From Quantified Self to Qualified Self – a Data Visualisation

Graduation Project Creative Technology

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Abstract

Over the years the Quantified Self movement has been widely discussed. Especially, considering the well-being. Self-tracking devices such as smartwatches and smartphones, allow users to track variables that can represent one own's well-being in a data visualisation consistent of quantified numbers. However, the key challenge with these data visualisation is that the user cannot create insight out of the displayed data. In other words, the user cannot place the objective data in his or her subjective experience.

This graduation report explores the possibilities of how the key challenge can be solved and the connection between the objective data and the subjective experience can be reconnected. The connection will lead to an extension of the Qualified Self, as the user expands one own's self-knowledge with the additional and supportive information gained from the data visualisation. The findings answering the research question: "How can a data visualisation of the Quantified Self be created such that the user is actively engaged with one's own data to shape one's own Qualified Self?" will then be used to design a data visualisation. This data visualisation will enhance user interaction and allow the possibility to compare multiple variables measured.

Based on a usability test of the data visualisation there is discussed that the Qualified Self is extended in means of confirmation, and design requirements are proposed for improving future data visualisations aiming to enhance the transition from Quantified Self to Qualified Self.

Acknowledgements

It gives me great pleasure and satisfaction in submitting this graduation report on the transition from Quantified Self to Qualified Self. In the process of making this report, many people gave me a helping hand. But, above all the two people mentioned below, it is, therefore, my pleasure to thank them for all time invested in the achievement of this report.

I would like to express my regards to Alma Schaafstal who gave me the opportunity to work on this project and support me through brainstorming together on how to create a data visualisation that enhances the transition from the Quantified Self to the Qualified Self.

I would also like to thank Randy Klaassen who has been a great critical observer and has been supportive in providing me feedback and teaching me how to upscale my research techniques.

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1. Introduction

In this section, the terminology "Quantified Self" and "Qualified Self" will first be explained, followed by a problem definition of why the transition between both is difficult. Subsequently, the goal to overcome this problem will be introduced with supporting research questions. Finally, the structure of the report will be defined to give an overview of how the research described in this report will lead towards the final end result.

1.1. Defining the Quantified Self and the Qualified Self

We all have some form of a Quantified Self. An old-fashioned example of the Quantified Self is the weighing scale in your bathroom. This piece of technology gives you the possibility to weigh your bodyweight every now and then. The number displayed on the weighing scale is a quantitative representation of yourself. This representation functions as supportive and additional information to expand the self-knowledge of your body. The same applies to the tracked number of glasses of water you drink per day or the tracked kilometres you run per week. Overall, the Quantified Self can be explained as "any individual engaged in the self-tracking of any kind of biological, physical, behavioral, or environmental information." (Swan, 2013, p.1). Thereby self-tracker tracks quantitative measurable variables, such as body weight, stress, sleeping behaviour or air quality. These variables can be measured with various measurement equipment, ranging from a simple pen and paper to advance sensors implemented in wearable devices. Being able to measure and store these variables gives the self-tracker the possibility to interpret and analyse the data correspondingly with the motivation of oneself. So, the Quantified Self, for example, expressed in body weight, allows you to compare yourself to your earlier self (previous measurements) or to others. By doing so, you get to know if you lost or gained weight and are closer to your ideal weight for example.

The self-tracking technology thus supports the user to obtain "self-knowledge through numbers" (Quantified Self Institute, 2016). However, it becomes even more interesting once the technology can give the user insight into how and why he or she lost or gained some weight, by tracking physical activity or eating behaviour for example. With this insight, the Quantified Self becomes the Qualified Self, as the objective data is combined with the subjective experience of the user (Swan, 2013). The Quantified Self is no longer just a number but is grounded by correlating factors. For the Qualified Self, insight regarding the measurement by the user is thus required.

In this graduation project, the Quantified Self will be expressed in variables (e.g. step counts, heart activity) considering the well-being of the user. The well-being of the user will be either measured

by self-reported questionnaires or by sensors embedded in ubiquitous and wearable technologies (e.g. Fitbit, Apple Watch and smartphones in general). So, the data obtained will either be subjective or objective. Finally, this data will be used to create a data visualisation with the aim to enable the transition of the Quantified Self to the Qualified Self.

1.2. Challenges

Variables like step counts and heart activity are a form of representing the well-being of the individual. The technology simplifies the data collection, management and visualization for the individual and represents the variables statistically to the user ready to be interpreted. The variables are represented in a data visualisation and dependent on the interpretation an insight can be created of one's own well-being by the user. If an insight is created, the user can draw conclusions about one's own well-being based on the Quantified Self and thus the Qualified Self is formed. So, to do so, the data of the Quantified Self need to be configured such that insight can be created by the user. This configuration, however, seems to be complicated. Multiple studies confirm that self-trackers are facing difficulties with this configuration, as there is an infinite number of ways in which the tracked data can be combined to generate insight (Li et al., 2011; Choe et al., 2014; Lupton, 2014). Besides users without prior self-tracking experience do not feel connected with their data and are therefore less likely to change behaviour or use the technology for a long-term period (Rapp & Cena, 2016; Patel et al., 2015).

So, the key challenge of the transition from the Quantified Self to the Qualified Self is that the users do not feel connected with the data visualisation of their personal data. This disconnection makes the difference between observing and understanding the results of the Quantified Self measurement.

1.3. Goal and research questions

In order to enable the transition from Quantified Self to Qualified Self, I will research throughout this graduation project how the user and self-tracking technology can be reconnected again, through actively involving the user of a self-tracking device with the quantified data to create a qualified understanding. By enhancing the user's freedom to gain a subjective insight by controlling an objective data visualisation of the well-being of their Quantified Self, I am aiming to form the Qualified Self with the user rather than displaying it to the user. This aim leads to the following research question:

1. How can a data visualisation of the Quantified Self be created such that the user is actively engaged with one's own data to shape one's own Qualified Self?

Additionally, sub questions to this research are added to find the underlying barriers of the challenge of the transition from the Quantified Self to the Qualified Self. These sub questions will be answered in the State-of-the-Art Review:

1. Why do users feel disconnected with the data visualisation of self-tracking technology?
    a. How can this connection be recreated?
2. What related systems of the Quantified Self and Qualified Self do exist?
    a. How can these systems be compared?

Since the well-being of the user can still be expressed in many variables, I have chosen to use university students as my target group and stress as the key variable. By doing so, I will create a data visualisation for university students where they will have the possibility to gain insight into stress by controlling the made data visualisation for this graduation project. I will elaborate on the chosen group in Chapter 4.

1.4. Structure of the report

The structure of the rest of the report will be described here. The structure is based on the Creative Technology Design Process (Mader & Eggink, 2014) (Appendix A).

In Chapter 2 a State-of-the-Art Review will be described. This section consists of two parts, the first part will be the background research and the second part will be the State-of-the-Art Research. The background research will investigate academic literature defining the challenges with nowadays self-tracking technologies. The purpose is to understand why users often feel disconnected with self-tracking technologies and how this disconnection can be prevented during this graduation project. The results will be used as fundamental for the later introduced concepts.

