b) The option to share the zombie run with others.

Figure D.4: Results after the run.

Appendix E

Prototype

To understand how the system behaves, a UML state machine diagram has been set up. Figure E.1 shows how states change status or lead to other actions based on the received input. The dark circle indicates the start of the system. The set-up of the system such as the initialisation of the variables will run once. After the set-up is completed, the Node MCU will start looking for available networks. If it can not connected or cannot connect to a saved network after 4 seconds, it will (re)configure to run in soft access point mode in order for Wi-Fi stations[1] to connect to it. Once connected, the system will receive the travelled distances from the web server and will process and print the incoming data. For example, if the last difference is smaller than 0 and the new difference is larger than 0, the system will know that the other runner caught up. This will be followed by the timer which initialises the back top motor, followed by the side motor, and lastly the front motor. After completion, the system will return to idle.

However, once a broadcast is received — which holds that a social touch is sent by the other user — the state will change to ”received social touch” which initialises the back bottom, back middle and back top motor. The timer will run the back bottom motor first, followed by the back middle motor and lastly the back top motor. Once this is completed, the system will return to idle. One should note that this is not triggered by the compared travelled distances, but instead by the touch sensor. When the touch sensor is touched by a user, a parallel process will be follow: the back bottom

[1]In this project, mobile hot spots or a mifi will be used.

