UI/UX Analysis and Design of Running Dashboard for Injury Prevention

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ABSTRACT

User Interface (UI) and User Experience (UX) design is naturally an important part of the Human-Computer Interaction field, since virtually all applications have an interface through which users interact with the machine. Recent years have brought an exponential increase in the research of sports data analysis and visualization. Among all forms of exercise, running has become the most popular sport activity due to its health benefits, but the downside of running is the high injury risk. With current research and development towards extracting kinematic data from video recorded runs, risk factors can be detected and used to reduce injuries. This research entails designing and analyzing a runner's dashboard, with the aim of preventing injuries. A prototype in the form of an interactive dashboard is developed, using video recordings of runners and their gait data. Finally, a preliminary user evaluation is conducted, which shows that the interface scores higher than average on the System Usability Scale and that its components provide access to meaningful data.

Keywords

Human-computer interaction, user interface, user experience, sports visualization, dashboards

1. INTRODUCTION

Running has fast become a popular exercise because it comes with numerous health benefits and it is easy to integrate into people's lives: the equipment needed is minimal and it can be done solitarily, at any time and place. According to Fitbit data, it is the most common workout activity in the world[1]. Nevertheless, this activity involves high impact forces for each ground strike and 37% to 70% of runners are getting injured every year [8]. An incorrect posture remains the primary cause of running injuries, together with gait asymmetry, provided the fact that most injuries are unilateral [28]. In order to automatically detect an incorrect or asymmetric posture, kinematic data is collected and used in a gait analysis. The use of wearable running sensors is a popular method of collecting biomechanics data, but newer development allows the data to be collected solely from video recordings using motion capture and machine learning algorithms [15], which can then be filtered , smoothened , interpolated and normalised in order to be displayed in readable graphs. This research will use gait analysis data from the lower body sagittal plane, because knees, legs and feet are the most affected areas when it comes to running injury [25]. Videos recorded from the side-view perspective therefore suffice and provide relevant variables, namely foot strike, tibia angle, knee flexion, hip extension, trunk lean, overstriding and vertical displacement [23].

For runners and trainers to visualize and interact with the data, a user interface is needed. Considering the number of variables and the large range of data points, a dashboard is a suitable visualization technique for this purpose. Dashboards have become popular due to the exponential increase in the information technology field based on big data and analytics [4]. Each dashboard is different due to the variety of customer needs, but capturing, formatting and displaying the data on a single screen are the core elements in creating one.

This research uses the User-Centred Design process framework in the creation of a running dashboard, with the main goal of highlighting posture irregularities for injury prevention. Once a dashboard prototype has been created, user evaluation will classify its effectiveness on the System Usability Scale, as well as establish whether it brings value to the user.

1.1 Research Questions

To achieve the aforementioned objectives, the research is developed on the basis of four research questions:

RQ1: How can the relevant entities and their relationships be modelled in constructing a running analysis dashboard in order to prevent injuries?

RQ2: Once the dashboard is constructed, how can the data be visualised interactively?

RQ3: How high does the created dashboard score on the System Usability Scale?

RQ4: How helpful is the dashboard in providing access to meaningful data?

2. RELATED WORK

This section presents findings of related work in the field of UI/UX design with a focus on dashboards, sports visualization and running analysis.

[1] https://www.fitbit.com/global/us/activity-index

2.1 UI/UX and Dashboards

In 1988, Norman published *The Design of Everyday Things* [13], a book which established principles of UX design and had a great influence on later work in this field. Most importantly, his work expressed and emphasized that users' needs and preferences have to be thoroughly explored in the development of a product. One of his seven design principles focused on the simplicity of task structure: the user does not need to be overloaded with having to remember a lot of things about the system, considering that on average people can remember three to five items at a time [5]. Another principle states that all elements need to be visible, sparing the user the time and effort to search for hidden buttons or sections. Norman is also responsible for establishing the term "user-centred design" [12], which is now the core practice of UI/UX Design.