The State-of-the-Art Research will focus on the already existing systems relevant to either the Quantified Self or the Qualified Self. The analysis of these systems will be of relevance to discover the highlighting elements and missing elements of these systems which then, in turn, will also be used as fundamental to design the later introduced concepts.

Chapter 3 describes the ideation phase for the data visualisation of the Quantified Self to the Qualified Self. The ideation phase will consist of eight concepts based on background research and State-of-the-Art research. The purpose is to explore the conceptual possibilities that can be

considered as data visualisation. The results can then be used as a broad variety to eventually define the final concept.

In Chapter 4 the specification phase is described. The final concept will be defined as the conclusion of the specification phase. In this phase, the specifications of the data visualisation will be provided. First, the variables that will be used as data to be visualised in the data visualisation will be defined. These variables will be linked to the target group university students and key factor stress. Second, the requirements of the described variables will be used to specify the functionality of the final concept based on the concepts designed in Chapter 3.

Chapter 5 describes the realisation phase. This section explains how the data visualisation is developed and what technologies are being used to make the development of the data visualisation possible.

Later in Chapter 6 the data visualisation will be evaluated. The evaluation will be done using a usability test with a small group of participants. The participants of the test will gather personal data for seven days and later analyse this data in the designed data visualisation during a semi-structured interview. In this interview, the participants will interact with the data visualisation following a task list and give their opinion about the data visualisation to the researcher. The purpose of this evaluation is to find design tweaks and discover whether the data visualisation enables the user to go from Quantified Self to Qualified Self. The results will be used to improve the design and answer the research question.

The final Chapter consists of concluding statements and a recommendation for possible future work.

2. State-of-the-art Review

This section is split into two parts. The first part will be the background research. During the background research, there will be explored what the underlying barriers of the main problem of achieving the transition from Quantified Self to Qualified Self are. Furthermore, there will be explored how to overcome these barriers. Lastly, related existing systems of the Quantified Self and Qualified Self will be described in the State-of-the-Art Research. These systems will be compared to one another in the conclusion of the State-of-the-Art research.

2.1. Background Research

In this section, the underlying barriers of the main problem of achieving the transition from Quantified Self to Qualified Self will be discussed. These underlying barriers construct a disconnection between the user and the self-tracking technology. Once an understanding of the underlying barriers is created, possible strategies to overcome the barriers will be discussed to reconnect the disconnection between the user and self-tracking technology again. As conclusion research question 1 as stated in Section 1.3. will be answered.

2.1.1. Influence of technology in the transition of Quantified Self to Qualified Self

The aim of the Quantified Self is to "create self-knowledge through numbers" (Quantified Self Institute, 2016). Therefore, the variables measured by the self-tracking technology are developed to inform the user about one's own well-being by expressing behaviour in quantified data (numbers). To make this quantified data easy to interpret by the user, data visualisations are designed. These data visualisations enable the representation of the measured data to the user. This technological representation of the user's well-being in variables can be referred to as virtual data doubles. The data doubles are various data flows or streams abstracted from the human body enabled by self-tracking (Haggerty & Ericson, 2000). The data flows or streams form a knowledge of personal well-being that can be analysed and reflected on. Examples of data doubles are as simple as step counts, heart activity, duration of physical activity or blood pressure.

Depending on the design of the data visualisation and the interpretation of the user, the data doubles can create insight into the well-being of the user. For example, if the user can see that his or her number of step counts are particularly lower during working days, as he or she works behind a desk on working days and loves to walk on free days. With this insight, the Quantified Self becomes part of the Qualified Self, as the objective data is combined with the subjective experience of the user (Swan, 2013). Through the interpretation, the data then becomes valuable to the user.

Important to note, the Qualified Self could be referred to as the consciousness of the user. The user has self-knowledge about one own's well-being, however, this self-knowledge can be extended using the additional and supportive information of the Quantified Self. For the transition of the Quantified Self to the Qualified Self, an insight regarding well-being by the user is thus required. If the user views the data visualisation but only sees the number of steps walked per day but cannot place them in context, the objective data is not combined with the subjective experience of the user and the Qualified Self is not reached.

This makes the transition of the Quantified Self to the Qualified Self dependent of two factors. Namely, how the objective data is visualised to the user and how the user interprets the data. Both these factors are also dependent on each other, as a good visualisation is easier to interpret by the user, while a bad visualisation is more difficult to interpret by the user. But also, as the perception of the well-being of the user influences the perception of the visualisation. It could be said that there is a mediating relationship between the data visualisation and the user. Don Ihde, as quoted by Peter Paul Verbeek (2006), defines this mediation as a hermeneutic relation between the technology and the user:

> "In this relation, technologies provide a representation of reality, which requires interpretation. […] A thermometer, for instance, establishes a relationship between humans and reality in terms of temperature. Reading off a thermometer does not result in a direct sensation of heat or cold but gives a value that requires interpretation to tell something about reality." (Verbeek, 2006, p.365)

The hermeneutic relation between the data visualisation and the user gives the user a new way of interpreting one's own well-being by expressing well-being in virtual data doubles. According to Ihde, technology transforms what humans perceive and thereby always amplifies certain aspects while reducing other aspects. The data doubles displayed in the data visualisation, therefore, amplifies the variables that can be measured by the technology (e.g. the number of step counts) while reducing the variables that cannot be measured by technology but are measured by the human senses (e.g. feelings). The data visualisation thus shapes the perception of the well-being of the user, while the user also, in turn, shapes the perception of the data visualisation by their own ideas and practices (Ruckenstein, 2014).

However, the expression of the well-being in the technical aspect is limited to the possibilities of the technology itself. It, therefore, makes the data visualisation reliant on only these variables that can be transmitted by the technology. This in turn creates the possibility that users do not feel

connected with their data displayed in the data visualisation, because their interpretation of well-being (e.g. I feel healthy) is different than the expression of well-being displayed by the technology (e.g. the data visualisation displays that my step counts and physical activity are below average). So, there needs to be some similarity interpretation of well-being to make the relation between the data visualisation and the user dynamic. But this seems to be difficult, as recent studies have found that users without prior self-tracking experience do not feel connected with their data and are therefore less likely to change behaviour or use the technology for a long-term period (Rapp & Cena, 2016; Patel et al., 2015). In the next sessions, the underlying barriers of this disconnection between users and self-tracking technology will be explained.

2.1.2. Passive relation between the user and the self-tracking technology

The underlying barriers of disconnection between the users and self-tracking technology will be explained by reviewing multiple research studies. The aim of finding these underlying barriers is to discover usability flaws of the current self-tracking technology because understanding these flaws will create the possibility to prevent making the same mistake while designing the data visualisation of this graduation project. The disconnection is in this section referred to as the passive relation between the user and the data, the user and the data-visualisation and the user and the data configuration.