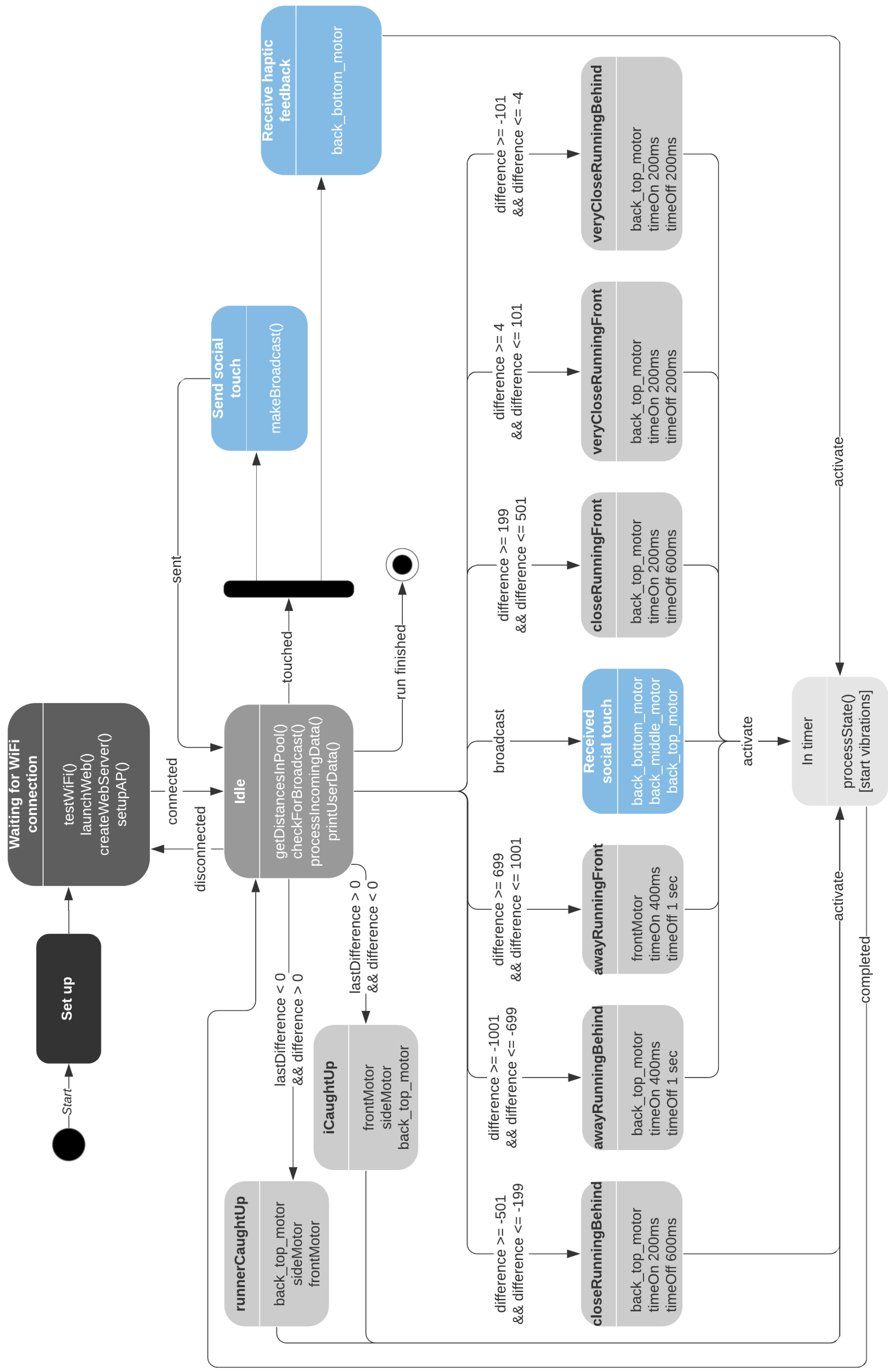


Figure E.1: UML state machine diagram of the system.