Dashboards have also been subject to research. Data visualization was introduced early in the year 1914, with the publication of *Graphic Methods for Presenting Facts* by Brinton [27], which highlighted the importance of finding appropriate ways to present data in clear and interesting ways and provided a starting point for more modern dashboard design. The large interest in dashboards appeared as a consequence of the evolution of big data, when the Internet became widely accessible and applications started to deal with large data sets that needed to be analyzed and visualized effectively. What started out as a single-view board that served as an overview of key performance indicators (KPIs) has evolved through the new technologies to become a complex visualization technique with multiple interactive interfaces and data interpretation, helpful in decision making, motivation and learning [18]. But even though dashboards hold the potential of adding a lot of value to users, this is not always the case. Stephen Few explains in his book, *Information Dashboard Design: The Effective Visual Communication of Data*, that dashboards rarely live up to their expectations, because most of them fail to communicate the insights that they are intended to provide [7]. Instead, they only aim to display as many metrics as possible, therefore failing to adopt an effective design that gives the user the information they are looking for, in an instant. More research has shown that designing a dashboard that truly brings value is done by identifying three key elements: the metrics that users need to visualize, their context and the visual representation that fits them the most, such as the chart type [3].

2.2 Sports Visualization and Running Analysis

Visualization techniques that provide insight into athletes and sports players' performance and strategy have been on an upward trend, causing robust research in the field. According to a 2001 study, the two most popular sports visualization techniques use augmented reality to place virtual elements on top of videos, or 3D modeling to generate multi point perspective virtual replays [16]. Video indexing is another active area of research and development, which is based on having a video player next to the data and a system that takes users to the relevant part of the video when clicking on a data point or set [17, 24]. There are numerous other contributions in sports data visualization, and the most recent ones tend to be based on machine learning algorithms used for motion capture, data collection, analysis and aggregation (computing new data from existing knowledge, i.e. predicting the winner of a future game) [15].

In regards to running, the availability, as well as the use of monitoring and analysis applications has increased considerably over the last years [11]. Research and development continues to grow, as studies have shown that people who use such applications tend to be more physically active and adopt a healthier lifestyle [6]. Technologies such as 2D or 3D motion capture are used along with cameras or wearable sensors and are the core of many recent running analysis systems. A 2018 study compared different motion capture technologies used for running and found that kinematics measured on the sagittal plane are significantly more consistent than data measured on the frontal and transverse planes [26]. Moreover, due to the high injury risk, there is vast research on its prevention, including findings which confirm the potential of accurate injury predictions using gait analysis through motion capture [14].

2.3 Knowledge gap

As mentioned in the previous section, multiple research studies have been conducted on the extraction and analysis of kinematic data, which can be used to predict running injuries. However, the studies only present graphs that resulted from the data extraction algorithms (e.g. motion capture) and there is no user interface attached to them. Outside literature, applications that provide such analysis use dashboards for visualization, but they only exist in professional settings such as clinics where physicians interpret the results for the runners, due to the complexity of the system. Considering the lack of a system that is available for the users themselves, it becomes apparent that research and development of a user interface is needed.

3. METHODOLOGY

Rather than following the standards of scientific research by being purely analytical and aiming to establish universal facts, this research implies investigating and testing methods, ideas and technologies. It is therefore a research by design, following the methodology of User-Centred Design [12] divided into four phases: Plan, Design, Implement, Review.

The first phase, Plan, consists of reaching a deep understanding of the current situation through analysis of dashboards and data visualization in the field of sports, especially running, along with identifying stakeholders and requirements. The Design phase involves considerations of structural and design choices, exploring the technologies available (i.e. video indexing), and creating a low-fidelity prototype of the dashboard. During the Implement phase, the prototype is further refined and developed as an application of an interactive dashboard that can be accessed by users. Finally, the Review phase is based on user evaluation, which is used to assess the usability of the system and whether it brings value to users.

