MSc Interaction Technology
Master Thesis

Promoting Transformative Self-Reflection to Support Running Experience Through a Dashboard Design

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Contents

Abstract

Running is a popular physical activity that benefits from technology. Advances in running technologies, such as GPS and heart rate monitors have enabled runners to collect running parameters. These parameters provide runners with insights to self-reflect on their performance or technique. There are various levels of self-reflection, with transformative reflection being one of them. Achieving a level of transformative reflection level engages runners in a thought process to make adjustments in future efforts. Additionally, video technology combined with running parameters can help runners reflect on their techniques. Observing one-self in a video and visualizing running parameters have shown benefits in supporting self-reflection, but there is an under-explored area of combining the two elements to promote runner's transformative self-reflection. This report explains the process of designing a dashboard where abstract visuals are combined with drone video to promote transformative self-reflection for runners. To achieve this, three studies were conducted: (1) survey, (2) design sessions, and (3) user evaluation. The survey identified cadence, trunk lean, and pelvic drop as the most relevant running technique parameters, with abstract visuals being the preferred imagery for reflecting on the running experience. These insights were used in design sessions, where runners created sketches of the running parameter visualizations incorporating basic elements (colors and shapes) and interactive elements (color-changing and shapeshifting). Subsequently, a dashboard featuring drone video and abstract visuals was developed using the MoveNet Lightning model for human pose estimation to augment the visualizations. The final user evaluation using TSRI demonstrated the dashboard's capabilities in promoting transformative reflection, providing runners with valuable insights and a more enjoyable self-reflection experience.

Keywords: running, running parameters, running technology, self-reflection, transformative reflection, user evaluation.

Chapter 1

Introduction

Running is a popular physical activity [1] [2], where people all over the world are running as a means to achieve individual goals. Karahanoğlu et al. conducted a study to identify runners' goals for using trackers when running [3]. In the study, runners' goals are classified into two main categories are achieving a particular performance goal and keeping running as a habit. In terms of a performance goal, runners want to achieve a certain running pace or distance, or participate in a competition environment such as a marathon [4]. Furthermore, there is a desire to keep running as preventive health efforts, such as exercising blood pressure [3] or stress level [5].

Technologies and running data have been implemented to help runners achieve their individual goals. Existing running technologies include watches designed specifically for runners (e.g., Garmin, Polar, and Suunto) which utilize GPS, heart rate monitors, and accelerometers to collect a range of data such as pace, time, heart rate, and distance. Recent advancements in wearable devices have enabled the measurement of various parameters related to running technique. By utilizing wearable sensors, researchers have demonstrated the ability to determine technique parameters such as foot strike type (FST), ground contact time (GCT), cadence, vertical oscillation (VO), and knee flexion-extension angles [6] [7] [8] [9]. Analyzing sports data has consistently been shown to enhance performance [10] [11] [12]. With running data, runners can receive information about their performance and enable them to make adjustments about their performance in alignment to their individual goals. Two popular technologies such as smartwatches and mobile applications are able to track running data. For example, with Strava mobile application runners can obtain information regarding their speed, elevation, distance, time calculated off GPS data, heart rate, and cadence power [13]. These sets of parameters are beneficial for runners where they can look back at their data and make adjustments in the future, or supporting reflection. Studies have explored how running data can be used to support performance through self-reflection, including smartwatch applications [3] [14], and data visualization and dashboards [15].

Zimmerman describes self-reflection as a post-performance process including an individual's response to their own experience [16]. He describes two processes involved within self-reflection: self-judgment and self-reaction. Self-judgment is a process of judging one's own performance and constructing correlations with the results. Self-reaction is a person's reaction towards their performance effort, and it depends on the sensitivity of their self-judgment process. Referring to the studies that have been discussed above, self-reflection can be facilitated through video technology. Video technology offers different perspectives and nuances that may not be visible through data. Videos can illustrate the complexity of running motions whereas numerical or statistical data alone can not. Thus, video technol-

ogy provides an opportunity to support reflection in sports. The use of video technology has shown a significant influence for dart throwing performance [17], learning tennis skills [18], and running performance and technique [19]. Based on these studies, the use of video technology helps a person to analyze and identify areas for improvement which leads to a better self-reflection. Dowrick describes the process of observing oneself in a video form with an adaptive behavior as self modeling [20], which brings positive effects on motivation, self efficacy and skill acquisition [21] [22].

There are different approaches to do self-reflection based on time. Schön describes three types of reflection: reflection-in-action, reflection-on-action and retrospective reflection-on-action [23]. Reflection-in-action is interpreted as reflection that occurs in the middle of the activity. For reflection activity that occurs within the context of the activity but not in the middle of the activity, such as in-between games and practice, is considered reflection-on-action. Retrospective reflection-on-action is reflection that occurs after the activity. Gilbert and Trudel stated this reflection as a "thinking back" type of reflection since the activity has passed, making it impossible to address the issue for that particular moment or activity. Instead, any insights gained can only be applied in future efforts [24]. They describe the first two types of reflection as methods of learning through experience, while the third type is a method of learning from experience.

Acknowledging the benefits and timing approach for reflection, there are ways to design for self-reflection. Fleck and Fitzpatrick provide a framework to design for self-reflection with consideration towards aspects of reflection, one of which is levels of reflection [25]. They describe the five different levels of reflection as: R0 Description, R1 Reflective Description, R2 Dialogic Reflection, R3 Transformative Reflection, and R4 Critical Reflection. At the R3 transformative reflection level, individuals engage in reflection with the intention of reorganizing their actions, prompting them to question and challenge their personal assumptions, resulting in a change in practice. Kocielnik et al. further described as these levels of reflection aligned with three stages of reflection from Atkins and Murphy [26]: (1) noticing, (2) understanding, and (3) future actions [27]. Noticing involves becoming aware of events and patterns without trying to understand them. Understanding focuses on analyzing the situation from various perspectives to formulate explanations and observations. Future actions is the final stage, where the previous understanding leads to new perspectives, lessons, or insights for the future. This last step corresponds to the level of transformative reflection, where past events are revisited with the intent to reorganize and implement changes in the future. Studies have shown observing one-self previous efforts can lead to valuable insights which leads to a better performance or technique [17] [18] [19]. Thus, this study aims to promote transformative reflection, providing a method for runners to reflect on their past efforts, gain valuable insights, and support their running experience.

Data visualization and video technology have the potential to support runners in self-reflection. However, the potential of combining these two elements to promote transformative self-reflection in runners remains under-explored. A study by Balasubramaniam et al. showed that there is a desire for runners to gain insights and improvement aid from their video recordings [19]. Therefore, they propose one approach to address this is by employing a dashboard to enhance runners' reflective experience. Based on this, there is an opportunity in enhancing the experience into a transformative reflection through the use of a dashboard combining drone video and running data visualization. Hence, the purpose of this study is to answer the research question: **how to promote runners' transformative self-reflection through a dashboard design?**

This report details the process undertaken to address the research question. First,

it reviews related works on running parameters, designing for reflection, and measuring reflection to contextualize the study within the existing landscape. Following this, the study design, which includes three distinct activities to gather the necessary information, will be explained. The results of each study activity will be discussed immediately after describing the study design, as some findings influenced subsequent activities. Lastly, the discussion and conclusion sections summarized all the insights gain and explained how the study directly address the research question.

Chapter 2

Related Work

The following sections will delve into existing studies and practices that inform the design of experiences aimed at enhancing runners' self-reflection. There are three sections that will be discussed in this chapter: (1) Running parameters provide runners with information that aid them to achieve their individual goals. Given that each running parameter holds distinct significance for each runner, it is required to gain an understanding of which running data or parameter is preferred by runners to tailor designs to their needs. Related works within the spectrum of running parameters will be discussed in the Running parameters section. (2) Using the running parameters, there are design techniques that can be implemented to promote runners' reflective experience to create an interactive dashboard. Related works about design techniques to promote reflection and dashboard will be discussed in the Design for reflection section. (3) A measurement technique is needed to determine whether the dashboard is successful in promoting reflection for runners. Related works for measuring self-reflection will be discussed in the Measuring reflection section.

2.1 Running Parameters

Running data or parameters is one possible aspect based on the sports interaction technology (ITECH) framework [28] that can be used to design to enhance running experience [29]. There are four types of running parameters: spatiotemporal, kinematic, kinetic, and physiological. Spatiotemporal parameters provide spatial (distance) and temporal (time) information related to the gait of running. Examples of these parameters include average speed and total distance. Kinematic parameters describe the motion of points and bodies, which are collected through information such as angular/linear positions and acceleration. Kinetic parameters refers to the associated forces, moment, and torque which affect the running body (e.g., ground reaction forces, braking force, pressure distribution). Physiological parameters provide information of cardiovascular and respiratory systems in regards to running. Heart rate, blood pressure, and respiration rate are examples of this parameter.

Different running parameters provide different insights for runners in regards to achieving their individual goals. A study showed that runners consider heart rate, pace, and distance to be the most relevant data for them [30]. Heart rate is deemed the most important, as it can indicate potential heart problems. Pace and distance are crucial during the run itself, with runners wanting to know their current speed and the distance covered to decide when to stop. Additionally, there have been studies exploring running parameters and their correlation with performance [31], injuries [32] or motivation [4]. Emig & Peltonen in their study hint at new ways to predict athletic performance using running

parameters [31]. Zadeh et al. explored the connection of parameters that might lead to injuries [32]. In another study, it has been shown that running parameters have an impact towards runners' motivation [4]. Furthermore, Jensen & Mueller describes two kinds of running parameters in their work: performance and technique, with performance parameters being time, distance and pace while technique parameters refers to the kinematic features of a runner such as stride length and frequency [33]. These technique parameters affect runners' efficiency, risk of injures and ultimately the performance result [34].

In their study, Balasubramaniam et al. found runners' three most preferred parameters are pace, trunk lean, and time [35]. While Balasubramaniam et al. highlighted the relevancy of real-time feedback for these three parameters, it remains uncertain whether they are equally effective in enhancing runners' reflective experiences. Acknowledging this, it is necessary to understand runners' most preferred running parameters within self-reflection context before designing the dashboard. The existing studies discussed above highlight the wide range of running parameters, underscoring the importance of understanding runners' preferences for self-reflection. This ensures that the dashboard is tailored to meet their requirements in regards to enriching their self-reflection. This leads to the first sub-research question of this study: **what is runners' most preferred running parameters that are relevant for their self-reflection?**

2.2 Design for Reflection

The interest in reflection and technologies to support self-reflection has grown [36], with some interactive experiences being created to promote reflection [37] [38]. There have been studies exploring techniques that can be employed to design for reflection. A study by Ekhtiar et al. suggested design considerations for achieving a specific level of reflection based on the work of Fleck and Fitzpatrick [25]. They found that incorporating goal setting, activity recommendations, and highlighting benefits can effectively promote transformative reflection [39]. Slovak et al. describes three components that can be considered in designing technology for transformative reflection: (1) explicit, (2) social and (3) personal components [40].

Explicit components refers to re-shaping the experiences of the learners through specific tasks or tools to enable reflection. This means the technology can be designed to generate emotional or interpersonal experiences, or even directly scaffold the reflection process. One approach to achieve this is by configuring the temporal perspective, which aligns with Bentvelzen et al. design resources of using time as a way to construct a new perspective which can lead to a reflection process [41]. Examples of this perspective are past and future. Past can be used to enhance reflection by offering users the possibility to revisit their data, i.e. retrospection. Meanwhile, future can be used by letting users consider their future, instead of triggering memories.

Social components refers to a set of social resources the learners can draw on, hence providing support to others who support the learning. Two possible resources in this component are conversation and comparison. Conversation can be used to provide reflection by letting a person have a conversation with others or with technology, while comparison provides reflection by letting a person compare their current status to an 'ideal' status, which can be an arbitrary norm or comparison to others. An arbitrary norm or absolute reference can be a certain number that needs to be achieved by the person (e.g. vegetable

consumption [42]), while comparison to others is leaning towards more social involvement, such as leaderboards [41].

Personal components are internal qualities of the learners to grasp the experience. The designed technology can heighten learners' motivation to increase engagement within the experience and experience a new perspective which leads to discovery [41]. The sense of discovery (e.g. "Aha!" moments) will lead to reflective thoughts.

Looking at the possible resources discussed above, past temporal perspective will be implemented into the design to provide self-reflection for this study. In addition to using past temporal perspective, considering the nuanced, often unseen, elements of running outside the physical attributes might contribute to promoting runners' self-reflection. This is aligned with the somaesthetics design approach.

Somaesthetics is a multidisciplinary field based on pragmatist philosophy, emphasizing the acknowledgement of the body-mind or soma [43]. This informs methodologies that are centered on experience [44] [45], resulting in designs that facilitate participants to have enhanced awareness towards their own bodily sensations and movements [46]. Furthermore, crafting an experience for running, which is a bodily interaction, may require qualities that can't be seen with the naked eye, such as haptic and dynamic elements. Developing these qualities is considered an important aspect of interaction design [47] [48]. Some design methods such as dance and somatics [49] [50] tries to focus on the felt experience of movements. Hence, somaesthetics approach is applicable to help develop those qualities, and utilize it for designing. Somaesthetics has been adopted as a theoretical basis for various interaction approaches centered around the experience.

Soma Design [51] is a design approach that focuses on the first-person body experience throughout the design, deployment and evaluation experiences. The goal is to enhance the somatic awareness and sensory appreciation of both designers and end-users. There are four interactive qualities that can be used within soma design: (1) subtle guidance to guide a person's focus, (2) adjusting temporal and spatial places for reflection, (3) providing feedback to follow the body rhythms, and (4) providing means to articulate bodily sensations [51]. Additionally, the practice of somaesthetic has proven to assist designers in identifying design issues in the ideation phase, and facilitates a more effective prototyping of interaction [44]. Since running is very much a physical activity, it can be said that it involves full perception and sensation of one's body. Hence, somaesthetics will be applied for the design to promote runners' self-reflection.

In order to enhance the reflective experience of runners, it's important to decide on an interactive artifact. One form of artifact is a dashboard, which helps people to identify trends and patterns, and guide them toward informed decisions [52]. There have been studies exploring visual feedback devices as a mean to deliver feedback to runners. The use of graphs [53], colors [54], or shapes [55] allow runner to react and understand better their running performance and technique [53] [54] [55]. Drawing is one of many instruments for developing visuals. Gamboa et al. introduced a design method called conversational composites, which enables designers to use physical mediums and layers of sketches to generate ideas, including those for dashboard design [56]. As mentioned earlier, it has been shown that dashboards shown on a screen provide benefits in facilitating self-reflection [15]. This is aligned with the proposed idea by Balasubramaniam et al. to employ a dashboard to enhance runners' reflective experience [35]. A dashboard can be designed to enable self-reflection based on runners' preferred parameters. This leads to the second sub-research question: **what is the runners' running parameters visualization preference that**

can promote their reflection?

2.3 Measuring Reflection

As previously stated, the aim of this study is to enhance runners' self-reflection activity. A dashboard is to be designed for this purpose. To assess the effectiveness of the dashboard in promoting reflection, a measurement technique should be employed to measure the quality of runners' self-reflection activity. The development of reliable self-reflection and insight measurement would provide researchers and practitioners a tool to assess metacognitive processes such as self-reflection which leads to a better understanding of how self-reflection contributes to purposeful behavior change [57]. For some time, the Private Self-Consciousness Scale (PrSCS) [58] has been often used to measure self-reflection and insight. PrSCS comprises two subscales; internal state (PrSCS-ISA) and self-reflection (PrSCS-SR). Studies showed that the items of the PrSCS-SR do not accurately capture the essence of self-reflection because PrSCS-SR has been found to correlate positively and significantly with measures of psychopathology [59]. A new measurement questionnaire, Self-Reflection and Insight Scale (SRIS), is designed to be an improvement on the PrSCS. While the PrSCS measures private self-consciousness as a single construct, the SRIS makes a distinction between self-reflection and insight as separate but related constructs. Self-reflection refers to the examination and evaluation of one's thoughts, feelings, and behavior, whereas insight refers to the clarity of understanding of one's thoughts, feelings, and behavior. The SRIS questionnaire consists of 6 items each that measure the need for self-reflection and engagement in self-reflection, and 8 items that measure insight. The complete SRIS questionnaire can be seen in figure 2.1.