2.1.2.1. The relation between user and data

The relation between the user and data is often passive because the Quantified Self differs from the human in representing the variables measured by self-tracking devices. Well-being can be represented as Quantified Self (e.g. heart activity) and represented as a Qualified Self (e.g. sickness). This difference of representing the well-being can cause the creation of two different identities of the user, a so-called 'actual human self' and a so-called 'virtual best self'. As it can be the case that the Quantified Self identifies the heart activity as being healthy while the Qualified Self identifies the user as sick since the user feels sick. As visualized in Figure 1 the two are almost contradictory in representation. However, it must not be forgotten that both 'Selves' represent the same body, namely the user's body.

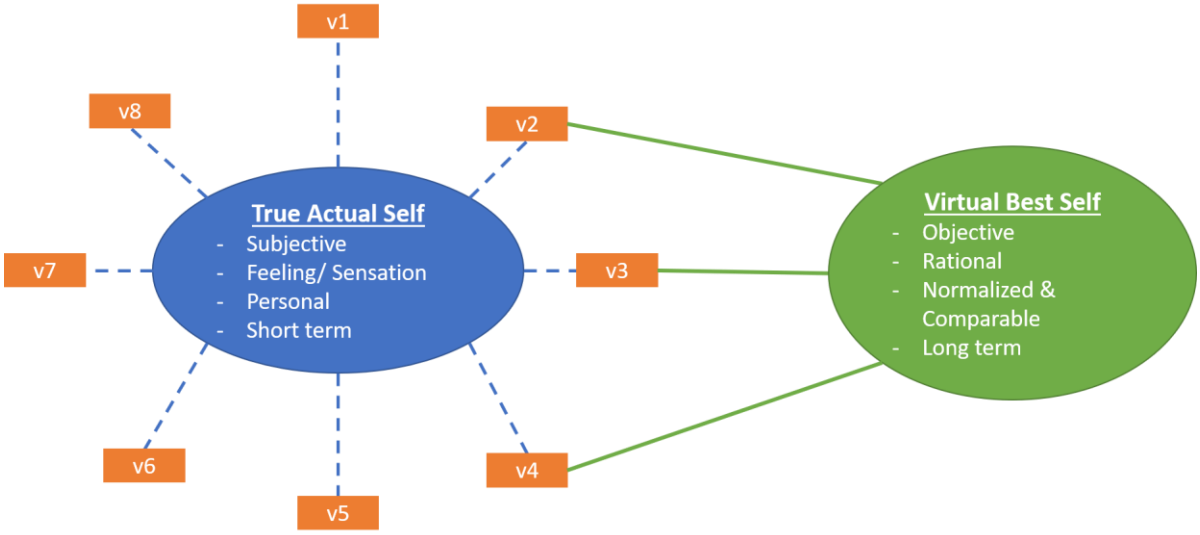


Figure 1, Visualisation of the 'actual human self' and 'virtual best self'

The 'virtual best self' is, therefore, an abstract and passive representation of the 'actual human self'. Understanding the essence of representation of values is required to prevent the user from believing that the 'virtual best self' is equal to the 'actual human self' because it serves only as an addition.

It could be the case that the user believes the Quantified Self more than the Qualified Self, with as a result that the user resists feeling sick as the technology indicates the opposite. Bode and Kristensen (2016) highlight that "self-tracking is not only about making part of the self visible but also serves as an aim to get to know what is perceived as the "real" I.". In other words, if the Quantified Self is believed by the user without combing the Qualified Self, the 'actual human self' is overwritten by the 'virtual best self'. So, while the function of the representation of the Quantified Self is to extend the user's self-knowledge of the body, it needs to be understood by the user that these data doubles are only an addition to, or so to say indication of, the 'actual human self' and not the comprehensive truth.

2.1.2.2. The relation between the user and data visualisation

To make the transition between the Quantified Self to the Qualified Self, the data visualisation should be structured in a way that the user can give personal value to the data. As already discussed in the introduction, this can be done by analysing and comparing the data in order to draw conclusions. However, research studies indicate that the data doubles are often not holistically visualised by commercial devices. A study of Li et al. (2011) found that ubiquitous and wearable self-tracking technologies do not efficiently generate comprehensive insights for the users, as participants of the study were required to compare their data by using pieces of paper or reviewing

their data logs their selves in order to create useful insight. Likewise, Choe et al. (2014) and Lupton (2014) stated that the users are facing difficulties with the implementation of the data, as there is an infinite number of ways in which the tracked data can be combined to generate insight. Thus, the data visualisations of the data doubles are often hard to interpret by the user and consequently remain a passive representation of the body.

2.1.2.3. The relation between data configuration and user

The cause of the passive relationship between the data visualisation and user is because the user is not part of the data integration by most wearable devices. The data integration of the data visualisation is based on a feedback loop consistent only on data doubles and thereby lacks human interaction. The data is measured by the technology, analysed by the technology and visualized by the technology. This results in no immediate engagement with the user and tools.

As the user only can view the Quantified Self of the data visualisation but does not know how the technology measures these variables. The consequence is that the user can interpret the technology, measuring the well-being of the user, as a black box. The user knows it tracks variables from the user's body and knows the outcome. But how these measurements are done is often withheld. Consequently, the lack of engagement disinterests the user to reflect on data and therefore also one's own self (Rapp & Cena, 2016). These findings echo with the findings of Li et al (2010) which concluded that "an appropriate balance of automated technology and user control should be applied within each stage to facilitate the user experience" (p.556). So, the interpretation of a data visualisation of the representation of the user's body is passive because the user is not made part of the data integration.

2.1.3. Transforming the passive relation into an active relation

Although a lot of research studies have been performed to explain why the relationship between the user and the self-tracking technology is passive, only a little research has been performed on how these findings can be implied in self-tracking technology to make this relation more active and thereby enhance the Qualified Self by the user. Considering the studies that are performed, there can be said that the data integration of the current self-tracking technologies needs to be adapted in order to transform the passive relation into an active relationship. To make the relation between the user and self-tracking technologies active, two main strategies can be structured: On the one hand, make the automated data integration process more human and on the other hand engage humans in the data integration process.

The first strategy 'to make the automated data integration process more human', can be explained as adapting the data with a meaning-making functionality for humans (users). For example, instead of displaying the outcome of the step counts and heart activity of the day as a number, combine the data with GPS and display the outcome on a map. This methodology creates more insights for the user, because "most humans are not good at thinking statistically (i.e., quantitatively), but are good at thinking in stories (i.e., qualitatively)" (Swan, 2013, p.94). Moreover, by making the data integration more human centred, the data visualisation will become easier to be interpreted by the user (Meyer, 2014). So, the quantitative data can be translated upstream to data that relates more directly to the user's interest, to create a more active relationship between the user and the self-tracking technology.