Permission to conduct user evaluation was granted from the University of Twente Ethics Committee. The target number of participants was 15, which is sufficiently large for the System Usability Scale (SUS) evaluation, because it has been proven that, unlike other questionnaires, it does not present a correlation between the sample size and reliability. SUS can therefore be used for evaluations with as few as two users and the results remain nevertheless reliable [21]. The participants were recruited through the grapevine due to Covid-19 not facilitating visits to sports clubs, on the criterion that they have had experience with running (and running tracking applications). Moreover, they all fall into the same age category of 18-28 years old. The participants were given a short introduction of the research and shown a short demo of the dashboard, after which they could access the web application themselves, experiment with the dashboard and then fill in the evaluation form.

The System Usability Scale was created in 1986, but nonetheless remains a rapid and effective way in the UI/UX field to evaluate the usability of a system [1]. On that account, the user evaluation of the interactive running dashboard will be conducted using SUS to measure the score. SUS consists of a 10-item Likert scale questionnaire, which measures the effectiveness, efficiency and satisfaction perceived by the users. Below is the list of items:

1. I think that I would like to use this system frequently.
2. I found the system unnecessarily complex.
3. I thought the system was easy to use.
4. I think that I would need the support of a technical person to be able to use this system.
5. I found the various functions in this system were well integrated.
6. I thought there was too much inconsistency in this system.
7. I would imagine that most people would learn to use this system very quickly.
8. I found the system very cumbersome to use.
9. I felt very confident using the system.
10. I needed to learn a lot of things before I could get going with this system.

According to a study on 500 such evaluations, the average SUS score of a web interface is 68/100 [22], and therefore a lower or a higher score would instantly provide insight into the usability and whether design improvements are needed. For reference, a survey on more than 1000 users revealed that Microsoft Excel scored 56.5, Microsoft Word scored 76.2 and Google Search received 92.7 points [9].

To answer RQ3 and RQ4, user evaluation is conducted. A digital form was sent to the participants, consisting of two parts. The first part, used to answer RQ3, contains the System Usability questionnaire made of 10 items on the Likert scale.

The second part of the evaluation form is used to gather information for RQ4 and consists of three open questions that are meant to reveal the insights that the elements of the dashboard bring to the user:

1. How does the division of data per gait phase help or hinder the effectiveness of the dashboard?
2. How does the video element help or hinder the effectiveness of the dashboard?
3. How does the graph element help or hinder the effectiveness of the dashboard?

4. PROTOTYPE

This section will describe the first three phases of the User-Centered Design approach, namely "Plan", "Design" and "Implement".

During the "Plan" phase, the stakeholders of the system were first identified. Since injuries can occur during any type of running, the dashboard's intended users are recreational runners, athletes and their coaches.

Next, other running dashboards were compared in terms of the elements that they contain. For example, many mobile applications have a map element showing the route of the run. Since the dashboard designed in this research does not require wearable sensors, including a mobile phone, and focuses on injury prevention, a map element will not be considered. When it comes to dashboards that analyze kinematic data, the common element that different systems have is a graph of the raw data of the run. However, most of the observed dashboards that provide deep analysis were meant to be used for professionals such as physicians or trainers in a clinic. This shaped the requirement of the dashboard of this research to provide access to meaningful insights to any type of runner, from recreational to professional.

In answering RQ1, the relevant entities of the dashboard were established to be the video element showing the recorded run and the meaningful data that was extracted from it. The latter first consists of the raw data extracted using motion capture algorithms, more specifically the value of variables foot strike, tibia angle, knee flexion, hip extension, trunk lean, overstriding and vertical displacement at each frame of the video recording. For such large data, a line chart is a suitable visualization, since the points are continuous. In addition, the meaningful data also consists of an element which explains the user the risk of injury, its cause and possible solutions to diminish it. Therefore, a text box element needs to be added to the dashboard.

In answering RQ2, what makes a dashboard interactive is the ability to allow users to filter and manipulate the data set over multiple dimensions, depending on the specific analytical focus. For example, a non-interactive dashboard would display the whole data set on a single-view page, which can be suitable for certain projects (e.g. projects that do not require a large number of variables and KPIs), but nowadays almost all dashboards are constructed to be interactive due to large data sets. For the running dashboard, interactiveness is needed in order not to overwhelm users with all data points of a run, since there are seven variables being measured. To achieve this, the data is divided per gait phase and the contents of each element change dynamically when selecting a specific gait phase: the video jumps to a frame showing the runner's posture during that phase, the text box displays injury risk information found at that phase, and the graph shows the most relevant variable. In addition, manipulating the video and the graph content is possible at all times, such that users can navigate through the running cycles of the video (or play the video freely) and change the variable shown in the graph using a dropdown menu.