Engagement in self-reflection
- I don't often think about my thoughts (R)
- I rarely spend time in self-reflection (R)
- I frequently examine my feelings
- I don't really think about why I behave in the way that I do (R)
- I frequently take time to reflect on my thoughts
- I often think about the way I feel about things

Need for self-reflection
- I am not really interested in analyzing my behavior (R)
- It is important for me to evaluate the things that I do
- I am very interested in examining what I think about
- It is important to me to try to understand what my feelings mean
- I have a definite need to understand the way that my mind works
- It is important to me to be able to understand how my thoughts arise

Insight
- I am usually aware of my thoughts
- I'm often confused about the way that I really feel about things (R)
- I usually have a very clear idea about why I've behaved in a certain way
- I'm often aware that I'm having a feeling, but I often don't quite know what it is (R)
- My behavior often puzzles me (R)
- Thinking about my thoughts makes me more confused (R)
- Often I find it difficult to make sense of the way I feel about things (R)
- I usually know why I feel the way I do

FIGURE 2.1: SRIS questionnaire [59]

Studies have explored the use of SRIS questionnaire for measuring reflection in technology context. Ford & Bryan-Kinns created Reflection in Creative Experience Questionnaire (RiCE) as a tool to assess people's reflection when using creativity-oriented technologies [60]. Based on the SRIS, Bentvelzen et al. developed the Technology-Supported Reflection Inventory (TSRI) [61]. TSRI is a scale that evaluates systems designed for supporting reflection. It has 9 items that cover three dimensions: insight, exploration and comparison. Insight dimension describes to what extent the interactive technology provides users with insights. Exploration dimension assesses the ease and pleasure of exploring personal data within the system. Comparison dimension measures the social aspect of the system that supports reflection. The complete TSRI questionnaire can be seen in figure 2.2 Measurement of self-reflection is required to determine whether the dashboard design is successful in promoting runners' reflection or not. This leads to the third sub-research question: **how effective is the dashboard design impact runners' transformative reflection?**

Insight
Q1: Using the system has led to a wake-up call to make changes in my life
Q2: As a result of using the system, I have changed how I approach things
Q3: Using the system gives me ideas on how to overcome challenges
Exploration
Q4: I enjoy exploring my data with the system
Q5: The system makes it easy to get an overview of my personal data
Q6: The system makes it easy to review my long-term personal data
Comparison
Q7: I reflect on my data in the system with others
Q8: The system helps me to discuss my data with others
Q9: The system makes me think about how my personal data relates with that of others

FIGURE 2.2: TSRI questionnaire [61]

Chapter 3

Study Design

The aim of this study is to promote transformative reflection experience for runners through the use of a dashboard design. To achieve this, the three sub-research questions that have been discussed previously are used as guidelines to design three studies which as a whole will address the main research question. The design thinking process [62] was followed to develop the dashboard: 1) empathized with runners to uncover their preferences through surveys, 2) generated ideas with runners to support design choices through sketching and movement-based design methods, 3) developed a functional prototype, and then 4) tested the prototype with runners. An overview of the study design can be seen in figure 3.1.

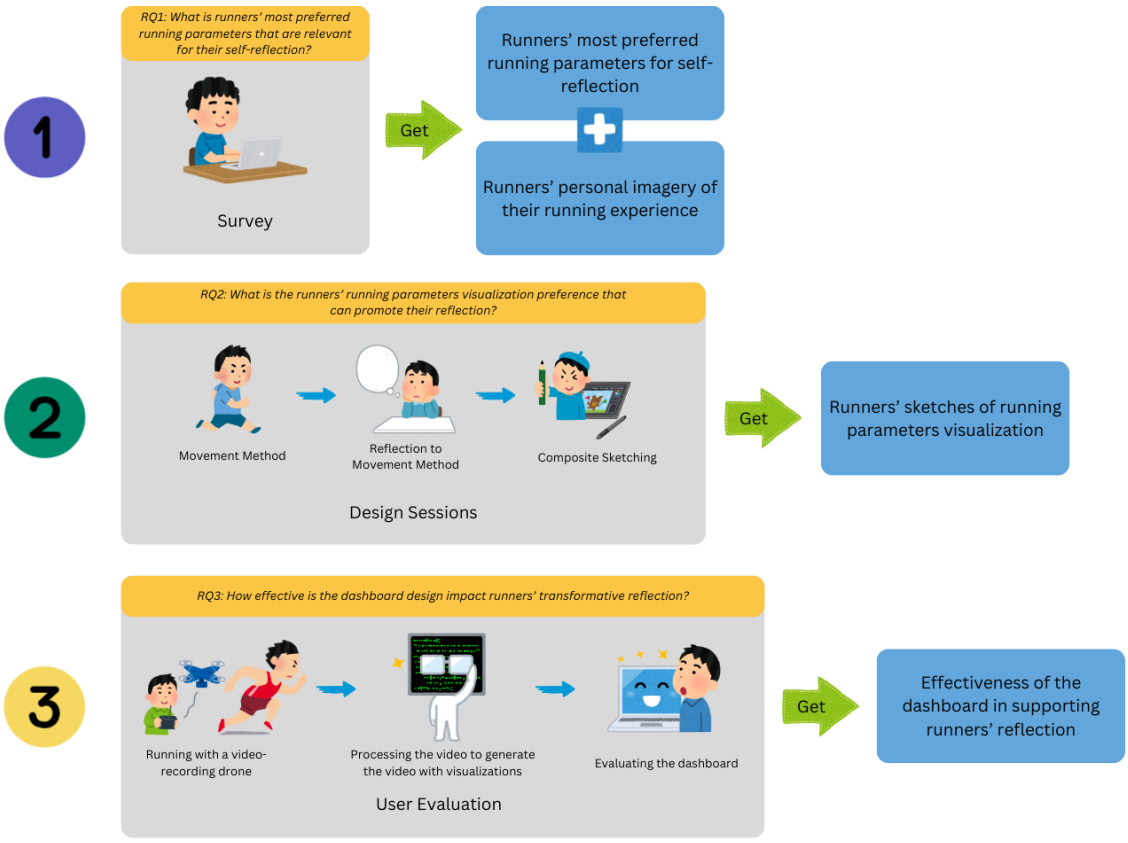

FIGURE 3.1: Overview of the study design: (1) Survey, (2) Design Sessions and (3) Evaluation. Each study activity tried to address one sub-research question.

The first study, survey, is conducted to find out runners' most preferred running parameters for self-reflection to address the first sub-research question: *what is runners' most preferred running parameters that are relevant for their self-reflection?* Three running parameters are chosen to keep the simplicity of the design solution and easy to understand by the runners. Following the first study, design sessions involving recreational runners were conducted to generate runners' design preference to support reflection to address the second sub-research question: *what is the runners' running parameters visualization preference that can promote their reflection?* Results from the design sessions are implemented into the prototyping of the dashboard. A user evaluation is then conducted using the prototype to figure out whether the design is successful in enhancing runners' reflection as the third study to address the third sub-research question: *how does the dashboard design impact runners' transformative reflection?* Each study procedures and results is explained in the following chapters.

Chapter 4

Study 1: Survey

The aim of the survey was to understand runners' running experience and most preferred running parameters in regards to their post-run reflection. The survey was conducted online. Before the survey was sent out, an ethics approval was done in accordance with the Ethics Committee Computer & Information Science at University of Twente. The following chapters will detail the survey questions used, outline the participant recruitment procedure, and discuss the results.

4.1 Survey Questions

The survey consists of four groups of questions: (1) demographics, (2) experience felt when running, (3) running parameters, and (4) visualizing running parameters. Each question is designed to get a better understanding of the participant. Demographics questions are employed to know better who the participants are, such as their age and running frequency. Questions regarding experience felt when running were useful to understand what recreational runners' felt or experienced before, during and after running. Additionally, since somaesthetic approach [51] were applied in this study, getting insights about what participants' emotions or thoughts were thought to be useful for later design exploration to promote self-reflection. Questions for visualizing running parameters were present to gather participants' preference on how they would visualize relevant running parameters that can enhance their self-reflection. The full list of questions can be seen in figure 4.1.

	Question	*Question type*	*Reasoning*
Demographics	Age	Text box	Understanding who were the participants.
	Running frequency	Single choice	
	Running app/other technology used	Multiple choice	
	Motivation for using running applications or technology	Text box	Understanding runners' motivation in using running applications or technology.
	Motivation for running	Text box	Understanding runners' motivation in running.
Experience felt when running	Emotions or thoughts before running	Text box	Soma design were incorporated by providing visual feedback related to their running parameters as a subtle guidance to direct a person's focus (Höök, 2018). By obtaining runners' emotions or thoughts, it provides insights to decide on visual feedback that are related to certain emotions or thoughts.
	Emotions or thoughts during running	Text box	
	Emotions or thoughts after running	Text box	
Running parameters	Running parameters in regards to performance	Ranking	Finding out which parameters were the most relevant in terms of performance.
	Utilization of running parameters in regards to performance	Text box	Understanding their experience of using the parameters to support performance.
	Running parameters in regards to maintain running as a habit	Ranking	Finding out which parameters were the most relevant in terms of running as a habit.
	Utilization of running parameters in regards to maintain running as a habit	Text box	Understanding their experience of using the parameters to maintain running as a habit.
Visualizing running parameters	Colors association with performance	Multiple choice	Finding out what color is most associated with achieving a performance goal. This is useful for design consideration of the dashboard.
	Colors association with keeping running as a habit	Multiple choice	Finding out what color is most associated with keeping running as a habit. This is useful for design consideration of the dashboard.
	Metaphor or visual imagery of performance	Text box	Finding out what metaphor or visual imagery that is associated with performance. This is useful for design consideration of the dashboard.
	Metaphor or visual imagery of keeping running as a habit	Text box	Finding out what metaphor or visual imagery that is associated with keeping running as a habit. This is useful for design consideration of the dashboard.

FIGURE 4.1: Survey Questions.

4.2 Participants Recruitment

Since the survey aimed to gain insights from runners, three specific criteria were established to ensure participants had sufficient running experience to provide meaningful responses: (1) be at least 18 years old, (2) be a recreational runner; run occasionally in the last 3 months, and (3) have experience in using running applications or other running technology (e.g, Strava). This information was given to all possible participants at the beginning of the survey, to make sure that they fulfill the requirements and be eligible for the survey. Convenience sampling was used for recruiting the participants for the survey. Since the survey was conducted online, the invitation was sent through online and social media channels such as emails and WhatsApp messages to minimize cost and time. The channels that received the invitation were participant recruitment for HCI research group, Interaction Technology student community and student athletics association at University of Twente.

4.3 Survey Results

The survey managed to gather responses from 30 participants, with a range of age of 20 to 39 years old (mean: 24.95, median: 24, standard deviation: 3.77). In terms of running frequency, the majority of participants run more than twice a week (40%), followed by twice a week (20%). Furthermore, Strava and Garmin Connect are the two most popular running applications or technology that is used by the participants. This result aligns with previous research indicating that sport watches remain the most popular technology for receiving information about running performance [30]. The complete result in bar chart form can be seen in figure 4.2 and figure 4.3.

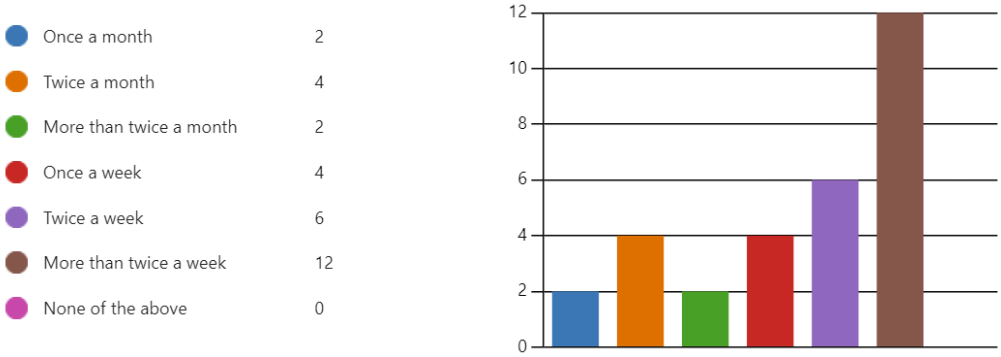

FIGURE 4.2: Running frequency from 30 participants, with more than twice a week (12) being the majority.

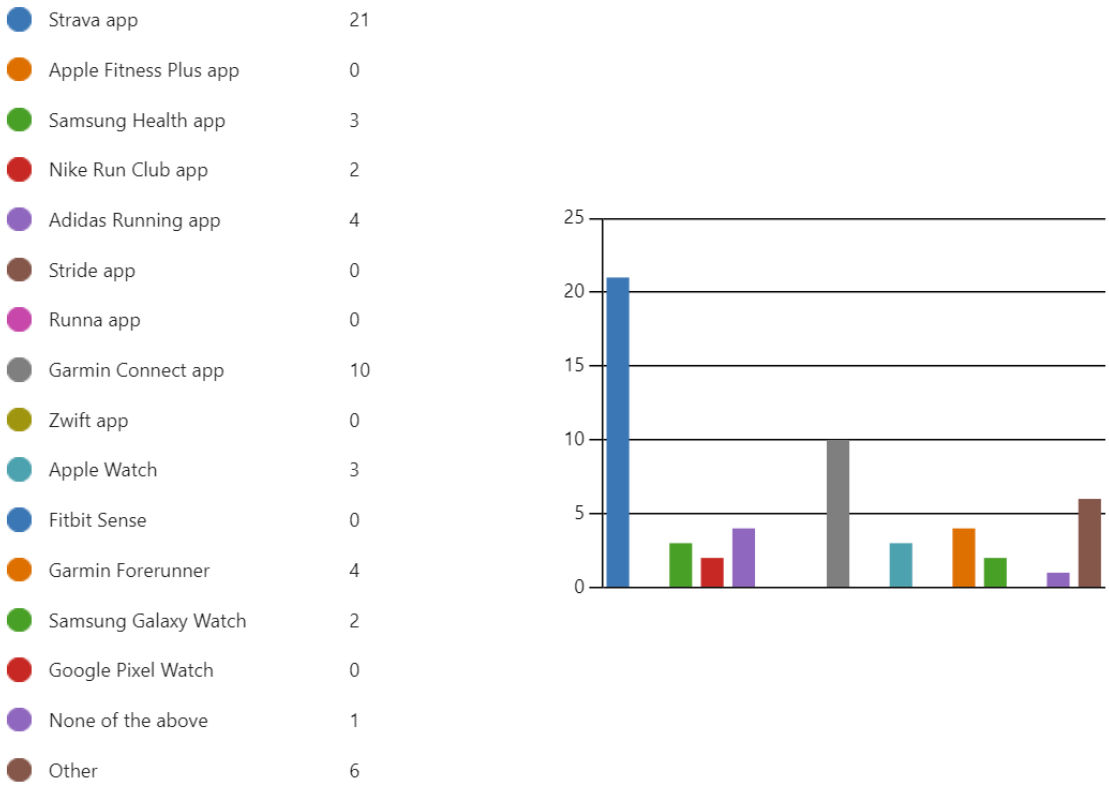

FIGURE 4.3: Running applications and technology used by 30 participants, with Strava app (21) being the most popular.

To analyze the running experience and running parameters data (refer figure 4.1 for the complete list of survey questions), a thematic analysis was conducted using Braun & Clarke's framework [63]. The thematic analysis in this study was done with an inductive (coding is done without any pre-existing coding frame), semantic (themes are identified based on the explicit meanings of the data) and realist/essentialist (theorize experience and meaning in a straightforward way) approach. Miro board was used as a tool to analyze the data. At the end of the thematic analysis, a thematic map was constructed. The thematic analysis was done by the author of this study with the steps goes as follows:

1. Generate preliminary themes
2. Review themes
3. Construct a thematic map

Each step of the thematic analysis process will be explained below.

4.3.1 Preliminary Themes

At the start of the thematic analysis, each response was placed on the Miro board as sticky notes. One sticky note represents one response. After all responses were placed, the researcher grouped them and gave each a group name. These first groups were preliminary themes. Each preliminary theme will be explained further below. To see the complete Miro board for the preliminary themes, please refer to Supplemental Material.

Runners' motivation

The survey asked two motivation-related questions to the participants: their motivation for using running applications or technology, and their motivation for running. The responses from these two questions are analyzed as a separate preliminary themes.

Motivation for using running applications or technology Five themes that encapsulate participants' motivation for using running applications or technology were formed: (1) tracking, (2) getting insights, (3) social, (4) progress and (5) guidance. It can be said that majority of participants use running applications or technology to track their run and getting insights about their run. This is aligned with prior study by Janssen et al., describing that runners used running application to monitor certain parameters, with distance, time and speed being the most popular [64].

Motivation for running Participants provided varying responses for their running motivation (figure 4.4). A total of 6 themes were created, with achieving (1) healthy condition being the most popular, followed by (2) enjoyment, (3) being in a good shape, (4) stress relief, (5) event preparation, and (6) mental training.

FIGURE 4.4: Preliminary themes of participants' motivation for running. Majority of participants expressed being healthy as their motivation.

Runners' experience

Following the motivation-related questions, participants provided responses regarding their emotions or thoughts in their running experience. These sets of questions were aimed to uncover participants' personal running experience. To get the complete picture, the questions were divided into three phases of run: before, during and after the run. For each running phase, participants provided their emotions or thoughts in the survey.

Before run Participants provided varying responses of their emotions or thoughts before they start their run (figure 4.5). The emotions or thoughts ranges from positive to negative in nature. The most popular emotions being **mixed feelings**, where participants expressed that they were excited or motivated and anxious or stressed at the same time.