While the above strategy leaves the data integration driven only by technology, the second strategy makes humans part of the data integration process. This strategy enables data integration driven by technology as well as by users. By doing so, the user is engaged and critical towards the collected self-tracking data. Integrating users in this process makes the representation of the collected data easier to reflect upon, as the representation represented their intentions (Whooley, 2014). Similarly, Li et al. (2010) discussed that by making the data integration more user-driven, the control of the data remains in the user's hands, and thereby persuade the user to be actively engaged with the self-tracking data. This strategy requires a participatory engagement of the user with the technology and is, therefore, time-consuming, however making the data integration technology and user-driven will lead to an active relation between the self-tracking technology and the user.

2.1.4. Conclusion

All in all, the users can feel disconnected with the Quantified Self because of three passive relations. The first passive relation defines the interaction between the user and the data. As the well-being of the user is expressed in technological variables, it can be that this expression is not related to the user's perception. If so, it creates the possibility that the user either gets obsessed with the data (sees the data as the new truth) or finds the data not interesting (sees the data as irrelevant). Secondly, there is a passive relationship between the user and the data visualisation. Multiple research studies confirm that the existing data visualisations are facing difficulties with displaying the multiple variables such that the user can understand how these variables can be related to one another. The consequence of the so to say 'bad' design withholds the user from gaining an understanding of the displayed variables. Lastly, there is a passive relationship between the data configuration and the user with already existing data visualisations, because the data configuration is often system-driven. This means that the user is not made part of the process of data gathering.

Involving the user in the data configuration will make the configuration more user-driven and thereby give the user an explanation of how and why the variables are displayed in the data visualisation.

The three passive relations all withhold the user from creating the Qualified Self from the Quantified Self. To overcome the passive relations, or so to say underlying barriers, two strategies have been discussed. The first strategy implies to give context to the data. The second strategy implies to involve users in the data configuration, such that the user can observe and process one's own data to enhance self-monitoring through self-tracking. Both strategies will enhance the transition from Quantified Self to Qualified Self.

2.2. State-of-the-Art Research

In this section, research to find comparable systems of the Quantified Self and the Qualified Self is described. The chosen systems are all related to self-tracking variables that indicate the well-being of the user. For both the Quantified Self and the Qualified Self five systems are selected. A total of ten systems are, apart from being explained, compared in the conclusion of this chapter. This comparison enables highlighting and missing elements of the systems to be used for the creation of the concepts in the Ideation phase.

2.2.1. Explanation of description related systems

All related systems will be individually explained with the use of a table, in which figures, the name and functionality of the respective system will be displayed. The functionality of both found Quantified Self and Qualified Self systems will be categorized in the variables they measure, the data visualisation and the data configuration. These three categories are identical to three causes of the passive relationship between the individual and the technology as described in Section 2.1. Additionally, the category data configuration is described either system-driven or user-driven. This distinction, as already described in Section 2.1.3, is researched by Li et al. (2010) to indicate the involvement of the user in the process of the data visualisation of self-tracking data and thus is an important indication to describe the relationship between the user and the data configuration.

2.2.2. Quantified Self

Comparable systems related to the Quantified Self are the self-tracking devices that measure variables related to the physical or mental health of the self-tracking individual with the use of sensors. The measurements of the variables are displayed in a data visualisation either on the self-tracking device itself or a paired smartphone. As there are many available systems related to the Quantified Self, the systems were chosen for the State-of-the-Art Research are commonly used systems (10+ million installs on smartphones) and known under the general public (rated as top apps in the category Health & Fitness in the Google Play Store[1]).

[1] Excluding the Health application from Apple. However, this app is well-known because Apple automatically installs and runs the app on all iOS devices.

Table 1: Description of Mi Band 3 & Mi Fit App

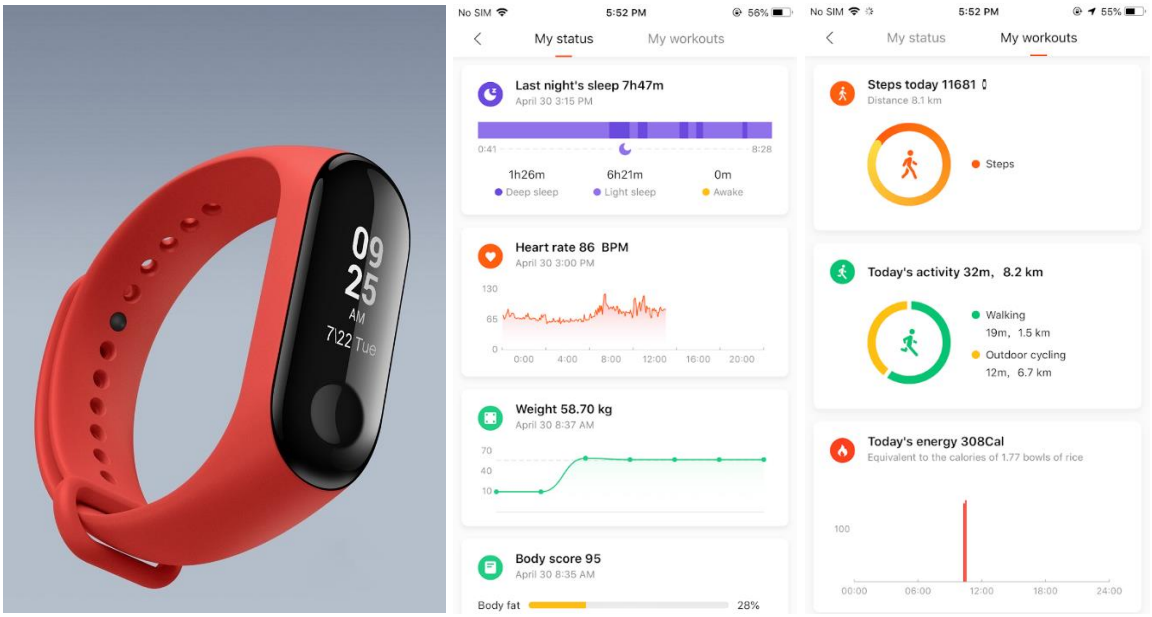


Figure 2, Picture of Mi Band 3 (on the left) and two screenshots of Mi Fit (on the right)

Mi Band 3[2] (left picture) (± €30,00)

Mi Fit 4.0.0[3] (2 right pictures) (free, Google Play Store and Apple App Store)

Measured variables	**Sensors:** 3-axis accelerometer, heart activity sensor **Variables:** Automatic step counter, calorie counter, sleep monitor, heart activity monitor, automatic exercise recognition
Data visualisation	The app displays measured data of the day in various graphs. For the indication of measurements over time; line, area and colour graphs are used. For the indication of measurements as a percentage; bar charts, pie charts and histograms are used.
Data configuration	System-driven, all variables are automatically measured by the Mi Band 3 or smartphone (with the installed Mi Fit app). The data is thus only displayed to the user, the user does not have the possibility to interact with the data or to indicate what or how he or she would like to see the tracked data.