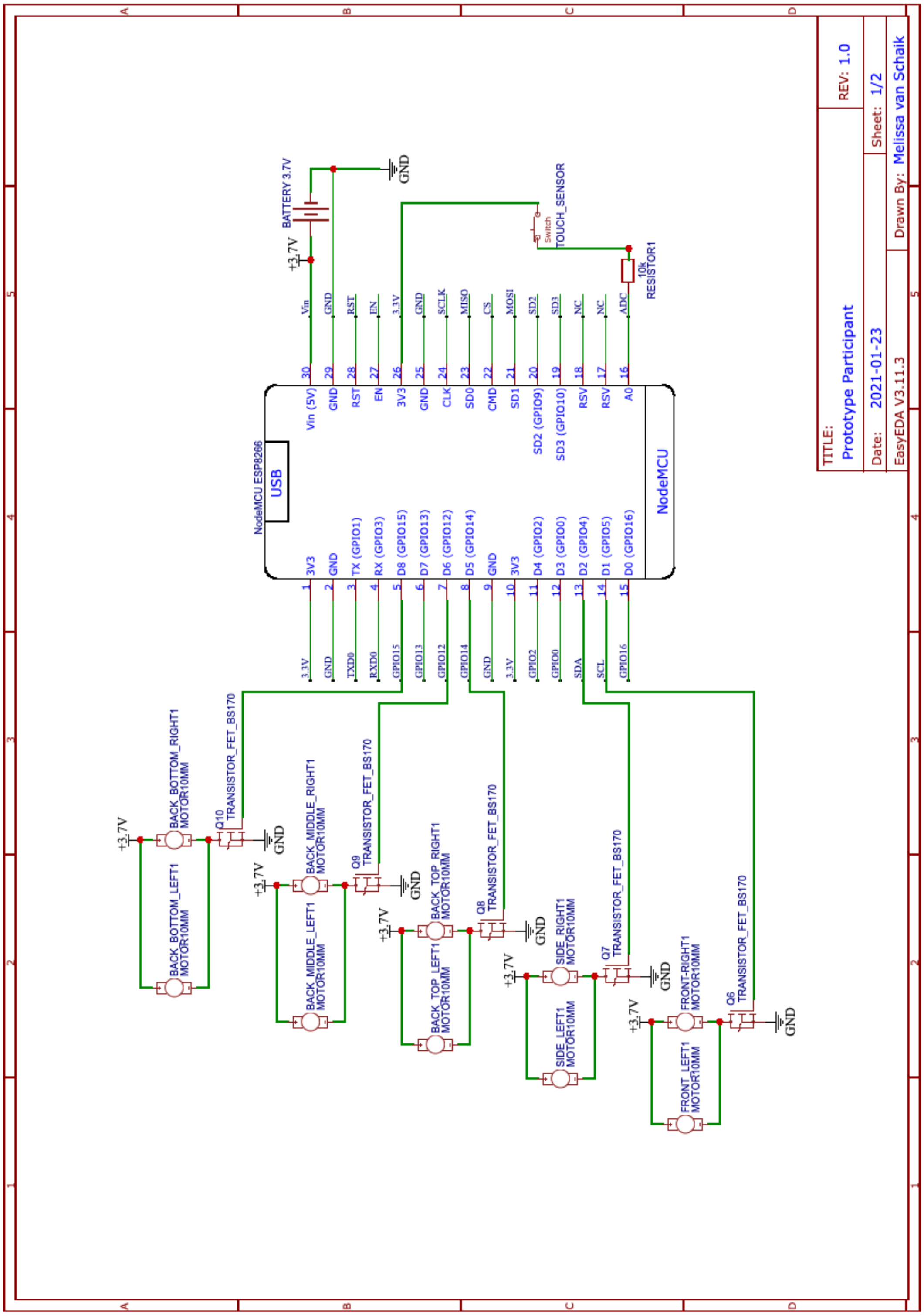


Figure E.2: Schematics of the prototype used by participant.