Once the planning was done, the "Design" phase started. The novelty of the dashboard consists of the navigation menu in the shape of a diagram of the gait phases, while the rest of the elements are common in data visualization techniques. To start with, the gait cycle was split into five phases: initial contact, mid-stance, take off, mid-swing and terminal swing. For each phase, the relevant variables were identified, which can be an indicator of injury risk. The idea is that the whole dashboard visualization is controlled by the described diagram, illustrated in Figure 1, by clicking on a specific phase.

Apart from the diagram, the dashboard contains three other elements that change dynamically depending on the selected gait phase. The video element contains the recording of the run, with the motion capture skeleton overlaid on the runner's body, which makes it easier for the user to identify the position of all four limbs at any point. The video frames are mapped to the corresponding gait phases, such that when a phase is clicked, the video jumps to the frame during which the runner's position matches the phase, in the first cycle of the run. To

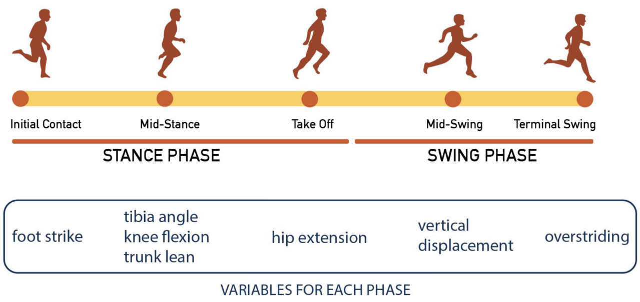

Figure 1. navigation diagram of gait phases

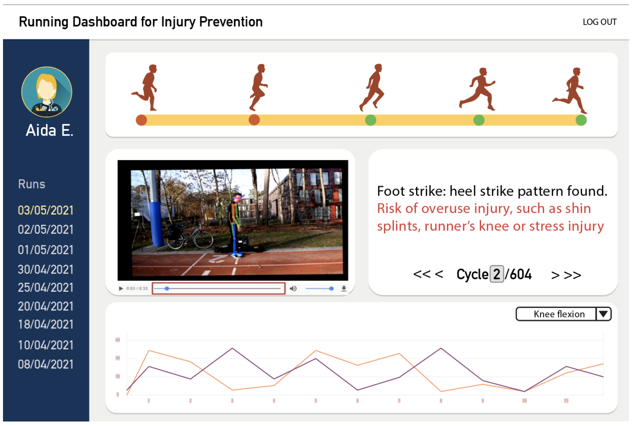

Figure 2. Low-fidelity prototype of the running dashboard

navigate to the other cycles, the user has a set of buttons on the next element of the dashboard, the information box. The information element describes whether there is an injury risk or not found during the selected phase, and in the former case, an explanation of the cause, injury risks and solutions is provided. Finally, the graph element shows the raw data from which the injury risks were derived, providing a deeper analysis. The graph changes depending on the selected phase by showing the most relevant variable for that phase. The low-fidelity prototype in the form of a mock-up created in Adobe Illustrator can be seen in Figure 2.

To the right of the dashboard elements, there is a sidebar containing user profile information (avatar and name), and a list with the history of recorded runs, which can be accessed by clicking on the specific date of a run.

For the "Implement" phase, in order to implement the mock-up of the dashboard, prototyping tools such as Figma were first investigated, which would have been sufficient for the purpose of the research. However, the prototyping programs do not support the functionality of video indexing that the dashboard needs. Therefore, the high-fidelity prototype was implemented as an web application, using HTML, CSS and JavaScript languages, on the basis of the Bootstrap front-end framework. Since the study focuses on the User Interface and User Experience, the back-end side of the application was not necessary to implement and it was therefore only simulated with hardcoded data. Instead of having participants run and use the video recording in the dashboard, a predetermined video of a runner is used. Similarly, the data of the graph and injury risks was manually fabricated and embedded into the source code instead of being generated from the video. A screenshot of the web page containing the dashboard can be seen in Figure 3.