[2] https://www.mi.com/global/mi-band-3/

[3] https://play.google.com/store/apps/details?id=com.xiaomi.hm.health&hl=en

Table 2: Description of Fitbit Inspire HR & Fitbit App

Figure 3, Picture of Fitbit Inspire HR (on the left) and two screenshots of the Fitbit App (on the right)

Fitbit Inspire HR[4] (left picture) (± €100,00) Fitbit App[5] (version varies with device) (2 right pictures) (free but in-app purchases available, Google Play Store, Apple App Store and Windows Store)	
Measured variables	**Sensors:** 3-axis accelerometer, heart activity sensor **Variables:** Auto Sleep Tracking, Automatic Exercise Recognition, Real-Time Pace and Distance, Personalised Guided Breathing, Reminders to Move
Data visualisation	The app has many options. Firstly, the data measured with the Fitbit Inspire HR is displayed in a dashboard. In this dashboard, the data is visualised in pie charts for each variable to indicate if the 'challenge' of that variable is reached for the day. If more detail per variable is desired, the user can swipe to the right to see the data of each variable per day over a week. Furthermore, the app gives the user the possibility to adjust the challenges, read 'personal' advice based on the measured variables and compete or compare one's own personal data with his or her community.
Data configuration	System-driven, the Fitbit Inspire HR measures the variables and configures this data in the data visualisation of the app. The only power the user has apart from displaying the data is to set the level of challenges. The app is thus goal-oriented, aiming to motivate the user by his or her competitiveness.

[4] https://www.fitbit.com/nl/inspire

[5] https://play.google.com/store/apps/details?id=com.fitbit.FitbitMobile

Table 3, Description of vivosmart 4 & Garmin Connect App

Figure 4, Picture of vivosmart (on the left) and two screenshots of Garmin Connect (on the right)

vívosmart® 4[6] (Garmin) (left picture) (± €100,00)
Garmin Connect™[7] (version varies with device) (2 right pictures) (free, Google Play Store and Apple App Store)

Measured variables	**Sensors:** Heart activity sensor, Barometric altimeter (alternative for GPS), Accelerometer, Pulse Ox **Variables:** Step counter, Sleep monitoring, Floors climbed, Intensity minutes, Body Battery™ Energy Monitor, All-day Stress Tracking, HeartRate zones
Data visualisation	Expanded visualisation of various variables. My dashboard consists of the last sports activity and the performance of individual variables per day or week. These variables are displayed in a pie chart or bar chart to indicate to the user if the goal is reached. To see more details the user can click on a variable given in the dashboard (see right figure). The app is designed to motivate the user by displaying the last activities and coaching on how these activities could be improved next time. Apart from this, the system motivates users by a badge system, possibility to set personal goals, complete challenges or to compare stats to other users.
Data configuration	System-driven. The app gets the data from the vivosmart and analysis of this data automatically. There is no option to interact with the data. The data can only be compared to competitors or to data from other periods of time.

[6] https://buy.garmin.com/en-US/US/p/605739

[7] https://play.google.com/store/apps/details?id=com.garmin.android.apps.connectmobile

Table 4: Description of Google Fit App

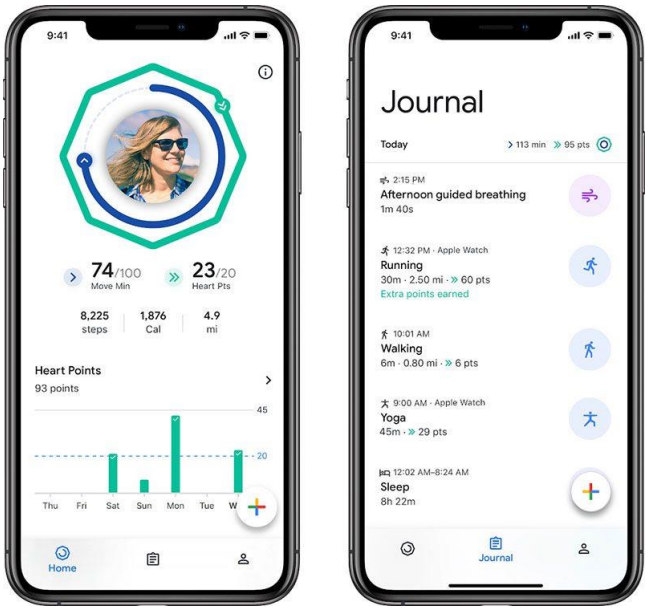


Figure 5, Two screenshots of Google Fit

Google Fit: Health and Activity Tracking[8] (version varies with device) (free, Google Play Store and Apple App Store)	
Measured variables	**Sensors:** built-in sensors of mobile phone, other apps or paired devices. Most basically uses GPS and a built-in accelerometer. **Variables:** Move minutes, Heart Points, Journal of Activities
Data visualisation	The app visualizes on the home page all variables measured of the day. The heart points and move minutes are displayed as pie charts, aiming to make the user aware of the daily goal (based on the advice of the National Health Centre of America) is reached. Apart from the home page, the user can see his or her journal of the day. In this journal, Google Fit displays the tracked activities, including the length of time of the activity, the heart points and the sort of activity.
Data configuration	System-driven, the measurements are displayed to the user. The app gives an overview of the activities

[8] https://play.google.com/store/apps/details?id=com.google.android.apps.fitness

Table 5, Description of Apple Health App

Figure 6, Two screenshots of Health App

Health App[9] (version varies with device) (free, built-in app with iOS)	
Measured variables	**Sensors:** built-in sensors of mobile phone, other apps or paired devices. Most basically uses a built-in pedometer. Walking distance, Step counts, Flights of stairs, Length of sleep
Data visualisation	Basic visualisation in the text of the measured step counts walked distance and number of flights of stairs per day. Apart from categorized per day, the data can also be displayed per week, month or year in a histogram.
Data configuration	System-driven. All measured variables are passively displayed to the user. No options to interact or set goals for example.

2.2.3. Qualified Self

In this section, the found related systems to the Qualified Self are displayed. These systems are data visualisation that enhances user interaction with the data. Apart from this, most of these systems give the user the possibility to compare different variables with each other. The possibility

[9] https://www.apple.com/lae/ios/health/

to compare different variables lets the user explore his or her personal data and learn from the comparison. This learning process eventually creates the Qualified Self.