FIGURE 4.5: Preliminary themes of participants' emotions or thoughts before running. Majority of participants experienced mixed feelings before running.

During run During running, majority of participants were experiencing a sense of **enjoyment**, while some are still experiencing mixed feelings. Some of the mixed feelings are caused by the physical toll that occurred because of the run, with some participants mentioned that the run is tiring or feels "heavy."

After run Participants responded on a positive note when asked about their emotions or thoughts after finishing a run. With various words to describe their positive feeling, **happiness** is the most popular emotions followed by proud and satisfaction being the emotions that the participants experienced.

Running parameters for self-reflection

The survey also gathered responses regarding recreational runners' approach in using running parameters for self-reflection. Two group of responses were analyzed based on two motivation [3] of performance or maintaining running as a habit.

Using running parameters for self-reflecting on performance Several preliminary themes were created during the analysis for participants' approach in using parameters for self-reflecting on performance. Most of the responses expressed the use of parameters to **get insights** such as heart rate, pace, or distance as a mean to self-reflection. It can be said that the responses for this question are the most unique and diverse, which makes a lot of them can't be grouped in themes (figure 4.6).

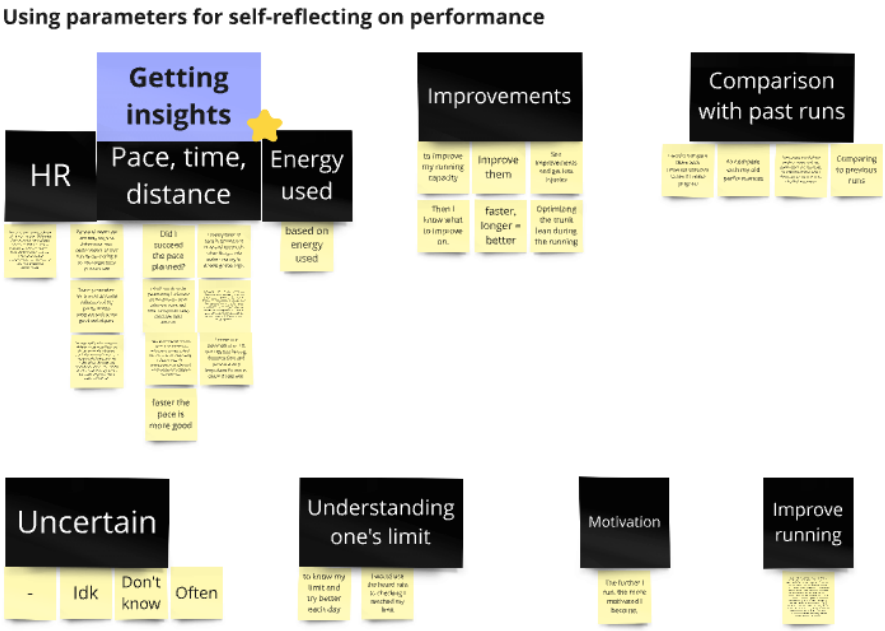

FIGURE 4.6: Preliminary themes of participants' approach in using running parameters for self-reflecting on their performance. Most participants describe as getting insights of the running data as a way to self-reflect on their performance.

Using running parameters for self-reflecting to maintain running as a habit Similar with the previous survey question, majority of participants responded about **getting insights** regarding their heart rate, pace, time and distance as a way to self-reflecting for maintaining running as a habit. Other responses are too diverse and can't be formed into bigger, more relevant themes.

Visualizing running parameters

The last set of questions tried to ask participants' personal imagery or visualization of their running experience. For consistency, the questions were also divided based on the two running motivation [3]: performance and maintaining running as a habit.

Imagery of running experience in regards to performance The responses collected for this question are highly diverse, with several preliminary themes created: (1) Animals, (2) Abstract, (3) Objects, (4) Battle, (5) Flying or floating movement, and (6) Human. It's important to note that the animal-related responses in this question might have been influenced by the framing of the survey question, which mentioned birds as an example. This could have led participants to respond in a way that directly related to the animal examples provided. This concern also applies for the next question's responses.

Imagery of running experience in regards to maintaining running as a habit Similar to the previous question, there are a big amount of themes created based on the diverse responses collected: (1) Animals, (2) Abstract, (3) Objects, (4) Selfness, (5) Human, (6) Nature, and (7) Battle. Due to the large number of themes, a review is necessary to refine and condense the existing preliminary themes.

4.3.2 Review Themes

In this next step, all the preliminary themes are re-read and reviewed by the researcher to modify and develop into more coherent and relevant themes [65]. This process leads to a new grouping or even a modified one. Each reviewed themes will be discussed below. For the complete overview of all reviewed themes on the Miro board, please see Supplemental Material.

Runners' motivation

The existing preliminary themes of motivation for using running technology and motivation for running were reviewed and then adjusted to create a more relevant and prominent themes.

Motivation for using running applications or technology After reviewing the preliminary themes, adjustments to the themes were done to describe the participants' motivation for using running applications or technology. It can be said that most participants are using running applications or other technology to receive insights about their runs by tracking and getting running data.

Motivation for running Each existing preliminary themes are grouped into two categories of running motivation: performance and maintaining running as a habit. After reviewing the themes, it can be concluded that most recreational runners' motivation are to maintain running as a habit (figure 4.7).

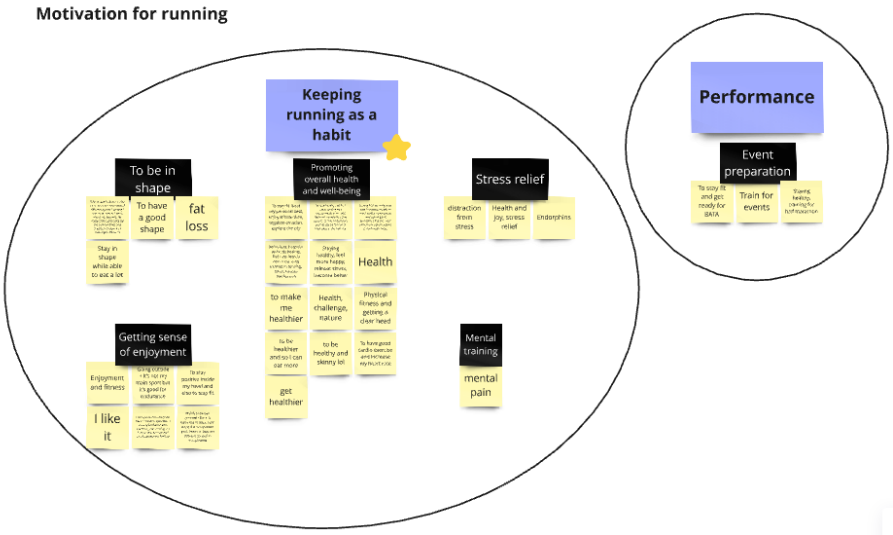

FIGURE 4.7: Reviewed themes of participants' motivation for running.

Runners' experience

As discussed in the preliminary themes phase, runners experienced mixed feelings before running, enjoyment during the run, and happiness after the run. Upon reviewing and refining these themes, the emotions before, during, and after the run remained largely unchanged. The notable exception is that happiness after the run is now grouped with other positive emotions under the broader theme of joy (figure 4.8).

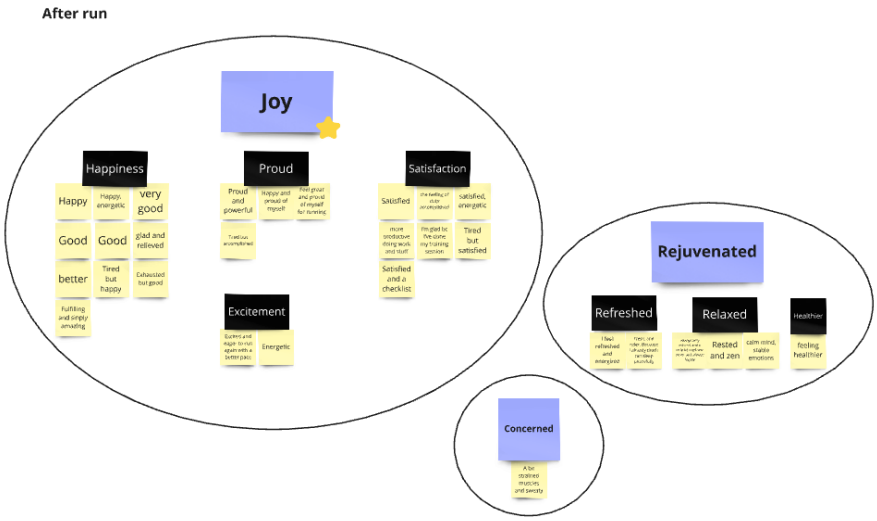

FIGURE 4.8: Reviewed themes of participants' emotions after running. A new theme of Joy is created and reworking the preliminary themes.

Running parameters for self-reflection

Similar with the previous reviewed themes, there were not many changes for themes in running parameters for self-reflection. Utilization of running parameters for both motivation (performance and maintaining running as a habit) still produced the same one big theme of getting insights of running data (e.g., distance, pace). See figure 4.9 for the new reviewed themes of using parameters for self-reflecting on performance.

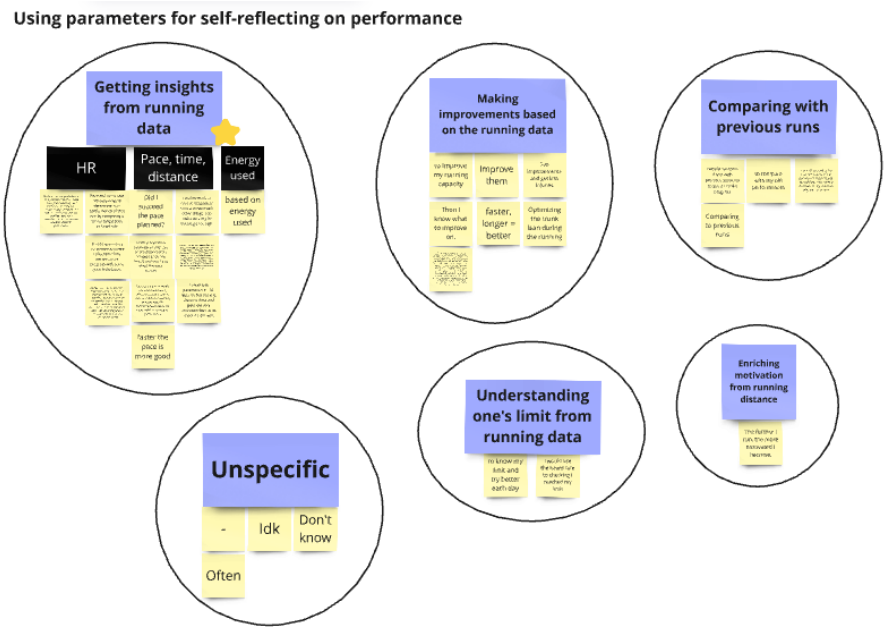

FIGURE 4.9: Reviewed themes of participants' approach in using running parameters for self-reflecting on their performance.

Visualizing running parameters

To visualize the running parameters in the context of maintaining running as a habit, the dominant theme based on the participants' preference is abstract visualization (figure 4.10). Most participants provided a broad response in terms of their running experience imagery (e.g., cool breeze, freedom, or summer). All these response are categorized within the abstract theme. This also applies for the context of performance. Other responses include animals and human objects (e.g., a drum kit, a white board). As mentioned earlier, responses regarding animals might be influenced by the framing of the survey question by mentioning birds as examples. Thus, abstract visualization is explored further in the next study as the approach to promote reflection for runners.

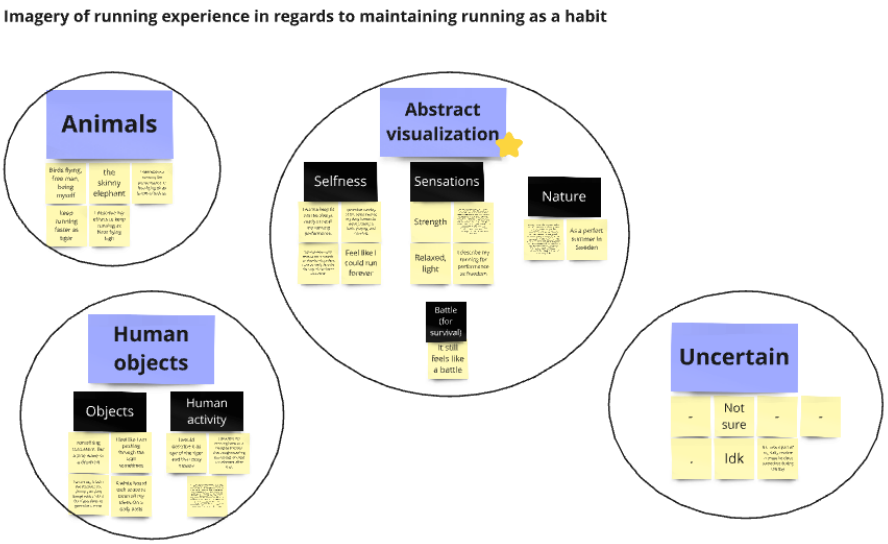

FIGURE 4.10: Reviewed themes of participants' imagery of their running experience in relation to maintaining running as a habit. Abstract visualization became the most popular theme among participants' responses after reviewing the preliminary themes.

4.3.3 Thematic Map

Having all the reviewed themes, a thematic map is then be constructed to encapsulate the participants' motivation and emotions on their running experience, and also their utilization of running parameters for self-reflection. The thematic map consists of three big themes based on running timing: pre-run, running, and post-run. Inside pre-run, runners decided to run to fulfill the motivation of keeping running as their habit, while also experiencing some mixed feelings. During running, they used running technology to track progress and collect running data while experiencing enjoyment. After the run, the self-reflection activity occur where they utilize running parameters to either compare their data to previous runs or make adjustments for future runs. Joy is the most prominent emotions of runners in this final phase. As mentioned above, abstract visualization is the most preferred visualization that depicts their running experience. Thus, an opportunity to use abstract visualization as a mean to promote self-reflection is included in the post-run phase which aligns to the goal of this study (see figure 4.11). This approach in visualization will be explored in the next study: design sessions.

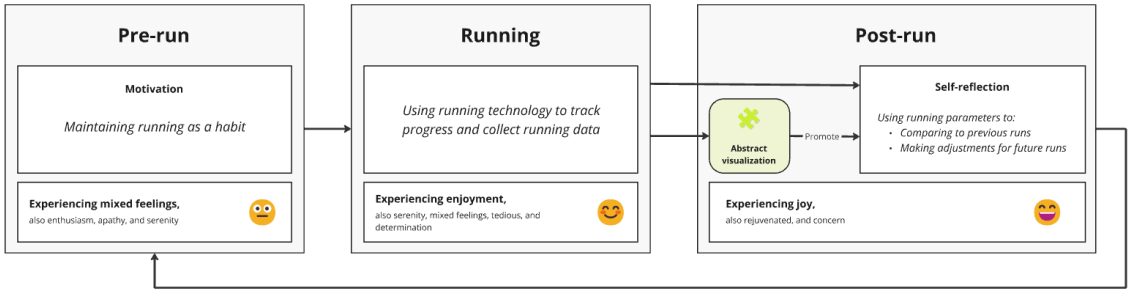

FIGURE 4.11: Thematic map for this study, constructed based on the survey results. Abstract visualization will be utilized to promote runners' self-reflection in the post-run phase.

4.3.4 Preferred running parameters

Survey results showed the four most preferred running parameters in terms of self-reflection, both in terms of performance and maintaining running as a habit, are (1) distance, (2) heart rate, (3) time, and (4) pace. This results are well-aligned with prior studies [30] [64]. Distance consistently ranked as the top parameter for self-reflection on performance and maintaining running as a habit. The full results can be seen in figure 4.12 and 4.13.

Motivational profiles

Based on the two groups of runners' motivation, there were 27 participants who aimed to maintain running as a habit (age mean: 25, median: 24, standard deviation: 3.9), and 3 participants who wanted to achieve a performance goals or training for events (age mean: 24.67, median: 23, standard deviation: 2.89). For participants who aimed to maintain running as a habit, the most popular parameters were: (1) distance, (2) time, and (3) heart rate. For participants with performance motivational profile, the most popular parameters were still the same: (1) distance, (2) pace, and (3) time. On other note, one participant within the performance group expressed that pelvic drop and trunk lean as their two most relevant parameters. Additionally, 25 participants indicated that distance was the most relevant parameter when using running applications or technology to gain insights. The remaining 5 participants, who use these applications primarily for social acknowledgment, identified time as the most relevant parameter. This preference for time was also noted by one participant who uses running technology for guidance.