Figure 3. High-fidelity prototype of the running dashboard

After the web pages were implemented locally, the running dashboard was hosted on a server so that the URL to the application could be sent to the evaluation participants.

5. RESULTS

This section represents the last phase of the User-Centred Design practice, namely “Review”.

5.1 System Usability Scale Score

In the end, 14 participants took part in the research by filling in the digital form. A table with the SUS questionnaire results can be found below (Table 1), where the columns denote the score of each item of the questionnaire and the rows represent the participants.

Table 1. score given by each participant per SUS item

	i1	i2	i3	i4	i5	i6	i7	i8	i9	i10
P1	4	2	4	3	3	1	5	2	4	2
P2	4	3	4	1	4	1	5	1	5	1
P3	5	4	4	2	5	1	4	2	3	3
P4	4	1	4	1	5	3	5	1	4	2
P5	5	1	5	1	5	1	5	1	5	1
P6	4	2	4	1	4	2	5	1	4	2
P7	5	1	4	1	4	2	5	1	5	1
P8	4	2	4	2	4	2	3	1	3	1
P9	4	2	3	3	4	1	5	2	4	2
P10	4	2	4	1	4	2	5	2	4	2
P11	1	4	3	4	3	1	2	3	3	5
P12	4	1	5	1	3	1	4	1	4	1
P13	5	1	4	4	5	1	4	1	4	3
P14	4	2	4	1	5	1	4	2	4	2

To calculate the SUS score based on the rating that each item received, a series of simple computations is necessary. For each item, there is a five point rating scale based on the range from “strongly disagree” to “strongly agree”, as follows: 1-strongly disagree; 2-disagree; 3-neutral; 4-agree; 5-strongly agree. Since the questionnaire contains alternating positive and negative items, the rating of odd-numbered items needs to be decreased by 1, while the rating of even-numbered items has to be subtracted from 5. Finally, the results of all previous computations for each item are added, and to convert the current range of values from 0-40 to 0-100, the sum is multiplied by 2.5. The mathematical formula can be found below, where i_n represents the rating that item number n received:

$$SUS = [\,(i_1 - 1) + (5 - i_2) + (i_3 - 1) + (5 - i_4) + (i_5 - 1) + (5 - i_6) + (i_7 - 1) + (5 - i_8) + (i_9 - 1) + (5 - i_{10})\,] * 2.5$$

The result obtained from this formula is presented in Table 2, computed for each participant. By averaging all 14 scores, the running dashboard has a SUS score of 79.46 out of 100.

Table 2. SUS score of all participants

	Odd items	Even items	SUS score
P1	20	10	75.0
P2	22	7	87.5
P3	21	12	72.5
P4	22	8	85.0
P5	25	5	100
P6	21	8	82.5
P7	23	6	92.5
P8	18	8	75.0
P9	20	10	75.0
P10	21	9	80.0
P11	12	17	37.5
P12	20	5	87.5
P13	22	10	80.0
P14	21	8	82.5
AVERAGE SUS SCORE			**79.46**

It is important to remember that SUS scores are not to be interpreted as percentages, and therefore even though the result can be said to be 79.46% of the maximum score of 100, what is actually relevant is that it falls into the 79.46th percentile. As previously mentioned, the average SUS score is 68, which means that it is in the 50th percentile. Figure 4 shows a graph of the normalization of SUS scores into percentile ranks [20]. By locating the average SUS score of the running dashboard on the graph, it can be observed that it belongs to the 90th percentile. This means that the score of 79.46 indicates that the running dashboard is perceived by users as more usable than 90% of tested systems, which corresponds to the grade of B (“Good”) on the letter grading scale. For a system to receive the grade A (“Excellent”), a score of at least 80.3 is needed, which is only 0.84 away from the score attributed to the running dashboard.