Table 6, Description of Exist

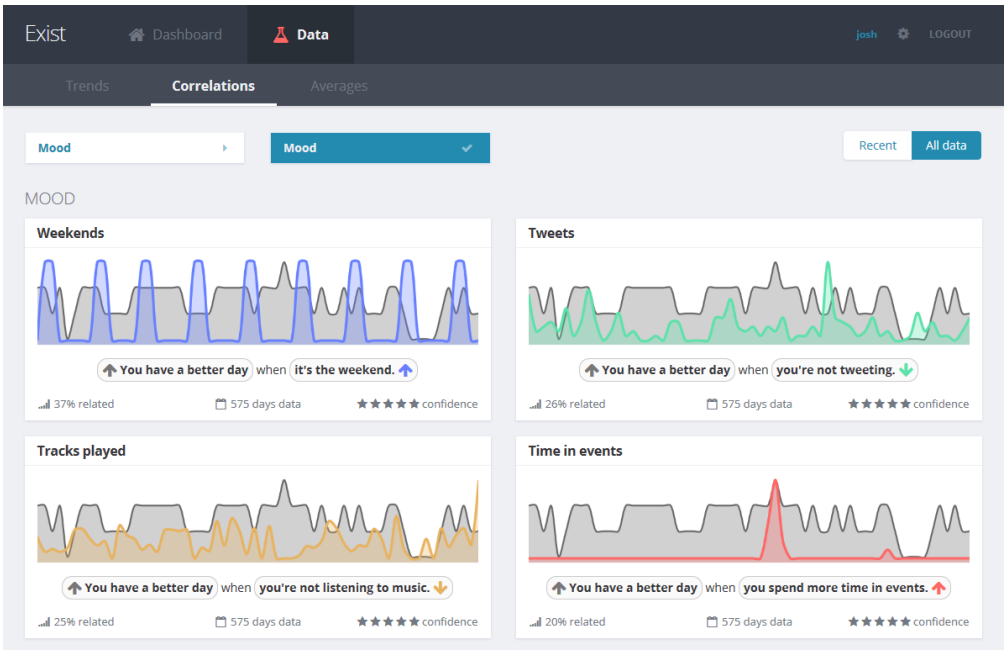
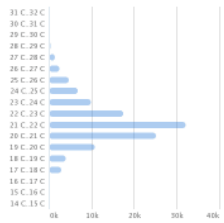


Figure 7, a screenshot of online web application Exist

Exist[10] (Online web application) "Track everything together, understand your behavior."	
Measured variables	**Sensors:** Non. Combines data collected from various apps and wearable devices (i.e. Apple Health, Fitbit, Garmin, Google Fit, Runkeeper, Strava, Calendar, Last.fm, Gmail, Instagram, Twitter). **Variables:** e.g. Step counts, Flights of stairs, Heart activity, Sleep behaviour, Exercise Recognition, Calories burnt, Appointments scheduled, Number of hours listened to music, Tweets sent.
Data visualisation	Visualizes possible correlations between different apps and self-tracking devices in area charts.
Data configuration	System-based. Exist automatically configures the gathered data automatically to find correlations. These findings of the correlations are based on the following aspects: 1. Percentage of relation 2. Days of data collected 3. Confidence

[10] https://exist.io/

Table 7, Description of Zenobase



What's the ideal room temperature for sleeping?

Combine data from an indoor weather station (Netatmo) with sleep data (Fitbit, Withings or SleepCloud).

Does the phase of the moon affect my sleep?

Correlate sleep data (Fitbit, Withings or SleepCloud) with the phase of the moon, or weather data.

Watch screencast »

Figure 8, Screenshot of homepage from Zenobase

Zenobase[11] (online web application) "Got data? Get answers."	
Measured variables	**Sensors:** Non. Gets data from manually inserted data from devices and apps such as Fitbit, Withings or SleepCloud. **Variables:** Large range of available data, dependent on the user' creativity. The tool is designed to compare personal data such as sleeping behaviour or stress to universal data such as the phase of the moon or weather.
Data visualisation	Graphical visualisation of a personal data set and universal data set over the same period. The visualisation is varieties of graphs such as histograms, scatterplots or line graphs. The aim of the visualisation is to let the user seek if a correlation between the two datasets can be found.
Data configuration	Mostly user-driven. The user inserts the datasets he or she would like to compare to find a possible relation. The system then displays the data in the desired plot. Using the correlation button, the user can apply a system-driven calculation to discover a statistical correlation.[12]

[11] https://zenobase.com/#/

[12] See screencast for explanation of the correlation option in Zenobase https://www.youtube.com/watch?v=b2q8CLRAPrM&feature=youtu.be

Table 8, Description of Optimized

Figure 9, Three screenshots of the data visualisations of Optimized

Optimized[13] (no longer available for download)	
Measured variables	**Sensors:** Non. Uses data gathered through synchronisation with the applications: Fitbit, Moves, Jawbone and Apple Health. **Variables:** Steps, Active Minutes, Weather, Temperature and Moon Phase and other variables gathered through the synchronised apps
Data visualisation	The data is visualised in various charts. Percentage graphs, such as pie charts or bar charts, are used to display the performance of the daily goals of the user. Apart from that, histograms or line charts are used as visualisation to display the values of the variables for a period of time. The app uses a strong colour style to give the user an impression of the type of various actions performed during the period of time.
Data configuration	System-driven and programmed to perform automatic correlation mining between various variables. The user does have the possibility to set goals for each variable and see his or her goal-oriented performance over time. However, the user does need to insert his or her mood and categorize his or her activities per day.

[13] http://optimized-app.com/

Table 9, Description of Reporter

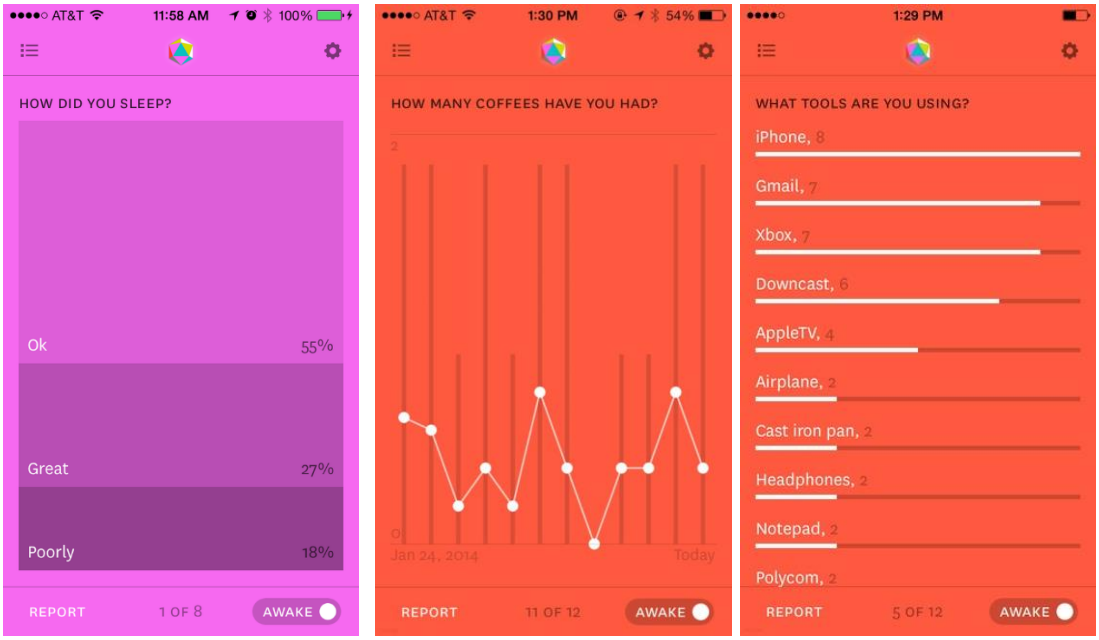


Figure 10, Three screenshots of the data visualisations of Reporter App

Reporter App (Only available at Apple App Store)[14] "Designed for Discovery"	
Measured variables	**Sensors:** Non. Gets data by use of questionnaire made by the user with the support of the app interface. These questions are randomly asked during the day of the user and designed such that they require a small amount of attention. **Variables:** Any variable the user would like to track per day, such as cups of coffee, quality of sleep, surrounded by people or time working.
Data visualisation	The visualisation of the data is dependent on the answer option selected by the question (see Figure 10).
Data configuration	User-driven. The user decides what and how he or she would like to track one's own personal data. However, there is no option to interact with the data. The only option is to export the data e.g. to a .csv file and compare the data manually.