This preference is understandable given the popularity of running applications like Strava, which provide users with performance-oriented information. Jensen and Mueller further confirmed this by stating current running technologies are dominated by performance-oriented metrics such as distance, pace and time [33]. Following the performance metrics, the survey showed that technique-related metrics are considerably relevant for recreational runners, such as cadence. Referring back to the study by Jensen and Muller, advancements in running technology can improve technique and form such as cadence and vertical oscillation. Another study indicates that cadence, trunk lean and pelvic drop are the three most preferred running technique parameters after distance, time and pace [35]. Given the abundance of existing performance-oriented running technologies [33] [66], the decision was made to focus on creating a dashboard that support running form and techniques. Thus, cadence, trunk lean, and pelvic drop were chosen as the primary parameters for subsequent steps in this study.

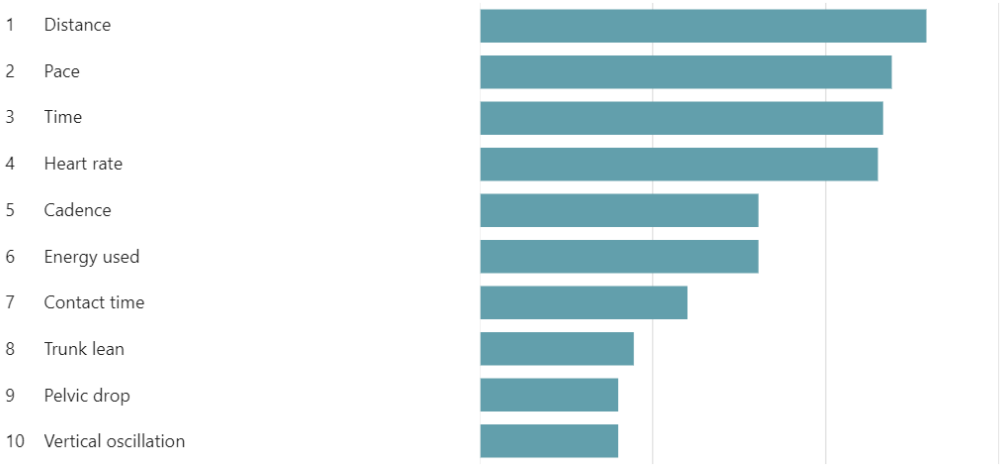

FIGURE 4.12: Recreational runners' preferred running parameters for self-reflecting on their performance.

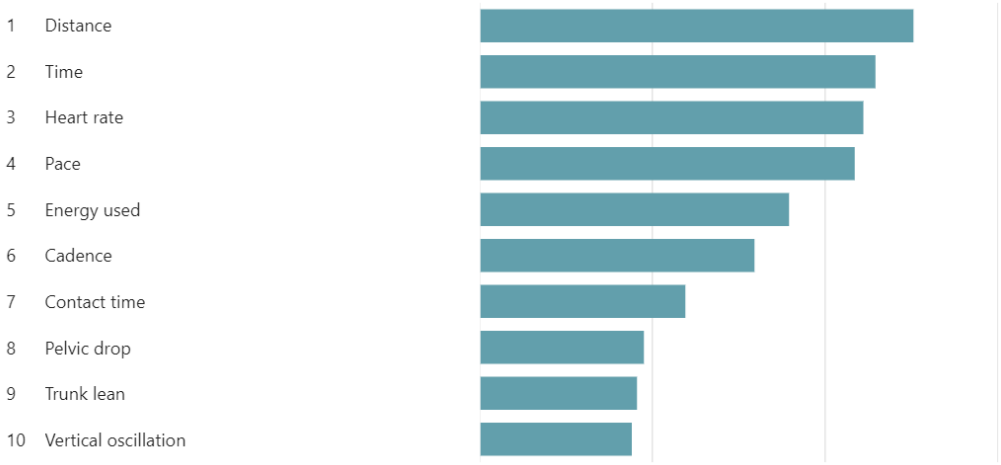

FIGURE 4.13: Recreational runners' preferred running parameters for self-reflecting to maintain running as a habit.

4.3.5 Color associations

When asked about colors that participants associate most strongly to running experience in terms of performance or maintaining running as a habit, results showed that red and green were equally the most popular colors (figure 4.14). This is aligned with existing research regarding the use of red and green in color psychology [67] [68].

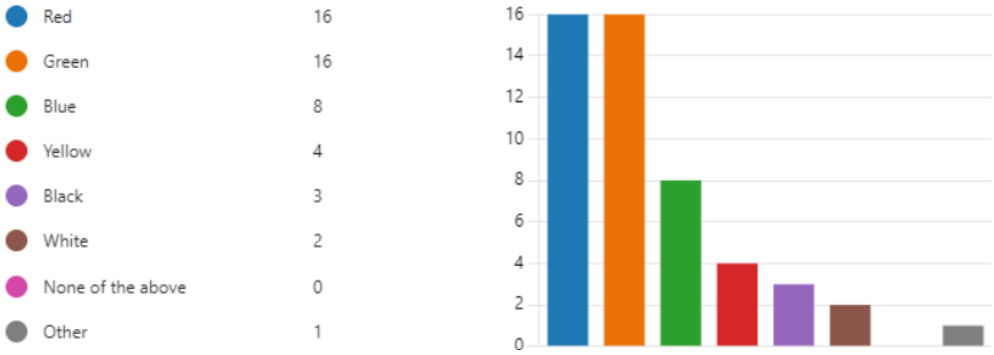

FIGURE 4.14: Recreational runners' colors associations in regards to their running experience.

4.3.6 Conclusion

The survey managed to address the first research question: *what is runners' most preferred running parameters that are relevant for their self-reflection?* with cadence, trunk lean and pelvic drop being the three relevant running technique parameters. Additionally, survey indicated that abstract visualization are recreational runners' most preferred imagery of their running experience. Acknowledging there might be some responses that were influenced by the framing of the question, the survey might be improved by avoiding the use of examples to not lead participants' responses. These information regarding parameters and abstract visualization acted as subjects for the next study. The design session is explained in the next chapter.

Chapter 5

Study 2: Design Session

Following the survey, the top three parameters (cadence, trunk lean, and pelvic drop) were to be visualized in the second study. Design sessions were conducted to explore the visualization of running parameters, drawing on both recreational runners' preferences and existing studies that highlight the underexplored aspects of running technique parameters. The sessions took into account the somaesthetics approach [43] and established design toolkit [69]. Recreational runners were recruited and go through several stages of the design session, including: movement-based design method, reflection to movement-based design method and composite sketching. In general, the design session involved participants running with modifiers for a short period of time, followed by a reflection activity to the run, and sketching running parameter visualization. The results from the design sessions were used to develop a low fidelity prototype by the author of this study.

5.1 Participants Recruitment

The design session involved participants who are recreational runners. There are several criterias to be eligible for participants. These criterias are made with alignment from the previous survey demographics (see 4.3), which indicates that the recreational runners are (1) within the 20-39 years old, (2) run occasionally in the last 3 months prior to the study, (3) have a motivation to maintain running as their habit, and (4) have experience in using running applications or other running technology.

To gather the participants, several recruitment methods are done: (1) contacting voluntary participants from the survey study, (2) convenience sampling, and (3) voluntary invitation to running associations or other groups through social media channels.

5.2 Procedure

The design sessions were conducted 1-on-1 with the researcher in an indoor setting, and took around 35-45 minutes per session. The session consists of three stages: (1) movement-based design method, (2) reflection to movement-based design method, and (3) composite sketching. The movement-based design method phase is video recorded, while the sketching activity is audio recorded. Each phase will be explained in more detail in the following sections. Furthermore, the participants were provided with drinks (water and isotonic powder), sketching tools, study information sheets and consent forms. The study was done in accordance with the Ethics Committee Computer & Information Science at University of Twente.

Stage 1: Movement-Based Design Method

As mentioned earlier, this phase was inspired by an established design toolkit named MecaMind [69]. MeCaMInD is a toolbox for designers that consists of various activities to design movement experiences. The activities within the MeCaMInD toolbox are constructed to direct participants to move actively. The toolbox also comes with different modifiers that can be used to tweak the focus of movement such as speed and direction.

For this design session, the chosen MeCaMInD activity was Daily Movements. The goal of the Daily Movements activity was to provide participants with a first-person perspective and the felt sensations of the running movement. This is aligned with the somaesthetics approach [43], which previous research has proven it can assist design ideation phase [44]. In this activity, the participants were asked to run for 4 minutes in a circle pattern and to focus on experience and the feel of their body during running. All the participants' runs were video recorded. During the run, there were modifiers applied in accordance to the three chosen running parameters: cadence, trunk lean and pelvic drop (see 4.3.4). Each modifier was created to provide an experience to participants where the specific running parameters are affected [69]. The aim of these modifiers was to "make the familiar strange" by introducing variations to the routine activity of running. For the cadence modifier, participants were asked to run with short and long steps to affect their steps per minute. This was followed by the second modifier where participants ran with their torso leaning forward to affect the trunk lean. Participants were also asked to run while exaggerating moving left or right of their body, or with a "wobbly" movement as a modifier for the pelvic drop. Within the 4 minutes running activity, there is a 30 seconds interval between one modifier to the next. The details of the modifiers' timing can be seen in table 5.1.

TABLE 5.1: Modifiers' timing during the movement-based design method.

Time	Modifiers
0:00 - 0:59	No modifiers
1:00 - 1:29	Run with short steps
1:30 - 1:59	Run with long steps
2:00 - 2:29	No modifiers
2:30 - 2:59	Run leaning forwards
3:00 - 3:29	No modifiers
3:30 - 4:00	Run with wobbly movement

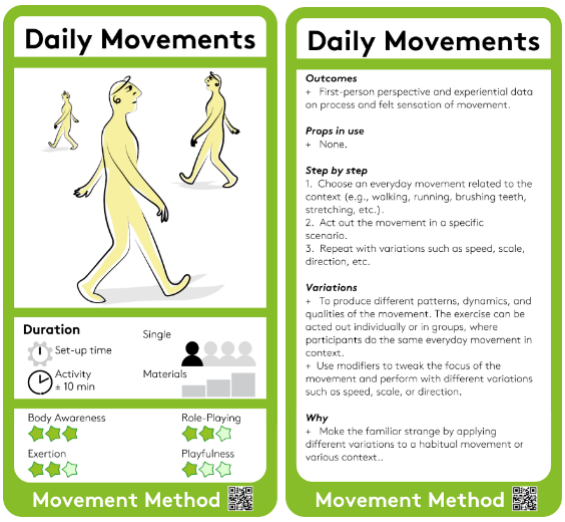

FIGURE 5.1: Daily Movements as the chosen MeCaMInD [69] activity and the first phase of the design session.

Stage 2: Reflection to Movement-Based Design Method

After the running activity, the participant sat down and was asked to reflect on the running. A reflection sheet was created to help the participant reflect, which can be seen in figure 5.2. The reflection sheet acted as a tool to let participants write down their feelings and body sensations that they experienced during running normally and running with modifiers. The aim of this phase was to understand participants' experience on the running activity, while also providing an opportunity for them to look back on their running and connect their experience to emotions and physical sensations. Since the next activity involved participants drawing sketches, this reflection exercise is beneficial as part of the somaesthetics approach [46] [51]. It allowed them to experience the feeling and sensation of self-reflection firsthand.

	Feelings/Emotions	Body sensations
Running normally		
Running with short steps		
Running with long steps		
Running leaning forwards		
Running with wobbly movement		

FIGURE 5.2: Reflection to Movement-Based Design Method sheet.

Stage 3: Composite Sketching

A study conducted by Gamboa et al. introduced conversational composites, a flexible sketching method using multiple physical and digital layers as a conversation technique between participants [56]. The study showed that conversational composites provide a subjective and nuanced approach to design. This became the inspiration for the method used in this study named composite sketching. Instead of using multiple layers to enable conversation between participants, this method uses multiple layers to convey ideas from the participants on their visualization preference regarding the running parameters. Figure 5.3 is an illustration on how the multiple layers worked in this method. The first layer (layer 0) is a screenshot from the video footage of participants' running during movement based design method, the second layer (layer 1) is where participants will sketch their running parameter preferred visualization, and the last layer (layer 2) is their desired dashboard interaction.

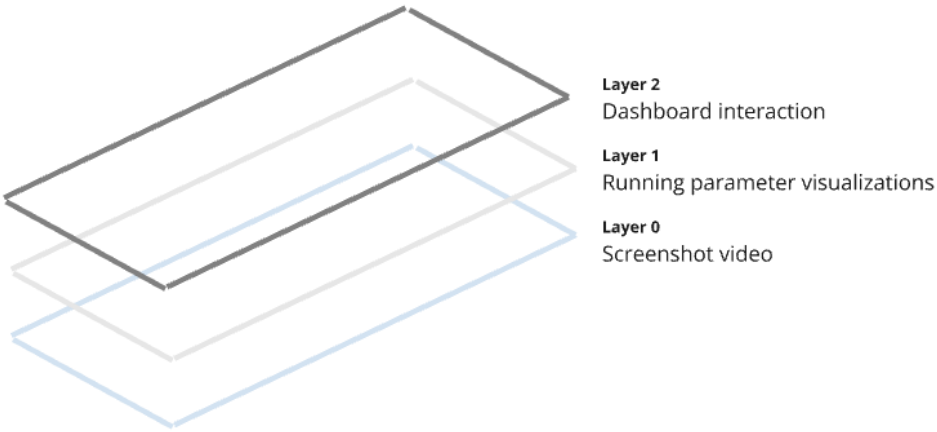

FIGURE 5.3: The composite sketching resulted in three layers: screenshot of the running video, running parameter visualizations and dashboard interaction.

In this phase, the participants were explained first about the running parameters that inspired the modifiers in the previous running activity. The aim of this explanation is to let the participants have a better comprehension about the three parameters: cadence, trunk lean and pelvic drop, before delving into sketching visualizations. Information card about the three parameters is shown and placed on the table to let the participants have the information necessary in the whole sketching activity (see Supplemental Material). The table setup of the sketching can be seen in figure 5.4. The sketching is conducted digitally with an iPad and an Apple Pencil, using Adobe Fresco.

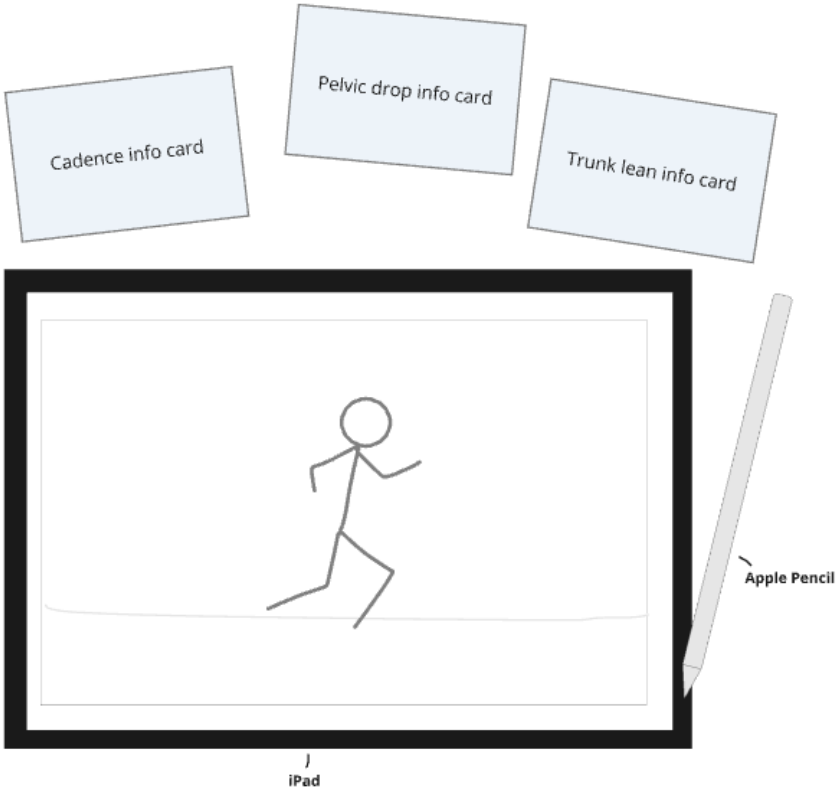

FIGURE 5.4: Participants' view during composite sketching.

The researcher then brought up the previous study that showed abstract visualization as recreational runners' preferred imagery of their running experience (see 4.3.3) and let the participant use this information as their choice of visualization. A definition from Prangsma et al. was used to explain the concept to the participants: abstract visualizations is a way to show information using visual elements such as colors or shapes whose meaning is based on convention, and does not resemble tangible objects [70]. During sketching, there were guiding questions that are used to help participants in coming up with their visualization sketches. The questions can be seen in table 5.2.

TABLE 5.2: Guiding questions during composite sketching.

Running parameters visualizations	
Q1	If the video can show you visual feedback for the three parameters, would you prefer to have one combined visualization for all three parameters or one visualization for each one parameter? Why?
Q2	What kind of visualization would you like to see when the parameters are optimal? You may draw multiple variations. Please describe the reasoning behind your drawing. *Follow-up questions:* Is it abstract enough? How would you make this more abstract?
Q3	What kind of visualization would you like to see when there's something not optimal regarding the parameters? You may draw multiple variations. Please describe the reasoning behind your drawing. *Follow-up questions:* Is it abstract enough? How would you make this more abstract?
Q4	How will the transition of the visualization be from optimal to not optimal state and vice versa? Please describe it.
Q5	Where is the location of this visualization should be within the video? Why?
Dashboard interaction	
Q6	Now I want to ask about the interaction with the video. Let's say the video is interactive. If there's any interactive features in the video that would be helpful to your reflection, what would it be? Why?
Q7	What kind of interaction do you want to be available with running data or parameters? Why?