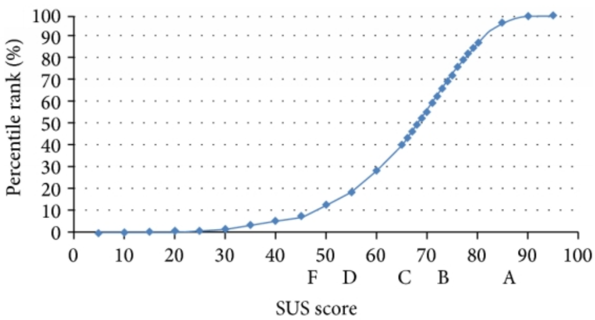

Figure 4. Percentile rankings of SUS scores

After the System Usability Scale was introduced in 1986, it was believed to be unidimensional and only reveal the construct of usability, but research from 2009 [10] states that it is composed of two subscales measuring the usability and the learnability. The usability of the evaluated system is indicated by items 1, 2, 3, 5, 6, 7, 8, 9, while the learnability of the system is indicated by items 4 and 10. The research therefore informs the readers that, if needed, items 4 and 10 can be omitted from the questionnaire in order to assess its usability and save some time, since the removal of the two items only decreases the reliability of the test by a negligible amount, from 0.92 to 0.91. However, it is encouraged to keep the two items in order to gain additional insights into the learnability of the system.

To calculate the learnability of the running dashboard, the scores of items 4 and 10 first need to go through the same formula used to calculate the whole SUS score. Because they are both even-numbered items, the calculation is of the form $[(5 - i_4) + (5 - i_{10})] * 2.5$. After applying the formula, the values are between the range 0-20, and thus need to be multiplied by 5 in order to obtain values within the 0-100 interval. Table 3 shows the final computation of each learnability score, which indicates an average value of 76.79 out of 100. Contrary to the instinct of comparing the value to the average SUS score of 68, it turns out that the scores of items 4 and 10 are on average approximately 10% higher than the other items, which means the value that they must be compared to is 68 * 1.10 = 74.8 [19]. Comparing the system's score to the average score, the result is that the ability of the running dashboard to allow its users to learn how to use it is above average, though not significantly higher.

Table 3. Learnability score of the running dashboard

	$i_4 + i_{10}$	Learnability
P1	5	62.5
P2	2	100
P3	5	62.5
P4	3	87.5
P5	2	100
P6	3	87.5
P7	2	100
P8	3	87.5
P9	5	100
P10	3	87.5
P11	9	12.5
P12	2	100
P13	7	37.5
P14	3	87.5
AVG learnability = 76.79		

5.2 Analysis of Open Questions

For the analysis of the open questions in the second part of the questionnaire, the researcher took the responses of each qualitative question and coded them into themes. The first step was to read the whole answers several times in order to understand in detail what each user intended to express through their answer. The chosen approach for theme creation is inductive coding, which means that the themes are identified and established based on the data from responses instead of having a predefined codebook [2]. There is one exception to this approach, concerning two themes that arise from the way questions are constructed. The user is asked about the ways individual elements of the dashboard help or hinder its effectiveness, and therefore there are two preliminary, broad themes, "help" and "hinder". If a user only expressed positive points, their response is given the label "help", respectively "hinder", should the answer only contain negative points. In the case of a mixed response containing both positive and negative points, the dominant tone assigns the label.

Outside the two general labels discussed above, the more targeted themes were constructed from scratch. For each question, the insightful parts of the answers were selected, meaning that words repeating the question, connectors and other irrelevant words of the phrase were ignored. They were read carefully, based on which connections and patterns were found, which resulted in the classification of the selected parts into themes, based on repetitive keywords. The parts that expressed the same idea were counted and grouped into one. Needless to say, each question generated different themes. An overview of the identified themes and the participant comments that fall into the themes are shown in Table 4. Next to the comments, the number of participants that share that opinion is specified between parentheses.