[14] http://reporter-app.com/

Table 10, Description of the configuration of Google Fit to Google Calendar

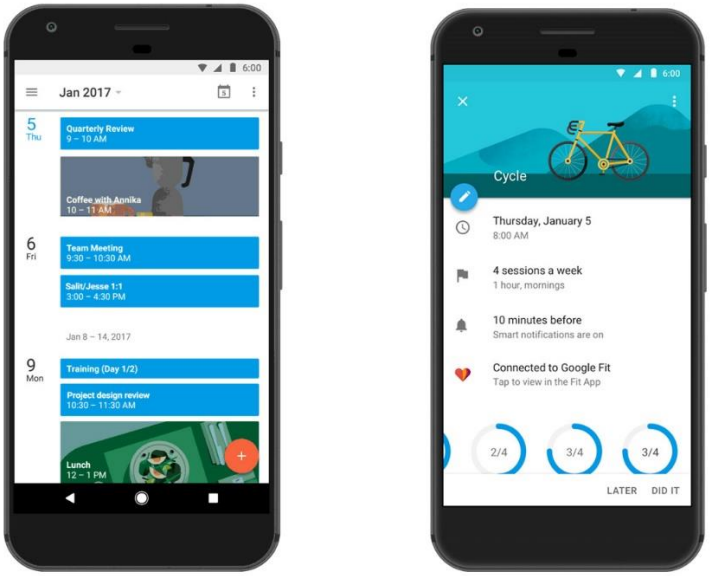


Figure 11, Two screenshots of the connection between Google Fit and Google Calendar

Configuration of Google Fit to Google Calendar[15]	
Measured variables	**Sensors:** Non. **Variables:** Activities planned in Google Calendar, Goals planned in Google Calendar (connected with Google Fit)
Data visualisation	This data visualisation is an extension to Google Calendar. The user can insert goals to his or her calendar and connect these goals with Google Fit, so once the goal is performed the stats are either displayed inside the Google Calendar app or Google Fit app. Using this extension gives the user the possibility to combine his or her health with one's own planning.
Data configuration	User-driven. The user needs to insert the goals manually, but once the goal is completed the stats are automatically updated inside Google Calendar.

[15] https://support.google.com/calendar/answer/6334090?co=GENIE.Platform%3DAndroid&hl=en

2.2.4. The conclusion from the State-of-the-Art Research

It can be said that the fundamentals of the related systems to the Quantified Self are much alike for various reasons, although each system is from a different company. The first comparison it that all systems automatically gather their data directly or indirectly via built-in sensors in either the wearable device or smartphone. These sensors are usually an accelerometer and heart activity sensor, only Garmin expands these basics with other sensors. The data sensed from these sensors is then used as a variety of variables defining the physical activity and health of the user. Noticeable is that the data visualisation of these variables is most descriptively displayed in the associated app. In this app, the variables are explicitly individually displayed in various graphs over time (e.g. hour, day, week, month, year). All systems, excluding Apple Health, externally motivate the users by using daily goals based on either user's preference, advisory of the various international health organisations or challenges of "in-the-app" created communities.

Moreover, the systems that display the Quantified Self all have system-driven data configurations. Apart from the goals per variables that can be adjusted by the user, the user only has the freedom to interpret the data visualisations. Leaving no options for user input or personalisation of the interface, this is a missing element in all systems.

The most advanced system is the vivosmart in combination with the Garmin Connect app. As already said before, the vivosmart grounds the output of the variables on more sensors than other devices. Additionally, the Garmin Connect app creates a lot of data visualisations for the user to discover. The app has the highlighting element of visualising stress activity in combination with physical activity. However, this element is hard to find as there are so many discovery options. This wide range of discovery options negatively influences the glanceability of the interface, whereas the other four systems are easier-to-use since the limited options. Anyhow the discovery options could be considered as aligned with the transition from Quantified Self to Qualified Self, as the user learns from one's own personal data by discovering.

To continue, all systems related to the Qualified Self have the possibility to combine the individually tracked variables. These systems thus display various variables in one graph of the data visualisation. By doing so, the systems give the user the possibility to interpret and discover possible correlations. This, however, does have the risk that the user will think certain variables are the cause of the outcome of other variables if a correlation is discovered. Even though the outcome could be caused by neither of the variables displayed in the system.

One of the highlighting elements of the related systems of the Qualified Self is the explore options embedded in the systems. These explore options enable the user to deeper understand the data and thus deeper understand where certain behaviour of the user comes from. Another highlighting element is a function of the Reporter app. This app enables the possibility for the user to use one's own creativity to discover own correlations in behaviour by self-reporting questions to collect data. This option gives users the freedom to decide which factors are believed to be of relevance. The missing element of the related systems is that the variables displayed in the data visualisation of all systems can only be displayed over time. There is no possibility to remove time from the y-axis and introduce another variable on the y-axis.

So, there could be said that the systems related to the Qualified Self are in contradistinction with the Quantified Self if focussed on the freedom of the user to interact with the data. The difference between the systems is the difference between observing and interacting with the data. Moreover, the Quantified Self systems seem to focus on short time feedback loops while the Qualified Self systems seem to focus on correlations between behavioural input and the physical or physiological markers. However, the manner of data visualisation to the user are relatively the same; displaying quantitative data over a certain period of time.

3. Ideation Phase

In this phase, possible concepts are discussed based on an individual brainstorm. These concepts are explained by using the knowledge gathered in Chapter 2. For each concept four sub-concepts are considered based on the State-of-the-Art Research. The sub-concepts are explained with the use of a short description and a drawing.

3.1. Foundation of the concepts

For the creation of the concepts, an individual brainstorm is performed. The individual brainstorm is a creative technique to find solutions (in the form of a data visualisation) to realise the transition from the Quantified Self to the Qualified Self. The foundation of the brainstorm is formed by the Background Research (Section 2.1) and State-of-the-Art Research (Section 2.2) form the foundation of the thinking process. Consequently, the concepts are split into two main segments, namely segment A and segment B. Segment A is connected to strategy 1 (based on the theories of Whooley & Li et al.) and thus has the objective to make the user part of the data configuration process of the data visualisation. So, for example, by giving the user the possibility to compare the number of step counts of one week to another week. Whereas B is connected to strategy 2 (based on the theory of Swan) and thus has the objective to give context to the data in order to make the data more human (adding a storytelling aspect to the statistical data). So, for example, by giving the user the possibility to tag every peak in step counts with tags such as a hike in nature, a walk to the supermarket or a walk during lunch break. Both strategies and segments have the main objective to expand the Qualified Self with the use of the Quantified Self by finding a correlation, and even better: causalities between multiple variables. In Table 11 an overview is made to summarize the discussed objectives of the concepts.