This final phase resulted in personal and unique sketches from each participant regarding their preference in receiving visual information about cadence, trunk lean and pelvic drop. All data and sketching from participants were analyzed and discussed below.

5.3 Design Session Results

The design sessions were conducted with 7 participants (4 females, 3 males) with all of them meeting the existing criteria of (1) be 20-39 years old, (2) run occasionally in the last 3 months prior to the study, (3) have experience in using running application or technology, and (4) have a desire to maintain running as a habit.

5.3.1 Reflection to Movement-Based Design Method

The reflection to movement-based design method phase in the design session showed that participants experienced various emotions and body sensations for each modifier. A thematic analysis is conducted to analyze participants' response on the reflection sheet (refer figure 5.2). Each response collected from the reflection sheet is grouped into themes. Thematic analysis showed that participants experienced different emotions and body sensations during five different modifiers in the running activity. For the complete overview of the themes, please see Supplemental Material. In terms of emotions, the participants experienced enthusiasm during normal run, enjoyment during running with short steps, uneasiness and enthusiasm during running with long steps, uneasiness during running leaning forwards, and uneasiness during running with wobbly movement. Furthermore, the participants experienced various physical sensations: body invigoration during normal run, body relaxation with rising body tension during running with short steps, fatigue and physical

discomfort during running with long steps, fatigue and heavy physical toll during running leaning forwards, and fatigue and losing balance during running with wobbly movement.

To encapsulate the participants' reflection, a participant journey map is created as an overview of every emotions and body sensations that were experienced (figure 5.5). From the map, there is a visible shift from positive to more negative emotions as participants experience the modifiers. This may be influenced by the long run duration in the later modifiers (pelvic drop), which made participants more fatigued and uncomfortable, compared to the earlier modifiers (cadence). Hence, an effect order bias [71] exists since the order of the modifiers might affect how participants' emotions and body sensations.

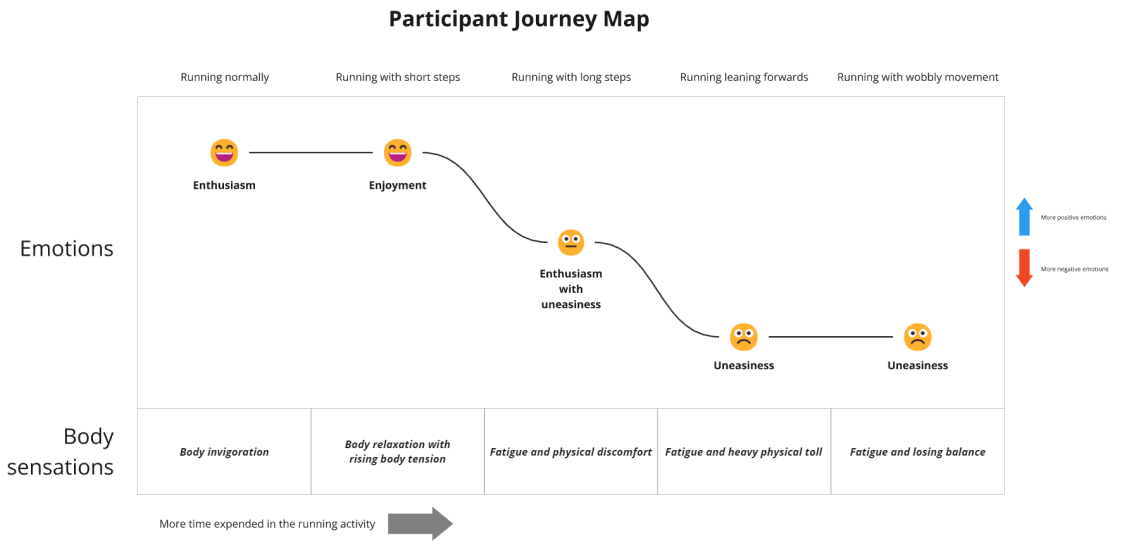

FIGURE 5.5: Participant journey map during the running activity in the design session.

5.3.2 Composite Sketches

During composite sketching phase, there were several abstract visualizations produced that depict participants' preferred way on running parameters visualization. To analyze them, the main takeaways are noted down for each sketch. Miro board was used for the whole analysis process. An example of this analysis process can be seen in figure 5.6. This note-taking process resulted in themes of visual elements that were used by the participants. The two big themes are (1) basic elements and (2) interactive elements.

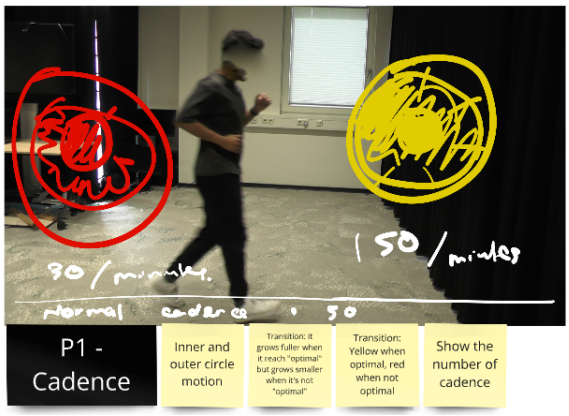

FIGURE 5.6: In each sketch analysis, all the takeaways are noted down to determine existing elements. This participant drew two circles indicating two states of his cadence: red when it's less optimal and yellow when it's optimal. He also indicated that the circle grows smaller or larger based on the reading of the cadence, with additional information (cadence number) displayed just below the visualization. All participants sketches can be seen in the Supplemental Material.

Basic Elements

Two basic elements were present across all participants sketches: colors and shapes, as means to convey information. In regards to colors, majority of participants use the color green to indicate "optimal" situation (figure 5.7), and the color red to indicate "not optimal" situation. One participant prefer the use of lighter colors to indicate "optimal" condition for the running parameters. This is aligned with existing studies that have explored the use of color green to indicate positive performance [68] and color red to indicate danger [67]. In terms of shapes, majority of participants depict their visualizations with two-dimensional shapes and human skeleton or silhouette. During the activity, human skeleton or silhouette is a popular initial approach among the participants before getting prompted to sketch in a more abstract manner, which led to the use of two-dimensional shapes. Additionally, one participant drew everyday objects (e.g., bottle of water) as their way to visualize information about running parameters.

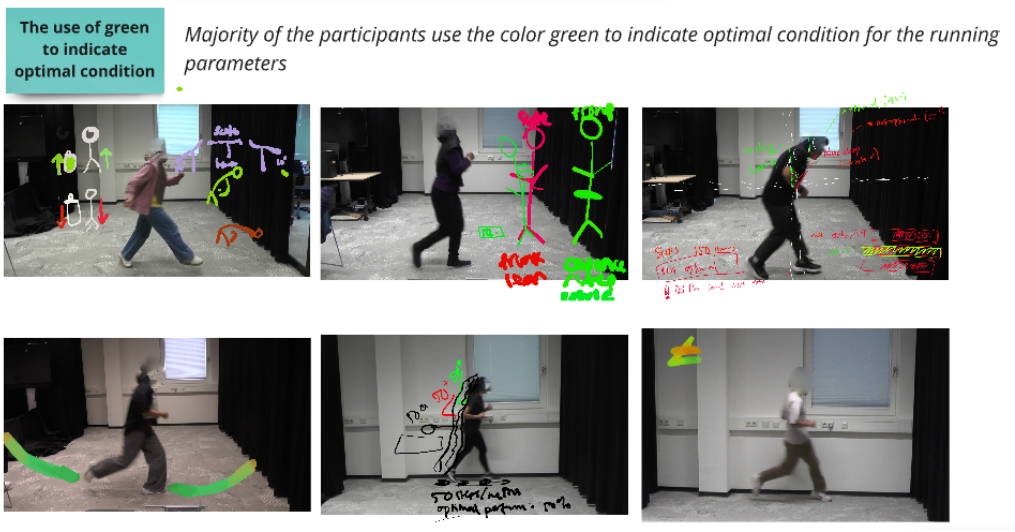

FIGURE 5.7: Despite the varying sketches that participants generated, almost all of them were using the color green to indicate "optimal" condition of the parameters. All participants sketches can be seen in the Supplemental Material.

Interactive Elements

Majority of participants describes their visualizations as interactive shapes that provide real-time information in correspondence to the video, whether they depict optimal or non-optimal conditions regarding the parameters. Since the use of colors were dominant, the participants add color-changing aspect as an interactive element to indicate optimal and not optimal condition within the running video. In other words, the visualizations will change its color based on the condition of the runner in the video. Additionally, to make the transition of conditions more prominent, some participants used shapeshifting approach to indicate changes in the parameters (figure 5.8). An example of this is the use of a fill in or fill out transition to indicate optimal and non-optimal parameters. The more full the shape is, the more optimal the parameter. To see the complete picture of the visual elements analysis, please refer to Supplemental Material.

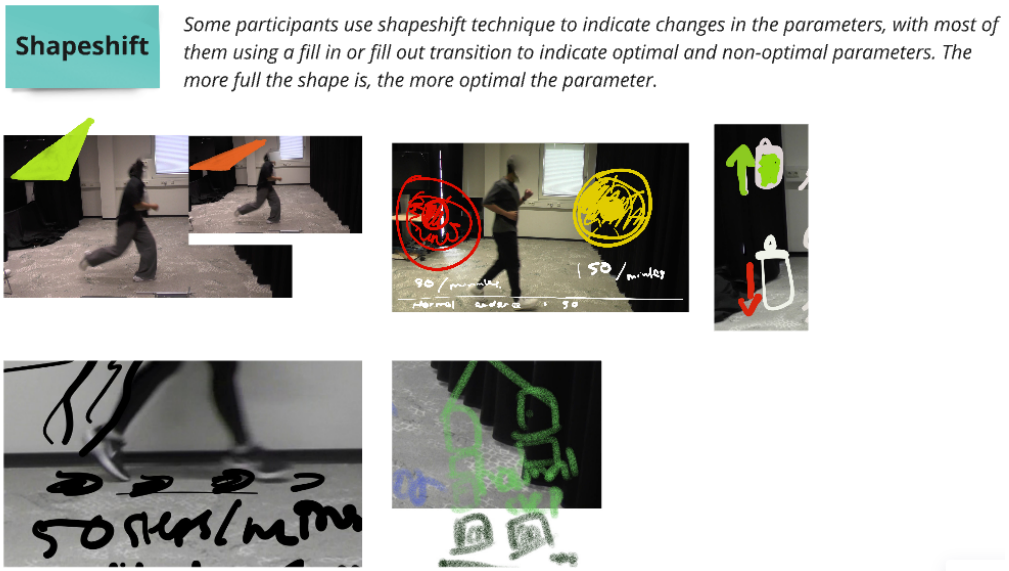

FIGURE 5.8: Shapeshifting is a prominent element in most of participants sketches, where the shape will react in a certain way to convey information about changes in the parameters. Examples being a circle that grows smaller or bigger depending on the cadence, and a triangle that tilts to right depending on the trunk lean. All participants sketches can be seen in the Supplemental Material.

5.3.3 Emotion Mapping

Looking at the participant journey map and composite sketch analysis, a connection is made between the participants' emotions and their sketches to find meaningful insights before getting started into dashboard ideation. There are three common connections that are made: (1) enthusiasm with the color green, (2) enjoyment, enthusiasm and uneasiness with a shapeshifting shape that gets fill in or out, and (3) uneasiness with the color red. The connection between colors and emotions aligns with existing studies, which show that certain colors tend to be associated with positive or negative emotions [72]. Furthermore, uneasiness caused by body leaning forwards excessively is associated with a line-shaped sketch getting excessively more tilted to the right in while uneasiness caused by exaggeratedly moving left or right (pelvic drop) is depicted with a shape moving out of balance. The full emotion mapping can be seen in figure 5.9.

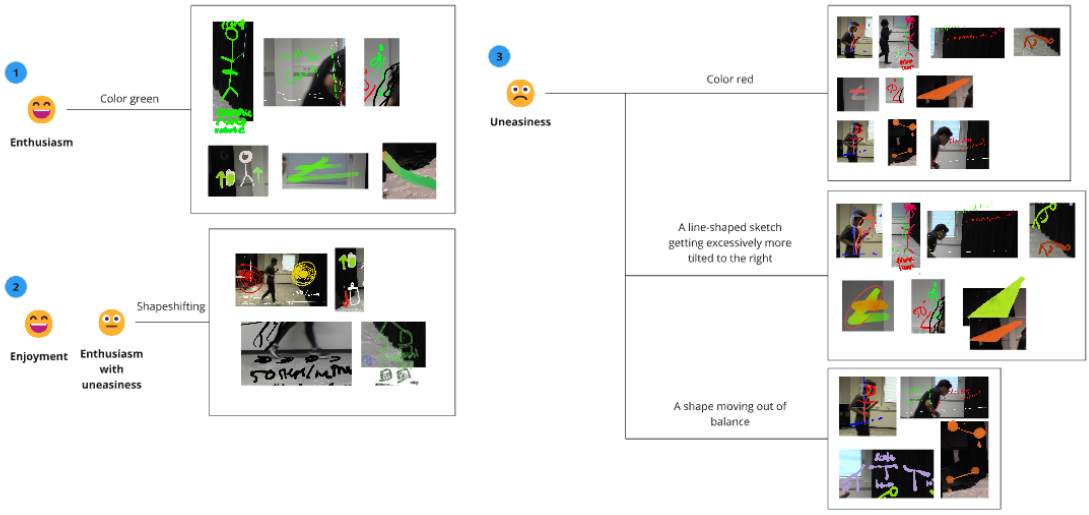

FIGURE 5.9: Emotion mapping: (1) The enthusiasm when running normally without any excessive movement is depicted with the color green, (2) The enjoyment, enthusiasm and uneasiness when cadence is affected is depicted with a shapeshifting shape that gets fill in or out, depending on the situation, (3) Top: The uneasiness caused by body leaning forwards excessively (trunk lean) and exaggeratedly moving left or right (pelvic drop) is associated as color red by participants; Middle: The uneasiness caused by body leaning forwards excessively (trunk lean) is visualized with a line-shaped sketch getting excessively more tilted to the right; Bottom: The uneasiness caused by exaggeratedly moving left or right (pelvic drop) is depicted with a shape moving out of balance.

5.3.4 Visualizations Location and Other Features

Participants were asked where the visualizations should be placed within the dashboard, with the top left corner being the most popular choice. Other suggested positions included the right side of the video and layered over the person. In addition to sketching running parameters, participants were asked to sketch their desired interactions with the dashboard to support their reflection. Popular features included descriptive text and video playback controls. Examples of descriptive text included cadence numbers, angle measurements, and tips for improving running. The video playback features participants favored included play, pause, and 10-second skip buttons. Other recommendations included a personal reflection form, video tutorial suggestions, and timeline highlights to indicate non-optimal conditions.

5.3.5 Conclusion

Looking at the design sessions, there were improvements that can be done with one suggestion is to have the modifiers randomized during the movement-design based method to avoid effect order bias [71]. While the composite sketching utilize a digital tablet which provide convenience, it might also be interesting to use physical medium instead (e.g., paper and water color) to enable more dimensions in the sketches that aren't possible in the digital form, such as different artistic expression of the participants [56]. The design session results revealed that runners' visualization preference in receiving information about their cadence, trunk lean and pelvic drop is two-dimensional shapes with color-changing

and shapeshifting features. Participants' perceive green to indicate optimal parameter, and red to show non-optimal parameter. Furthermore, each parameter is represented with one distinct shape that shifts based on the situation of the corresponding parameter. This information is used for developing visualizations within the functional prototype, which will be explained in the following chapter.

Chapter 6

Creating the Prototype

6.1 Low Fidelity Prototype

After conducting the analysis of all design session results, a low fidelity dashboard based on participants' preference is created (figure 6.1). The dashboard used all the basic and interactive elements introduced in the design session analysis. Each chosen parameter (cadence, trunk lean and pelvic drop) is represented by a distinct two-dimensional shape. Cadence is visualized with a circle, trunk lean with a triangle and pelvic drop with a rectangle. Additionally, all shapes have the same color-changing feature, with green indicating optimal condition, red indicating not optimal condition and yellow to depict in-between states. All the shapes are placed at the top left corner of the dashboard and within the video, in accordance to the participants' sketches.

Cadence Based on the design session results, majority of participants depict cadence with a circle-like shape that grows smaller or bigger. Thus, a circle is used to visualize the cadence within the video. The circle will turn red and have a small radius when the cadence is not optimal, and turn green and have a large radius when the cadence is optimal.