Table 4. Coding themes of the open questions

Question 1 (division of data per gait phase)
Easiness
"easy to read and understand data" (n=6)
"easy to access data and spot risks" (n=6)
Organization
"it breaks down the run, facilitating individual analysis" (n=2)
Accuracy
"precise perspective that pinpoints the risk of injury" (n=5)
"improvement through detail analysis" (n=1)

Question 2 (video element)
Easiness
"easy to detect and understand the problem" (n=4)
"easy to understand the exact movement" (n=1)
Feedback on motion capture skeleton
"color representation vividly differentiates between limbs" (n=1)
"useful for abstract view of the movement" (n=1)
"option to turn it on/off would be helpful" (n=1)
Benefits
"assists learning through real visualization of the posture and how it can lead to injury" (n=8)
"crucial in understanding the dashboard" (n=1)
"interactive through the cycle navigation buttons" (n=2)

Question 3 (graph element)
Issues
"too technical/vague for average user" (n=8)
Improvement feedback
"be able to identify the exact point of injury risk in the graph" (n=2)
"have more explanation to the graph" (n=2)
"simplify the graph e.g. show one cycle" (n=1)
"add more graphs" (n=1)
Benefits
"reflects the video, making it easier to interpret" (n=1)
"makes the raw data available to user" (n=4)
"allows deeper analysis" (n=3)

As for the initial dichotomy, the results yielded the following distribution:

- Division of data per gait phase: 14 "help", 0 "hinder"
- Video element: 14 "help", 0 "hinder"
- Graph element: 6 "help", 8 "hinder"

In response to the question about the division of data per gait phase (navigation diagram), three themes emerged, all positive, indicating that it brings easiness, organization and accuracy to the dashboard data. The majority of participants felt that the division makes the data easier to access, read and understand. A significant number of users (n=5) also stated that the element provides a precise perspective that helps pinpoint the injury risks.

The responses to the question about the video element are similar, in the sense that users found it easy to detect and understand the issue by visualizing their specific movement. In addition to this, a theme regarding feedback on the motion capture skeleton which overlaps the video was created. One person stated that the color representation helps in differentiating the position of the limbs at any time, while another participant felt that it is useful for a more abstract view of the movement, but there should be an option to turn it off. More positive feedback was given for the video element, such as the opinion that it assists the learning experience of users through real visualization of their posture and how it can lead to injuries, shared by eight participants. Two participants also expressed their satisfaction with the video being interactive through the cycle navigation buttons.

Finally, the feedback for the graph element turned out to be a combination of “help” and “hinder”, unlike the previous two elements that were only categorized into the “help” theme. Many participants (n=8) shared the opinion that the current graph element is too technical or vague for the average user to understand and use. They also provided improvement feedback to solve this issue: making it possible to identify the exact point of injury risk (possibly by simplifying it to show one cycle at a time), adding more explanation about what the graph represents, or even adding more graphs. Participants had positive opinions about the effectiveness of the graph element as well. Four of them found it useful to access the raw data that the injury risks are derived from, and three of them stated that it allows a deeper analysis of their running.

In conclusion, the results reveal that the gait phase division and video element are perceived as highly effective for users, but there are some issues with the graph element. By analysing the questionnaire responses, it becomes evident that the problem is not with the existence of the graph, but with its complexity.

6. DISCUSSION

The results of this research showed that the running dashboard for injury prevention is more usable than 90% of the tested interfaces in the form of a web application. When asked about each individual element of the dashboard, the users revealed that the elements are perceived as providing meaningful access to data, but the graph needs further refinement in order to be easily understood by all users.

A shortcoming of this research is that the data available in the running dashboard is not real data generated by the users’ interaction with the system. The evaluation therefore only touched the surface of the system, since users did not have to run and upload the video recording before using the dashboard. In order to thoroughly find the value and insights that it brings to runners, a complete system would be needed.

In addition to the paragraph above, since the dashboard has the main goal of injury prevention, it would have been interesting to measure to what extent it can satisfy this goal. To achieve this, a long-term study on runners that would capture their injuries and the effect of using the dashboard would provide a useful measure, but it was not possible during this research due to the time constraint.

7. CONCLUSION

This section revisits the four research questions that were the focus of the study, concluding the answers that were found for them.