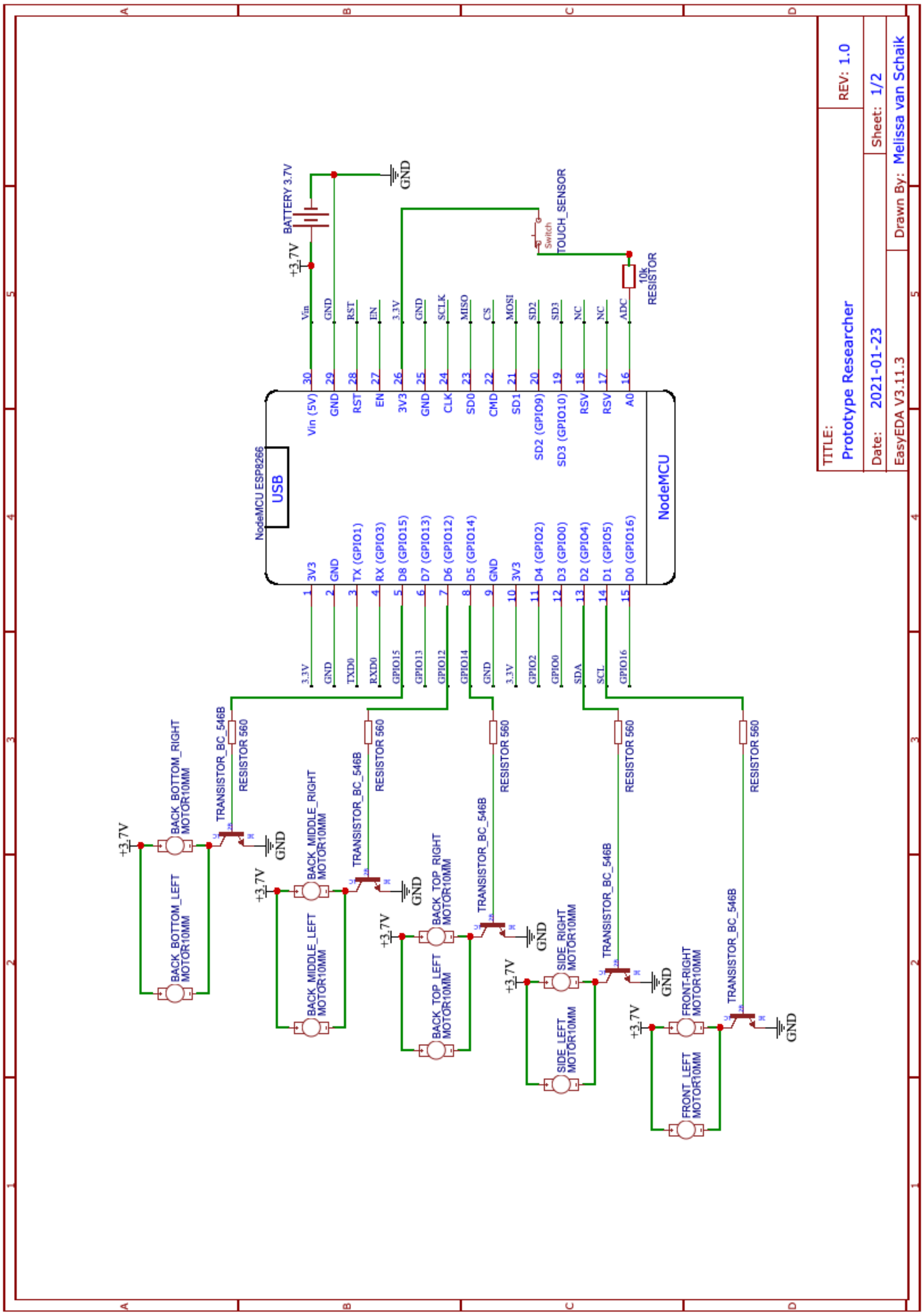


Figure E.3: Schematics of the prototype used by the researcher.

motor will run and a social touch is send to the web server. The back bottom motor will stop once the touch sensor is not touched anymore. After completion, the system will return to idle. The system will stop when the run is finished.

Appendix F

User test and evaluation

F.1 Information brochure

My name is Melissa van Schaik, and I am a third-year Creative technology bachelor student at the University of Twente. I am inviting you to participate in a research study for my thesis. Participating is voluntary, so you can withdraw at any time, without giving a reason. This document explains the study. Please feel free to ask any questions that you may have about the research. I will be happy to explain anything in greater detail.

I am interested in the user experience of my wearable. This means that I would like to determine whether a meaningful social touch can be transferred between joggers to motivate each other over a distance during a run. In order to do so, a user test will be performed outdoors followed by an evaluation . The evaluation consists of a semi-structured interview with open questions which will also be conducted outdoors. The user test will include a run between two runners over a distance. Before the start of the run, you can choose a particular distance that you are comfortable with. Both runners will wear the haptic wearable (a shirt with small vibration motors). When a jogger is falling behind, a particular vibration pattern is felt. The vibrations will be provided through small coin vibration motors. These motors are usually used in smartphones because of being small and light-weighted and are sewn inside the wearable so there will not be any direct contact with the skin. When a runner caught up and is now leading the run, a different vibration pattern will be felt. At any moment you can send a social touch to the other runner. This can be done by touching the sleeve on the t-shirt in which a rectangular silver sensor is incorporated. This way, you can motivate the other runner when he/she is for example falling behind. The sensor will also be incorporated in the haptic wearable and will not be placed directly on the skin.

This will take approximately 1 hour of your time. The interview will be recorded (only audio) and transcribed for analysis purposes. The user test will not be recorded through audio or video. Before the start of the run, you will be asked to open the website https://www.virtualrunner.nl/app/run. You will be asked to give permission for tracking your GPS location during the run on your smart phone. You are also asked to choose a made-up runner name. Your GPS location will be tracked during the run and stored on a webserver. These data will be deleted after analysis. Once a made-up runner name is chosen and permission for tracking your GPS location data is provided, you can press "Start run" and the run starts. All information will be kept anonymous. This means that your name will not appear anywhere and no one except me will know about your specific answers or GPS location tracking data. In any articles I write or any presentations that I make, I will make a made-up name for you, and I will not reveal details nor will I exchange any personal information with external parties. The GPS location tracking data will not be used in any articles or any presentations and will be deleted after analysis.