Trunk Lean The decision to use triangle is based on the design session results with participants' sketches produced a two-dimensional shapes depicting a certain angle to visualize trunk lean. The triangle will turn red when it's not optimal, and turn green when it's optimal. The triangle's top point moves based on the trunk lean; the more it tilts, the less optimal the trunk lean.

Pelvic Drop As per the design session results indicated, participants depict their pelvic movement with a horizontal line or a rectangle-like shape that moves based on their pelvic. The rectangle will shake to mimic pelvic movement running; the more shaky it is, the least optimal the pelvic drop. It will turn green when there's no pelvic drop, and it will turn red when there's a significant pelvic drop.

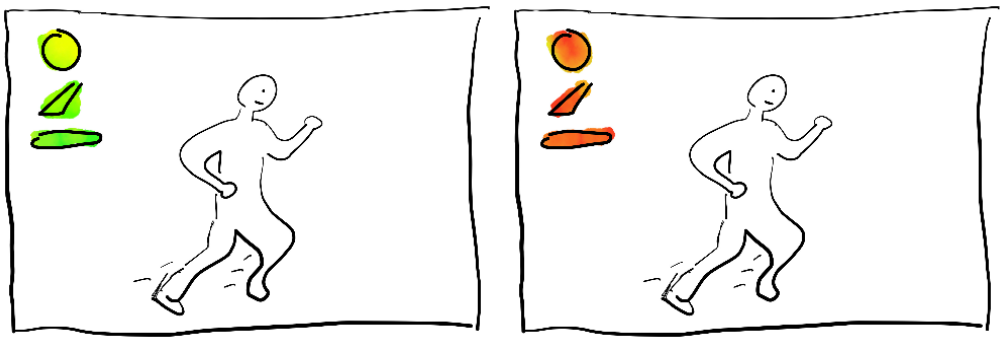

FIGURE 6.1: Three two-dimensional shapes are positioned at the top left corner of the video, each representing a different parameter: a circle for cadence, a triangle for trunk lean, and a rectangle for pelvic drop. Each shape features color-changing and shapeshifting properties. The shapes turn green when their corresponding parameter is optimal and red when it is not. The circle's radius expands or contracts based on cadence, with a larger radius indicating more optimal cadence. The top point of the triangle tilts left or right according to trunk lean, while the rectangle rotates in response to hip movement.

6.2 Functional Prototype

To create a functional dashboard prototype, MoveNet Lightning model was used to estimate human pose from a video. A Python program was created which employ the model to read and store the body keypoints of the person within the video, and using the keypoints the program is then able to calculate angles and position of certain body parts. These calculation results is then compared to specific numbers to determine whether the parameters were "optimal" or "less optimal" [73] [74] [75]. The information of whether the parameters are optimal or not were used to determine the animation (e.g., when it's optimal the shape will turn green). Overview of the process generating video with visualizations can be seen in figure 6.2, while a screenshot of the final video with the visualizations can be seen in figure 6.6.

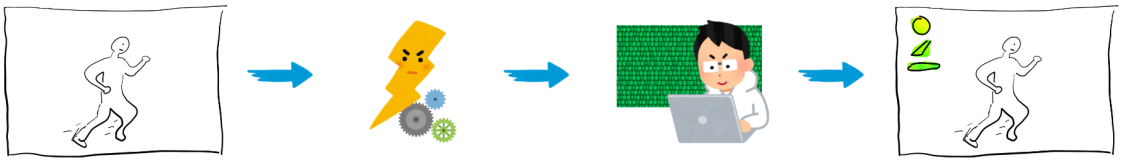

FIGURE 6.2: Overview of the process to generate the video with visualizations. (1) Drone video footage from Balasubramaniam's study is collected and used to be processed, (2) MoveNet Lightning process the video and store the body keypoints of the person in the video, (3) The program then calculates certain angles and positions from body keypoints to get the person's cadence, trunk lean and pelvic drop, (4) The cadence, trunk lean and pelvic drop is then visualized on the top left corner of the video.

6.2.1 Cadence

Three keypoints were used to calculate the angle of the runner's leg: left hip, left knee and left ankle. The cadence, or steps per minute, was determined by measuring the time elapsed for a single step. This involved two detections: (1) the angle of the leg from a straight position to a bent position and back to straight, with a threshold of 170-180 degrees used to determine if the leg is straight, and (2) the y-position of the left ankle. A step was counted if the leg moved from straight to bent and back to straight, while the y-position during the bend was higher than the y-position when straight. The program will then calculate the elapsed time for that runners' to produce one step (e.g., 0.9 seconds/step). To get the steps per minute, another calculation of 60 divided by the elapsed time is done. This calculation is then used to animate the circle, with a threshold of 160 steps per minute indicating optimal cadence [73], and anything below 160 representing less optimal (figure 6.3).

FIGURE 6.3: A visualization of cadence represented with a circle. Left: When cadence is optimal, the circle is green and large. Right: When cadence is not optimal, the circle is red and small.

6.2.2 Trunk Lean

Compared to cadence, calculating trunk lean was relatively straightforward as it only requires determining the angle of the upper body. The program detects three keypoints: the left shoulder, left hip, and left knee. The angle formed by these keypoints is then visualized with a triangle. A threshold of more than 15 degrees for the upper body angle is used to indicate suboptimal trunk lean [74]. Specifically, the triangle will turn red and tilt to the right if the trunk lean exceeds 15 degrees (figure 6.4).

FIGURE 6.4: A visualization of trunk lean represented with a triangle. Left: When trunk lean is optimal, the triangle is green and straight. Right: When trunk lean is not optimal, the triangle is red and tilt to the right.

6.2.3 Pelvic Drop

For pelvic drop, the keypoints of the left hip and right hip are used to visualize the pelvic movement of the runners. A threshold of more than a 10-degree angle [75] was set to determine suboptimal pelvic drop. If the pelvic angle exceeds 10 degrees to either the left or right, the rectangle will rotate significantly and turn red to indicate this less optimal condition (figure 6.5).

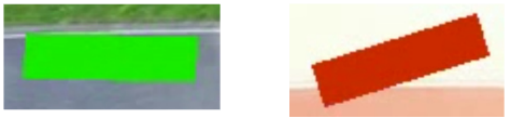

FIGURE 6.5: A visualization of pelvic drop with a rectangle. Left: When there is no pelvic drop, the rectangle is green and straight. Right: When there is a significant pelvic drop, the rectangle is red and rotated to the left or right; depends on the actual hips reading.

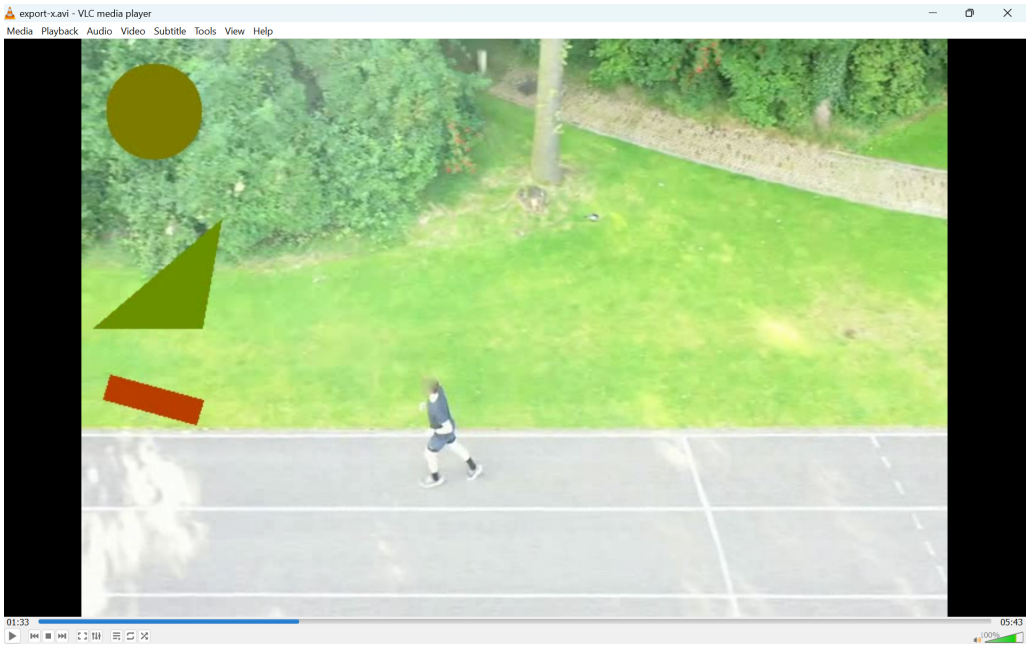

FIGURE 6.6: A screenshot of the video with visualizations. Circle represents cadence, triangle represents trunk lean, and rectangle represents pelvic movement. Each shape has distinct animations: the circle's radius adjusts to reflect the runner's cadence, the triangle tilts left or right based on trunk lean, and the rectangle rotates slightly in response to pelvic movement. Additionally, the colors of the shapes change to indicate parameter status: green for optimal and red for non-optimal.

Chapter 7

Study 3: User Evaluation

This dashboard prototype was evaluated to find out how it impacts runners' self-reflection experience. The evaluation was a within-subjects study, where each participant experienced two variations of the dashboard. The two variations of the dashboard were (A) video only, and (B) video with visualizations. The dashboard variations acted as independent variables, while transformative reflection became the dependent variable. For both version, VLC media player was used to view and play the video. A likert scale questionnaire was created and distributed for participants to measure their experience on reflection with and without the presence of the visualizations. Although techniques such as SRIS [59] provide a possibility to measure a person's self-reflection, it doesn't directly correlate to measurement of reflection within the running context. The TSRI questionnaire is deemed suitable for this study, since it evaluates HCI technologies designed for reflection [61]. Thus, a modified TSRI questionnaire was used, incorporating dimensions of insight and exploration while omitting the comparison dimension, to better address the aspects of post-run self-reflection. Open-ended questions are also used to gather qualitative feedback regarding the dashboard and their reflection.

7.1 Participants Recruitment

The recruitment methods for this study were consistent with those used in previous research, including (1) convenience sampling and (2) voluntary invitations to associations and other groups. No specific participant criteria were set to maximize the number of participants.

7.2 Procedure

Each user evaluation was conducted individually with the researcher(s) outdoors at UTrack University of Twente. Each session took around 40-60 minutes. On an important note, this evaluation study was conducted hand-in-hand with Balasubramaniam's study, where drone video data from his study was used as material to be processed within the dashboard to show running parameters visualizations. The evaluation itself was conducted straight after the participants were finished with Balasubramaniam's study. All participants received healthy snacks and drinks, study information sheet and consent form. Figure provides an overview of the user evaluation activities. The study was done in accordance with the Ethics Committee Computer & Information Science at University of Twente.

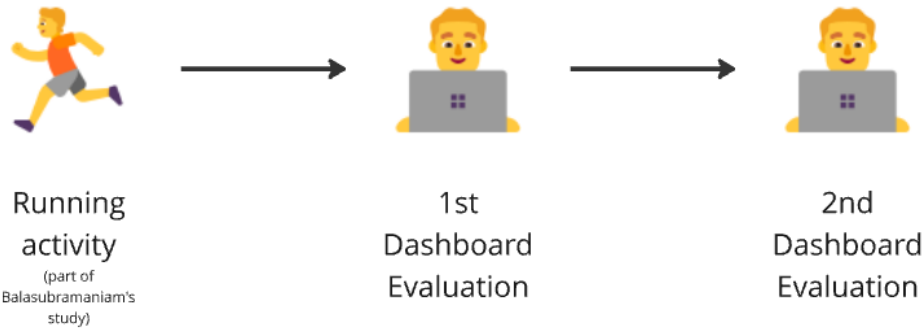

FIGURE 7.1: Overview of the user evaluation. (1) Participants ran with a video-recording drone, (2) interacted and evaluate the first version of dashboard, and then (3) interacted and evaluate the second version of dashboard.

Phase 1: Balasubramaniam's Study (Running Activity)

As mentioned earlier, the user evaluation study was conducted hand-in-hand with Balasubramaniam's study, where in his study a running activity with a drone is conducted. This is a continuation of Balasubramaniam's study regarding the use of drones in supporting running activities as pacesetters and video recorders [19]. This activity requires the participants to run with a drone acting as a guide, while it also capturing video of the run. The participants are asked to run for two full laps of the track (a total of around 800 meters) with the drone going at a speed of 10 kilometers per hour, while also having the option to withdraw from the run at any given time. After the run, participants were offered healthy snacks and drinks. The drone video footage was processed to generate abstract visuals for the prototype, which participants then interacted with and evaluated.

Phase 2: Dashboard Evaluation

After completing the running activity, participants were faced with one of the dashboard variation: (A) video only, or (B) video with visualizations. The order of which participant gets which variation first was randomized to avoid effect order bias [71]. The dashboard used during this evaluation study was VLC media player which provides participant to play, pause, timeline scrubbing, and other playback features. For video with visualizations, the researcher explained the meaning behind the visualizations beforehand to provide more context so that the participants were not entering the interaction blindly. To evaluate both versions, a modified TSRI [61] questionnaire form were used (see table 7.1). The form includes the insight dimension to assess the effectiveness the dashboard provides users with insights, and the exploration dimension to evaluate the ease and enjoyment of exploring personal data within the dashboard [76]. The comparison dimension is excluded as the dashboard focuses on self-reflection and does not enable reflection through social engagement. This TSRI form are handed to the participant, and after they were asked to provide answers to open-ended questions. The open-ended questions can be seen in table 7.2. These questions aimed to gather more insights about how participants perceived the dashboard and how it affected their reflection. The responses from these open-ended questions were audio recorded. After completing the first dashboard variation, participants

TABLE 7.1: The modified TSRI questionnaire form with 7-point Likert scale, with 1 being strongly disagree and 7 being strongly agree. The wording of "video (only/with visualizations)" in each item depends on which dashboard variation the participants are currently evaluating. If the participant is currently evaluating dashboard version B, the item will shown as "video with visualizations".

Insight							
Using the video (only/with visualizations) has led to a wake-up call to make changes in my running	1	2	3	4	5	6	7
As a result of using the video (only/with visualizations), I have changed how I approach things	1	2	3	4	5	6	7
Using the video (only/with visualizations) gives me ideas on how to overcome challenges	1	2	3	4	5	6	7
Exploration							
I enjoy exploring my running data with the video (only/with visualizations)	1	2	3	4	5	6	7
The video (only/with visualizations) makes it easy to get an overview of my running data	1	2	3	4	5	6	7
The video (only/with visualizations) makes it easy to review my long-term running data	1	2	3	4	5	6	7

TABLE 7.2: Open-ended questions during evaluation study.

Q1	What is your overall impression about the video (only/with the visualizations)?
Q2	What have you learned about your running that you didn't know before from interacting with the video (only/with the visualizations)?
Q3	How do you think that exploring the video (only/with the visualizations) has affected or will affect your approach to running?
Q4	Having interacted with the video, are there any actions you might take to improve or change your next run?
Q5	What areas of the video would you change or improve to support your reflection?

proceeded to the other version, interact with it, and then also filled out the modified TSRI form and answer the same open-ended questions.

7.3 Evaluation Results

A total of 15 participants (5 females, 10 males) were recruited for the dashboard evaluation. The age range from 23 to 47 years old (mean: 28.07, median: 26, standard deviation: 6.28). Four participants didn't have any prior running experience, while the rest had varying experience starting from 1 to 12 years of running experience. For participants who had running experience, the frequency of their run is between 1 to 5 times per week prior to the study. Each participant shared their unique motivations for running, which were categorized into two categories [3]: maintaining running as a habit and improving or achieving a performance goal. Eleven participants aimed to maintain running as a habit, while four participants ran to improve or achieve a performance goal. Additionally, 13 out of 15 participants have used running application or technology before with smartwatch being the most popular technology (10 participants). It is important to note that during the study, the first four participants interacted with a "dummy" prototype of the video

with visualizations. Due to technical limitations, the visualizations were not generated from actual readings and processing of body keypoints of the first four participants; instead, they used random animations. All responses from those four participants were still included in the analysis.

7.3.1 Technology-Supported Reflection Inventory

Looking at the insight dimension, participants reported an average (median) score of 12.33 (13) out of 21 for the video only version and an average (median) score of 15.13 (17) out of 21 for video with visualizations. This suggests that participants were able to gain more insights into their running using video with visualizations than video only. For exploration dimension, participants reported an average (median) score of 14.33 (15) out of 21 for the video only version and an average (median) score of 15.13 (16) out of 21 for video with visualizations. This implies that the video with visualizations were more enjoyable to explore for the participants when compared to video only. See figure 7.2 for the complete look at Technology-Supported Reflection Inventory results in box plot.