RQ1: How can the relevant entities and their relationships be modelled in constructing a running analysis dashboard in order to prevent injuries?

In the analysis and creation of the dashboard, it was established that for the goal of injury prevention, the relevant entities are the video element, the text box element where the injury risks are described, and the graph element. Regarding their relationship, the text box and graph contents are derived from the video recording, thus reflecting the movements of the runner.

RQ2: Once the dashboard is constructed, how can the data be visualised interactively?

To achieve interactiveness in the dashboard and allow users to manipulate the data over different dimensions depending on their analytical focus, the division of data per gait phase is used to filter the information. The selection of a phase manipulates the contents of the dashboard elements to show the relevant insights, but the users also have the freedom to navigate through the video and change the graph independently of the gait phase selection.

RQ3: How high does the created dashboard score on the System Usability Scale?

The findings of the evaluation conclude that the designed prototype is situated above average in terms of web applications usability, since the average SUS score of the questionnaire was 79.46 out of 100. Users therefore perceive the dashboard as being effective in allowing them to reach their goals, efficient and providing a satisfactory experience. From the SUS ratings, a learnability score of 76.79 can be derived, which is also above average, meaning that the interface allows users to familiarize with its elements and functionalities in a shorter time than most other interfaces.

RQ4: How helpful is the dashboard in providing access to meaningful data?

The second part of the user evaluation reveals through qualitative analysis that the individual elements which construct the dashboard are helpful in providing access to meaningful data about the risks of injury and guidance on minimizing them. The division of data per gait phase, which represents the novelty of the dashboard, is regarded as a means of easy access to the data, by organizing the run into phases and pinpointing the issues. When it comes to the video element, users share the opinion that visualizing their exact movement assists them in understanding the potential of injury and learning from it. Finally, the graph element is thought to have the potential of being highly effective in providing a deep analysis of the injury risk, but the way it was modelled in the prototype is too vague.

8. FUTURE WORK

Although the results of the evaluation are sufficiently satisfactory for a prototype, both the SUS score and the effectiveness of the dashboard can be further improved to reach better results.

Firstly, the answer to RQ4 revealed that the graph element is not easily understood by users, especially by those with little technical background in running tracking and analysis. For future work, an improvement is proposed. When a running cycle is selected, the line on the graph corresponding to that cycle could be highlighted. Moreover, because the graph shows data of the whole cycle, the points corresponding to the selected gait phase could also be emphasized. This way, the user can see the exact points of the graph that are representative for the selected gait phase within the selected running cycle.

Secondly, the injury risks description and visualization could as well go into more depth. One suggested idea was having different shades of red corresponding to different levels of injury risks in the diagram of gait phases. This way, if multiple phases present irregularities, the user can already see before selecting a phase which one is the most severe. An illustrated example following a scale of three shades of red can be seen in Figure 5. Moreover, the current system does not distinguish between individual cycles when identifying an injury risk. It can happen that the risks are only present during a few cycles, and in a future version of the dashboard this aspect could be indicated in the text box element.

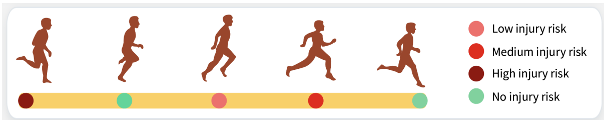

Figure 5. Navigation diagram with three shades of red

In addition, this research only focused on analysing and designing the dashboard page of a running application. In the future, the other pages of the system could be implemented and tested altogether. For example, a complete application would contain, in addition to the dashboard, a sign-up page, a user profile page and a functionality to upload video recordings, either modelled as a separate page or within an existing page.

A shortcoming of the research is that due to the global pandemic and the restricted time, the prototype could not be tested and evaluated by professional athletes or coaches. Conducting user evaluation with them could bring new insights and it would be particularly interesting to compare their feedback to the one received from recreational runners and investigate the differences.

In conclusion, the recommendations for future work fall into the categories of design, additional features and evaluation methods. The conducted research can be used as a design space for exploring more aspects of running visualization interfaces and evaluating them.

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