After the user test, an interview will be conducted outdoors. This will be recorded through audio. To evaluate the wearable, you will be asked whether you enjoyed wearing the wearable and what could be improved or changed. You will also be asked whether the different vibration patterns were intuitive and useful. You will also be asked whether you used the option of sending a social touch as motivation to the other user and if you have any recommendations or improvements.

The benefit of this research is that you will be helping me to understand the user experience of my haptic wearable. There are no risks involved for participating in this study. This also includes that no physical contact is involved. However, before the user test you can try out the wearable including the used vibration patterns. However, if you do not wish to continue, you have the right to withdraw from the study, without giving a reason, at any time. If you decide during the user test or the interview that you do not want to participate any more, please notify the researcher. The interview or user test will be stopped and your data will be deleted. If you decide after the user test or the interview that you do not want to participate anymore and want to delete your data, you can mail m.e.vanschaik@student.utwente.nl with a request for deletion. Your data will be deleted. The link between your name and the anonymous data will be carefully, securely and separately stored in a document locked in a desk drawer. This document will be deleted after the research is finished.

Data

Your GPS location data will be stored on a webserver and will be deleted after analysis. The GPS tracking data and the audio footage of the interview will only be reviewed by researchers directly recording this study. It will never be made public and/or shown to an external party. All the research material will be used and stored according to the rules and guidelines of the GDPR. The audio will be deleted after transcription. The complete transcribed interviews and GPS location data are only accessible to the researcher directly involved in this research. Parts of the transcribed interviews can be quotes in the thesis, this will be in such a way that the quote is not traceable to the participant.

More information

If you have any questions regarding this research, you can contact Melissa van Schaik (m.e.vanschaik@student.utwente.nl). For advice of an independent expert or the submission of a complaint, please contact Petri de Willigen, secretary of the Ethics Committee (053-489 2085, ethics-comm-ewi@utwente.nl). This is a committee of independent experts at the University of Twente. They are available for questions or complaints regarding the research.

F.1.1 Informed consent

The participant is asked to give written consent to the statements below and to sign the form. The researcher will also sign the form agreeing that the information sheet is provided to the potential participant and, to the best of her ability, ensured that the participant understands to what they are freely consenting.

- I have read and understood the information brochure, or it has been read to me. The goal of the research and the methods are clear. I have been able to ask questions about the study and my questions have been answered to my satisfaction.
- I consent voluntarily to be a participant in this study and understand that I can refuse to answer questions and I can withdraw from the study at any time, without having to give a reason.
- I understand that taking part in the study involves I give permission for participating in the research and for collecting and using my data as described above.
- I agree to be audio recorded for research purposes.
- I give permission to track my GPS location during the user test.

F.2 Questions asked during the interview

The interview will consist of multiple open-ended questions to allow for discussion, which can be viewed in Table F.1. The aim of the interview is to obtain a better understanding of usability and user experience of the system.

Focus of research	**Questions**
Opening of the interview	Read exploratory text and check informed consent
User experience of the haptic wearable	How did you experience wearing the haptic wearable during the run?
Usability of the haptic wearable	Did you encounter any problems or malfunctions of the wearable or system during the run?
User experience of the haptic wearable	What could be improved or changed?

User experience of the haptic wearable	Did you feel the different vibration patterns? What different vibration patterns did you perceive and did you understand the purpose of the haptic stimulation? Were the different vibration patterns useful and/or intuitive? Why?
Usability of the haptic wearable	Did you use the touch sensor? Were there any problems?
User experience of the haptic wearable	How did you encounter the use of the touch sensor? How did you experience the concept of sending and receiving a social touch? Do you have any recommendations or improvements?

Table F.1: Questions asked during the interview.