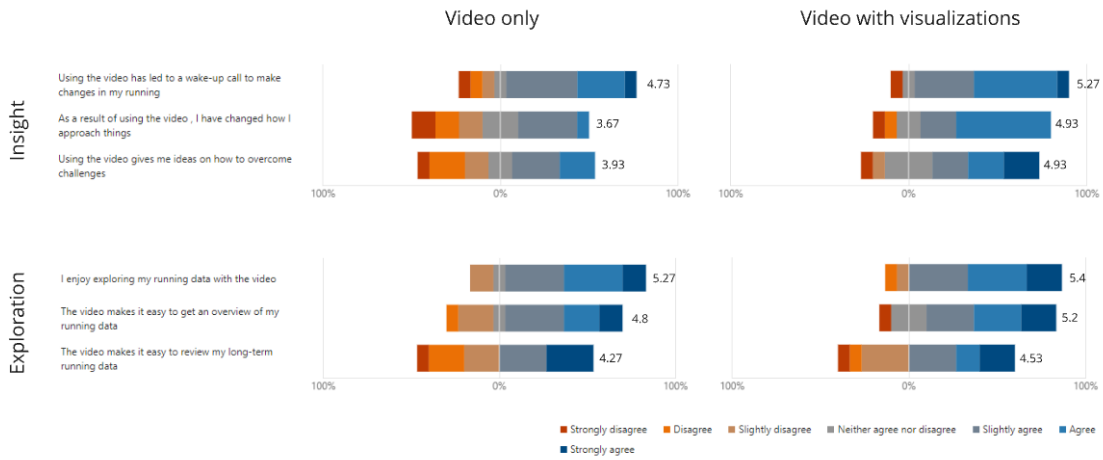

FIGURE 7.2: Modified Technology-Supported Reflection Inventory results from 15 participant. The results showed the insight and exploration dimension for two dashboard variation: video only and video with visualizations. Each item was scored on a 7-point Likert scale. Each horizontal bar contains responses for 15 participants, with average values displayed on the right of each bar.

7.3.2 Open-Ended Questions

Overall Impression

To elaborate more into participants' TSRI responses, open-ended questions were employed to get more insights on how the two dashboard variations are perceived by them. When asked about the overall impression about the video only version, the majority of the participants express enjoyment while interacting with the video: *"It was actually fun to to be able to watch myself running from that point of view because I never had the experience. And I could get a lot from it because I could see my posture that needs improvement -P13."*; *"I like that it can help you look at your running technique a little bit, and you can notice things and try to adjust them the next time you run -P6."*. While the majority of participants expressed enjoyment, a small number reported feeling bored when interacting

with the video-only version: *"Boring, because it's just me running and I don't get any feedback -P7."*; *"Just a video. So I think there's nothing interesting just to see myself on the video -P14."*. One participant also brought up that they feel the video only version lacks some information. For the video with visualizations, majority of participants expressed enjoyment as well after interacting with the video: *"The video is more interesting, with the visualizations I could see that there were some variations in how I ran -P5."*; *"Having the video is fun because you can see yourself and having the shapes makes it more appealing because you have something to look at -P12."*. In addition to enjoyment, some participants provided comments about the insightfulness of the visualizations: *"I think I really like the video with visualization. It gives you more reflections and it gives you some information that is objective, even though it's not that accurate -P8."*, but also the feeling of confusion: *"A little bit confusing because while I know what the visualizations represent I was not really sure how to Mapped them or interpreted them to the video that was next to It. So in general, a little bit confused -P15."*

Insight Dimension

Majority of participants expressed that they learn something new about their running techniques by interacting with the video with visualizations. Since the visualizations showed information regarding their cadence, trunk lean and pelvic drop, it's highly probable that this is the reason why they brought up running techniques as insights that they received: *"I was talking about my posture before, that my posture was slightly off so that might be something to improve I wasn't really aware of that before But with the visualization it became more clear -P13."*; *"Steps per minute, trunk and hip movement information are really new to me. In running, I think you're supposed to do it in a certain way, and the visualizations helped in a way to create a better form for me -P9."* This correlates to R2 dialogic reflection level [25], where runners reach the cycle of interpretation and consideration. While this also applies for video only version, there were some participants who commented interacting with video without visualizations does not provide anything insightful: *"Not really (learned something new) because there's actually no information -P14"*. This could be attributed to the sequence in which Participant 14 interacted with the dashboard. Specifically, they first engaged with the video with visualizations, which they found informative about their running technique.

Exploration Dimension

In regards to exploration, most participants expressed that both versions of the dashboard affected them by making them more aware about their running techniques. In the case of video with visualizations, some participants brought up that they are now eager to understand running techniques better: *"I think it will help improve my running one way or another. Of course, I will still need to look for more information on how I can improve myself, but I think the video is a good starting point -P5."*

Future Actions

When asked about actions that they might take to improve or change their running after interacting the video only version, eight participants commented that they don't have any future actions planned for their next run. This is different for the case when they were asked after interacting with the video with visualizations, with five of them expressed they want to adjust their running technique: *"I will try to remember what I've shown in this*

video and maybe just make myself (upper body) keep neutral -P11."; *"Maybe because the rectangle is more of a representation of the hip and I was first focusing on looking at my knees because I knew that was something I wanted to do. I could say that improving my knees could also have to do with how I position my hips during the run -P15."*, and three participants expressed they want to look up resources to understand running techniques better: *"I think I'll definitely browse the Internet to see and look at ways on how I can improve. ... In the future, I will try to look for more information and knowledge on how to run more properly -P5."*; *"Yeah, I think I will try to research more the better or the best form for running -P9."* This indicates the video with visualizations is able to help runners' gain a new perspective for them to make adjustments in the next run. This aligns with stage 3 of Atkins and Murphy's stages of reflection [26], where participants plan to make adjustments for their future runs, equivalent to the R3 transformative reflection level [25].

7.3.3 Effect of Dashboard Version Order on Participant Responses

As mentioned earlier, the evaluation was a within-subject study where participants interacted with two versions of dashboard: (A) video only, and (B) video with visualizations. The order of which version the participants received first was randomized to avoid effect order bias [71]. The following sections analyze how participants' responses to each version may differ based on the order in which they experienced the versions.

Group 1: Video only first

Participants who interacted with the video only version first provided comments on how the video is enjoyable to interact and provide new perspective which they rarely encounter: *"It's nice to see yourself running from a third point of view. I've never had that so it was good to see -P15."*. This is changed when they interacted with the video with visualizations, where majority of them found it interesting and found meanings from the visualizations. In terms of insight, both version provide the participants to look at their running technique and posture but for version B, some participants claimed that the visualizations have confirmed their thoughts that they have during the interaction with version A. While version A provides them the realization to make adjustments on their run and motivates them to run more, some participants felt the visualizations within version B directly pointed out specific aspect of their run that they need to adjust.

Group 2: Video with visualizations first

For participants who interacted with version B first, the pattern was more pronounced, as they found the video only version to offer little added value. When asked regarding insight or future actions after interacting with version A, most of them provided a very short response of "No" indicating that they didn't gain any insights or plans. Some participants even mentioned that after the interacting with the video with visualizations, it is boring to interact with the video only version: *"I think it's just a normal video ... it's just a boring video because I don't know there are changes and there's less interaction -P10."* Additionally there were two participants indicating that the visualizations weren't able to offer anything for them: *"I think the shapes didn't really make a change in what I had as feedback from the video -P12."*, although retrospectively P12 mentioned later that having the visualizations make it more fun because they have something to look at.

7.3.4 Participants' Improvements to Video with Visualizations

Nine participants provided remarks about adding extra information to the already existing visualizations as an improvement: *"It would be good to see what the parameters are, maybe with an actual value next to it -P4."*; *"If there are numbers (for the parameters), I think it's also useful for us to see how exactly the numbers look like -P14."*; *"A written explanation for example what it means when the triangle bends -P9."*; *"I think for in the beginning we can give more explicit explanation about the difference between colors, and then the triangle movement (and so on) to connect between the experience and the videos result -P10."* This suggests the need for numerical data and textual information alongside the parameter visuals to make them clearer for runners. Furthermore, there were some demands on a feature within the video to have an interactive overview of the recorded run where participants can click see a summarized data of their run and select on certain highlights of the run to look at: *"I think something like an average or an overview overtime would have been nice -P6."*; *"It would be nice to have a graph (overall view) and you can click on highlights -P4."*; *"Summary of in which minutes I did well and which minutes I did not do well -P5."* Other remarks include displaying performance data (e.g., speed, distance) within the video, and human-shaped visualization (e.g., stickman) instead of two-dimensional shapes.

7.3.5 Conclusion

The user evaluation indicated that the video with visualizations provided more insights and enjoyable experience compared to the video only version. The video with visualizations gathered higher score for all insight and exploration aspect in the modified TSRI form, and received more positive comments from the participants in regards to insights gained and future actions planned. This showed that the visualizations helped all participants reached R2 dialogic reflection level during the interaction, with some even reached R3 transformative reflection level [25].

Chapter 8

Discussion

This study is conducted to explore possibilities in promoting transformative reflection for runners using a dashboard design. To achieve this, multiple studies were, conducted including survey, design sessions and user evaluation with each study provides its own distinct sub-research question. The survey aimed to answers the first sub-research question: *what is runners' most preferred running parameters that are relevant for their self-reflection?* Results indicated that distance, pace, and time were the three most popular parameters. However, acknowledging the limited focus on technologies supporting running techniques [33], this study chose three technique parameters instead: cadence, trunk lean and pelvic drop. This decision aligns with another study identifying these as the most relevant running technique parameters [35]. Survey results also provided participants' personal experience during three phases of run, with mixed feelings being the prominent emotions before the run, enjoyment during the run, and joy after the run. Previous research has highlighted the existence of running emotions and how it influence the running experience [77]. In addition to the parameters, survey revealed that abstract visualization was the preferred method to depict participants' running experiences. Based on these findings, a thematic map (figure 4.11) was developed which highlights the contribution of this study to use abstract visualization that depict cadence, trunk lean and pelvic drop to promote runners' self-reflection in their post-run phase.

After deciding on the parameters, design sessions were conducted to address the second sub-research question: *what is the runners' running parameters visualization preference that can promote their reflection?* Composite sketching, inspired by existing conversational composites method [56], was employed where multiple layers of sketch were used to convey participants' ideas of parameters visualization. Somaesthetics approach [43] was implemented in this study to let participants felt the experience body sensations and movements before sketching. The design sessions resulted in two categories of visual elements being used to depict the parameters: basic elements and interactive elements. Most participants sketched two-dimensional shapes (e.g., circle, rectangle) and used green color to depict optimal parameter, while red color depicts non-optimal parameter. This is aligned with the existing color psychology studies with green is correlated to positive meaning, while red is correlated to negative meaning [67] [68]. For interactive elements, most participants visualized color-changing, shapeshifting shapes that react based on the runners' form.

These insights formed the foundation for the low-fidelity prototype. After understanding runners' visualization preference, a functional prototype was created using MoveNet Lightning model to enable human pose estimation and a simple Python program to generate the visualizations within the video. To address the third and final sub-research question:

how effective is the dashboard design impact runners' transformative reflection?, this prototype was evaluated in a within-subjects study where participants interacted with two dashboard versions: (A) video only, and (B) video with visualizations. To determine the effectiveness of each dashboard version in promoting self-reflection, a modified TSRI [61] form, including insight and exploration dimensions, was used. Additionally, open-ended questions were employed to better understand how the dashboard influenced participants' reflections and whether it had implications for their future efforts. This correlates with the study's original goal of promoting transformative reflection.

The user evaluation results showed that videos with abstract visualizations support better reflection compared to videos only, providing better insights and more enjoyable exploration. General impression towards the video with visualizations was positive, with most participants finding it enjoyable and insightful, though a small number of participants expressed confusion towards the visualizations. According to the three stages of reflection from Atkins and Murphy [26], all participants reach the stage 1 and 2 of noticing and understanding. This is equivalent to reaching R2 dialogic reflection level [25] where interpretation and consideration of explanations occur. For participants to achieve transformative reflection, the understanding that gained from the video with visualizations must lead to a new perspective and insights, enabling them to reorganize their future run. When asked about future actions, participants responded more positively after watching the video with visualizations. Some of them planned to adjust their running techniques or seek resources to better understand running techniques. Thus, it can be said that visualizations helped promote better transformative reflection.

Based on all the studies conducted, the author of this study proposes three suggestions for designers aimed to support runners' transformative reflection:

Focus on running technique parameters: This study showed that running performance parameters (e.g., pace, distance, time) are still the most prominent information that runners found relevant to them, which aligned with previous research is aligned with existing studies [30]. Acknowledging there has been a lot of existing technologies focusing on performance parameters, there is a lack of focus to support running technique parameters [33]. This study demonstrated that focusing on running technique parameters, combined with video technology, offers a new perspective for runners. This approach helps them gain insights, leading to improved self-reflection. Although this study chose cadence, trunk lean and pelvic drop as the visualization subjects, designers could consider other running technique parameters to be explored further such as vertical oscillation or contact time.

The use of abstract visualization: Based on participants' responses, this study proposes the use of abstract concept as the approach to visualize running parameters. Given that running is a personal experience that varies from one individual to another, the use of abstract visualization allows runners to conceive information in their own interpretation. This study suggests the use of simple two-dimensional shapes to convey information for runners, though it encourages designers to explore other approaches, such as incorporating three-dimensional shapes to enhance self-reflection. Additionally, this study recommends incorporating colors to further enrich runners' self-reflection. This is aligned with previous research regarding color psychology and emotions [67] [72]. Although this study prominently used the color green and red, designers are implored to experiment with a broader color palette to explore other alternative colors.

Incorporating interactive elements: Participants indicated that having visualizations with interactive features is crucial for providing a meaningful experience. This study proposes incorporating color-changing and shapeshifting features that act as live feedback during their run; in other words, the visualization should react dynamically based on the running parameters. For example, the colors could change from green to indicate "good" performance and red to indicate "bad" performance, and shapes like circles could grow or shrink accordingly. These interactive elements enable runners to interpret the interaction and correlate it with their runs. Furthermore, it is encouraged to explore other interactions beyond these examples, allowing for creativity and personalization based on individual preferences. For instance, during design sessions, one runner depicted their running experience as a weight scale, suggesting a visualization where the scale becomes balanced or unbalanced based on certain parameters. Designers are encouraged to explore various interactive elements to further enrich runners' self-reflection and support diverse interpretations of their running experience.

Reflecting on the study activities, there were areas that can be improved. Survey results regarding personal imagery of running experience could be framed better without mentioning examples to avoid leading the participants to adjust their responses based on the examples provided. During the design sessions, an apparent order bias in the sequence of modifiers (cadence, trunk lean, then pelvic drop) likely influenced a trend of shifting emotions from positive to negative as participants experienced the later modifiers. This issue could be addressed by randomizing the order of the modifiers. For the prototype, MoveNet Lightning was used for its fast human pose estimation. While time efficiency comes as its strength, MoveNet Lightning is less accurate compared to other models such as MoveNet Thunder or OpenPose. An improved prototype using a more accurate model could lead to a better self-reflection. While using specific thresholds [73] [74] [75] to determine optimal parameters can be effective, it might be more beneficial for the model to train and learn the runner's personal parameters first before assessing the optimality of their current run. This personalized approach could be a valuable improvement for the program in future research. During the evaluation study, drone video footage was used to capture participants' runs from a high angle. Since the model aims to read keypoints of hip, ankle, and shoulder, a high camera angle might not be the best condition to achieve this. Specifically for pelvic movement, it might be more accurate to gather keypoints by reading a video footage taken from frontside view of a person instead of sideview. Additionally, conducting the study in a public place introduced the potential for other people to appear in the frame, creating noise and affecting the model's accuracy in reading keypoints. This could be mitigated by using more personalized approach of the camera angles (e.g., same-level angle) and more controlled environment with no bystanders, reducing unnecessary noises. Furthermore, the measurement of transformative reflection effectiveness was done through open-ended questions. To better quantify runners' transformative reflection levels, exploring alternative, more quantifiable approaches would be beneficial.

Chapter 9

Conclusion

In conclusion, this project devised an approach to promote transformative self-reflection through a dashboard design. The study engaged recreational runners to determine relevant running parameters and running experience imagery through survey, and visualization preferences of the dashboard through composite sketching. This process resulted in a dashboard design that includes drone video footage of a runner accompanied by two-dimensional, interactive visualizations depicting cadence, trunk lean, and pelvic drop. By interacting with the video and its visualizations after running, participants reported gaining insight and enjoyment. They also noted that the video with visualizations offered them an opportunity to make adjustments for future runs, leading to improved transformative reflection. Future studies can explore additional visualization alternatives and consider other running technique parameters to further enhance the self-reflection experience.

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Supplemental Material

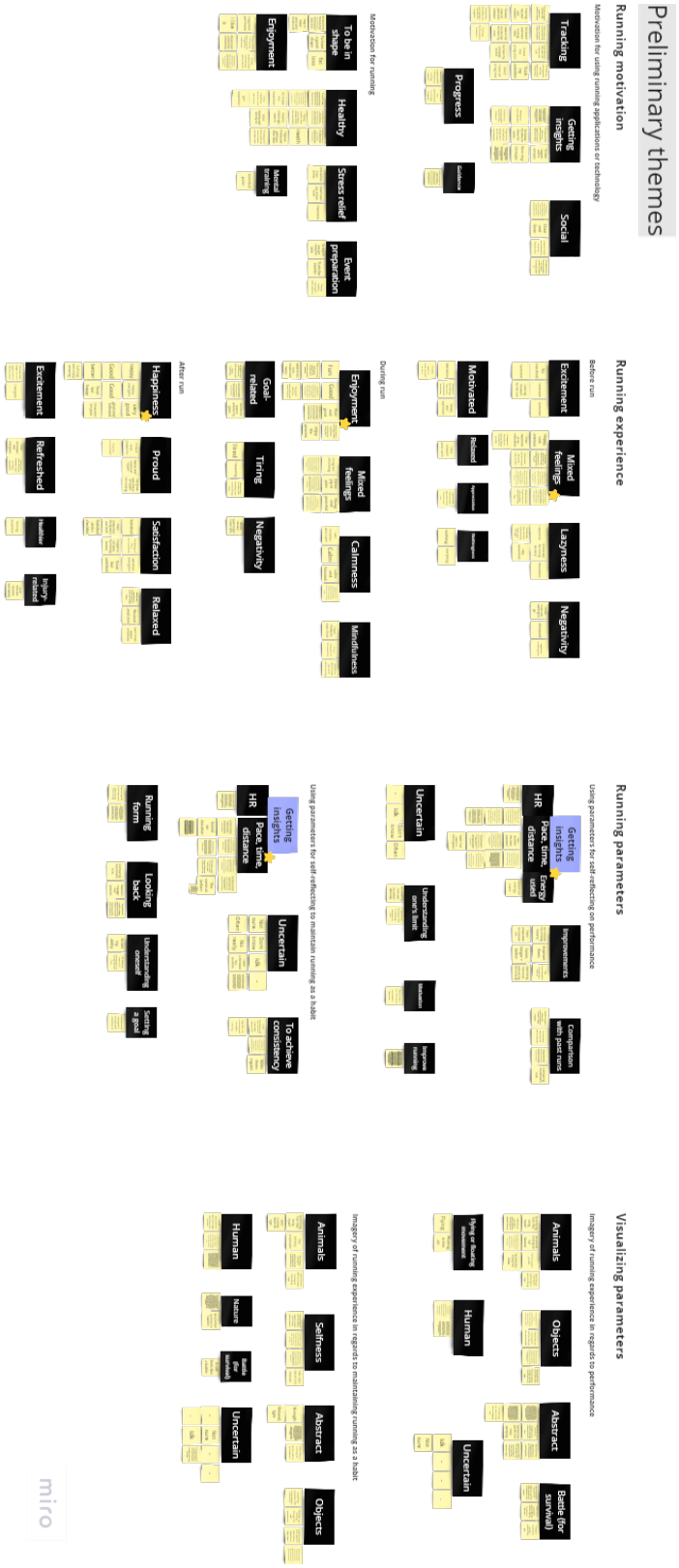

FIGURE 1: Preliminary themes from survey responses.

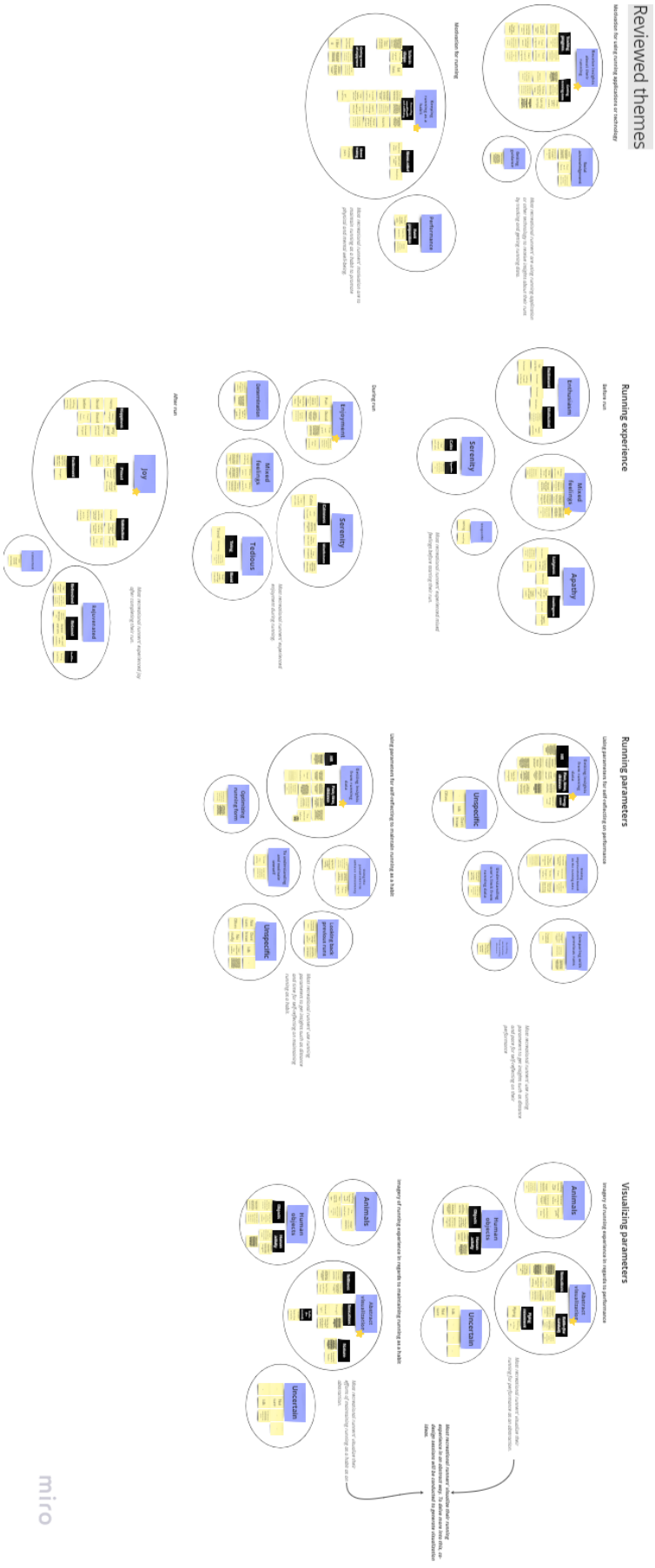

FIGURE 2: Reviewed themes from survey responses.

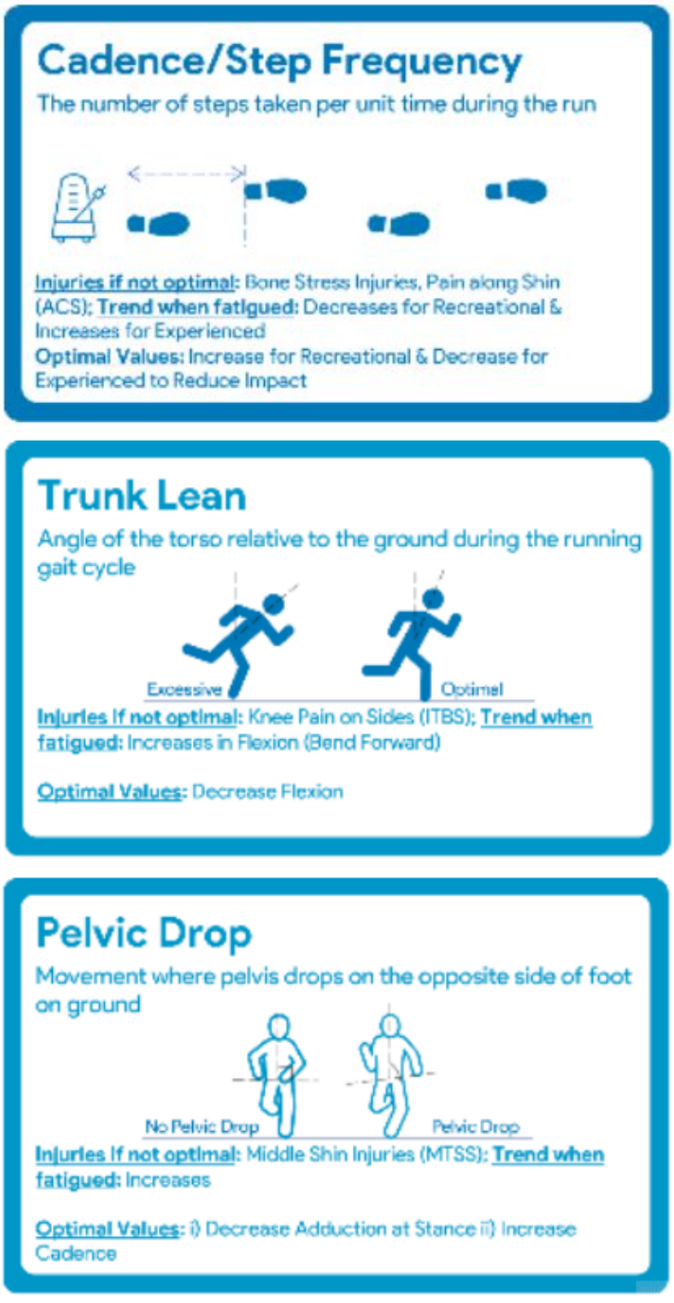

FIGURE 3: Information cards about running parameters shown to the participants during a design session.

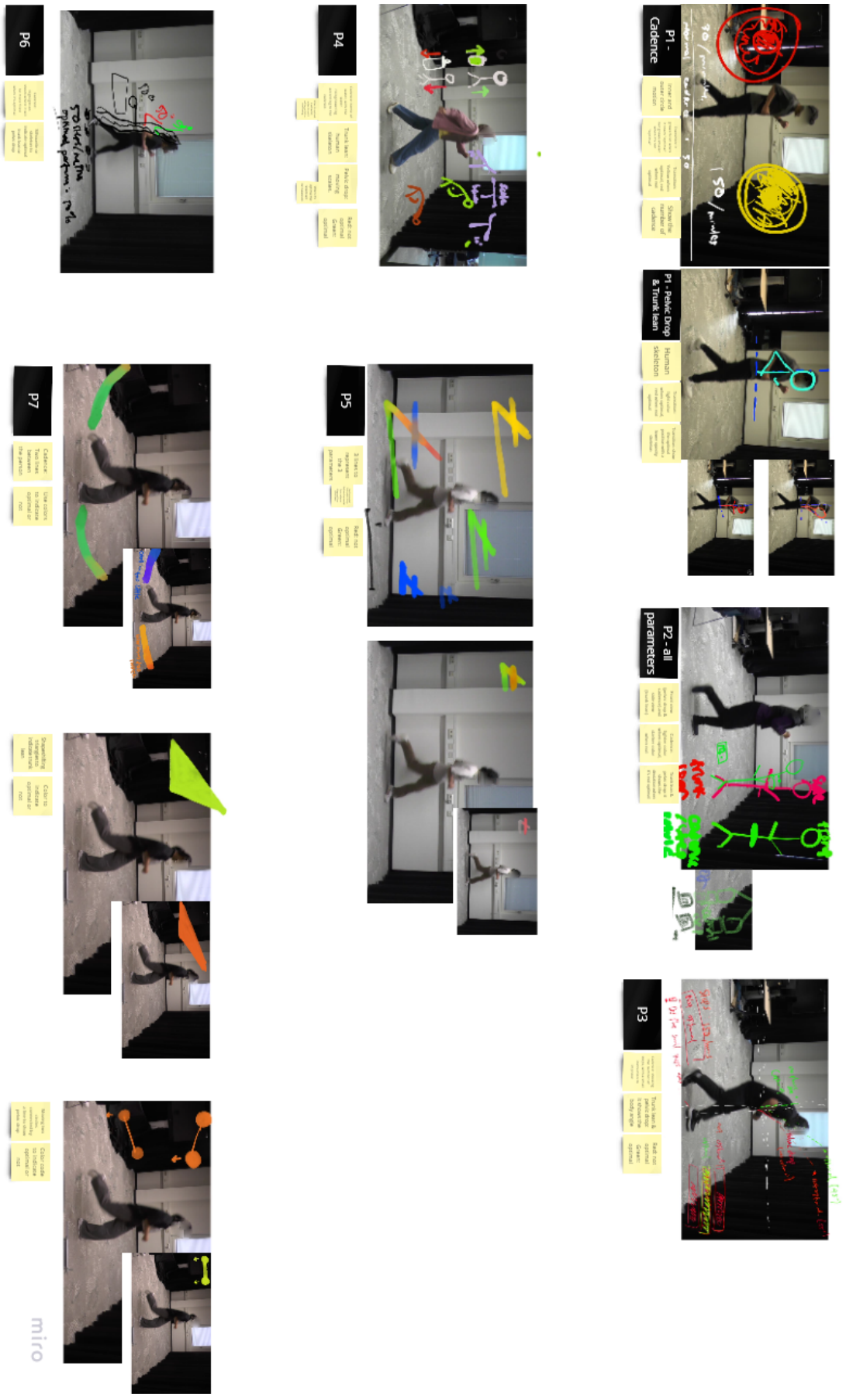

FIGURE 4: Participants sketches during design session studies.

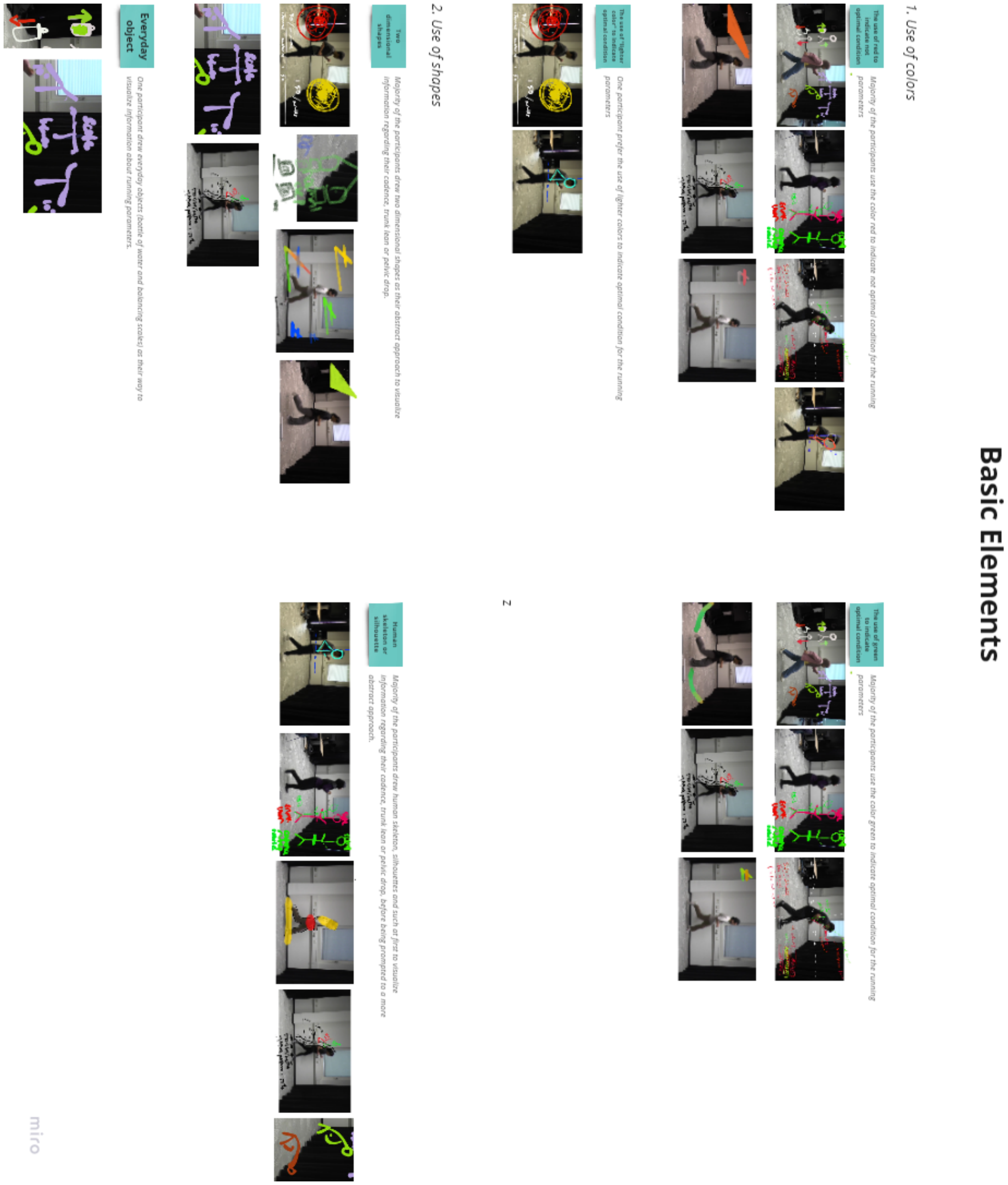

FIGURE 5: Basic elements analysis based on participants' sketches from design session studies.

FIGURE 6: Interactive elements analysis based on participants' sketches from design session studies.