Table 11, Overview of the objectives of the concepts based on Chapter 2

Objective	A1	A2	A3	A4	B1	B2	B3	B4
Finding correlations between multiple variables.	√	√	√	√	√	√	√	√
Data visualisation of self-tracking variables over time	√	√	√	√				
Data visualisation of self-tracking variables per activity, location or mood					√	√	√	√

Involves the user in the data configuration (Whooley, 2016; Li et al., 2010).	√	√	√	√				
Gives context to the data visualisation (Swan, 2014).					√	√	√	√

Both segment A and B consist out of four different concepts, so eight in total. These concepts are subsequently inspired by the conclusion of the State-of-the-Art Research described in Section 2.2.4. The eight concepts combine the highlighting elements of these systems with the missing elements of the systems as discussed. So, A1 to A4 has the objective to enhance the interaction between the user and technology and to combine multiple variables in one graph of the data visualisation instead of only separately displaying each variable in a different graph. While for B1 to B4 the focus is mostly on how data can be visualised differently inside the graphs than the most standard visualisation, namely connecting the Quantified Self variables to something else than the time.

3.2. Concept A – Interacting with your data

The purpose of these four designs is to enhance user interaction with his or her personal data to find correlations by the user his or herself. The interaction of the user with the data visualisation will make the analysis of data user-driven rather than system-driven. By letting the user discover and explore the recorded data he or she will be able to understand one's own behaviour (if for example action A is a consequence of action B).

3.2.1. A1: Find your own correlations

The concept A1 is a data visualisation that combines already existing personal data with quantified answers of self-reported data. The aim of this application is to let users explore self-thought possible relations between personal data, such as if the increase in heart activity is due to stress, cups of coffee consumed, physical activity or deadlines.

The user sets an exploration goal at the beginning of the trail aiming to let the user think about what he or she would like to discover about his or her behaviour using Quantified Self data. Depending on this variable the user can select other variables to discover if a possible correlation can be found. During the trial, the application removes unrelated variables after approval from the user, such that at the end of the trail only possible correlations remain. See Figure 12 for more details.

The distinction with this concept and already existing applications (such as Google Fit, Fitbit and Garmin connect app) is that the user actively works towards a goal of exploring and finding possible correlations in self-tracked data. The user becomes a researcher and interacts with the data for a longer period of time.

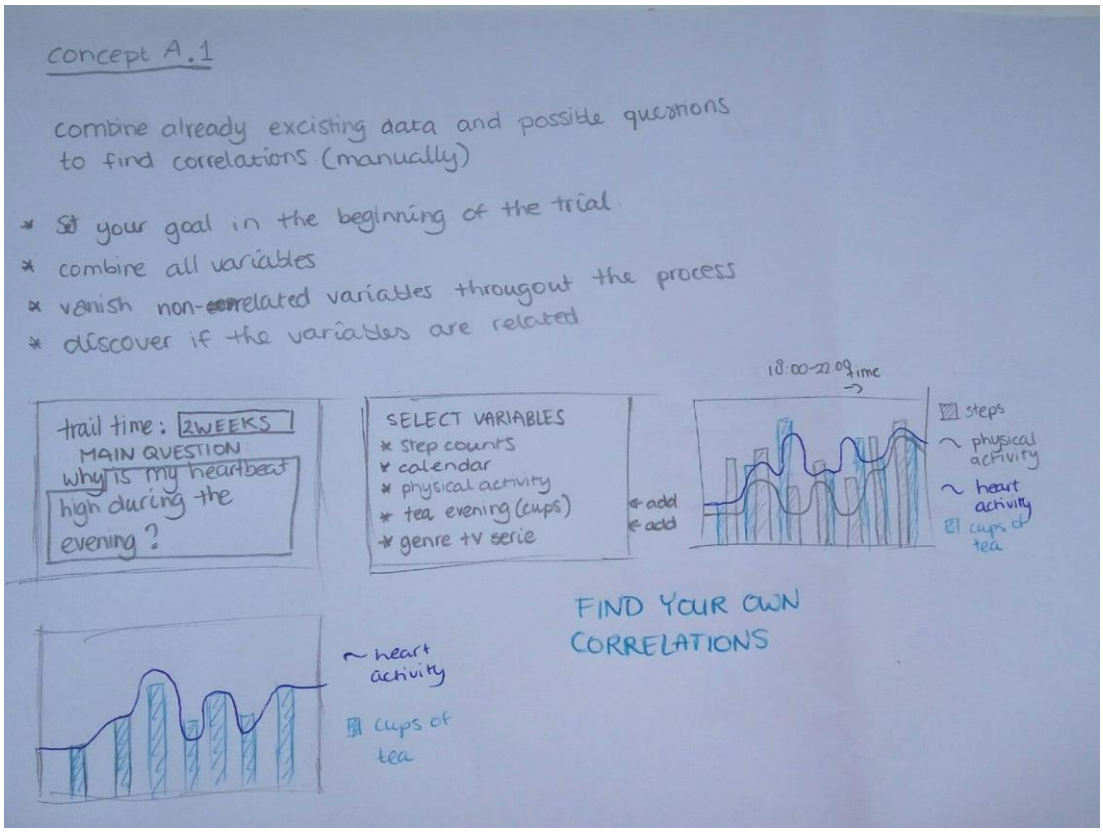


Figure 12, Drawing and explanation of concept A1

3.2.2. A2: Tinder your own personal data

The next concept is the concept of A2. This concept is based on the earlier discussed Exist web application and the idea of Tinder[16]. This concept allows the user to judge system-driven correlation data visualizations of various Quantified Self variables. These correlations are displayed at the end of a certain period to the user and the user can then swipe either to the right (like) or left (dislike). In this application swiping to the right will mean that he or she finds this correlation useful and swiping to the left will mean that he or she find this correlation not useful. Furthermore, if the user swipes the system-driven correlation to the right, the user gets the possibility to

[16] Tinder is an online dating platform where users can swipe through potential dating candidates. By swiping to the left the user "dislikes" the other user and by swiping to the right the user "likes" the other user, based on his or her profile. If both users "like" each other, the users are a "match" and get the possibility to chat with each other. https://tinder.com/?lang=en

substantiate the correlation by adding new user-driven sub-variables. These sub-variables are a collection of answers collected by answering a question every day for the duration of a week. Important to notice is that this sub-variable is always a self-reported collection of data, as all self-tracking variables are already analysed by the system to find possible correlations.

For example, the system finds a correlation in physical activity and stress level, the user swipes right and adds as sub-variable the question: "how busy at work are you on a scale from 1-10?". The user now answers this question every day. At the end of the week, the data visualisation displays the three variables in one data visualisation with each other. See Figure 13 for further details.

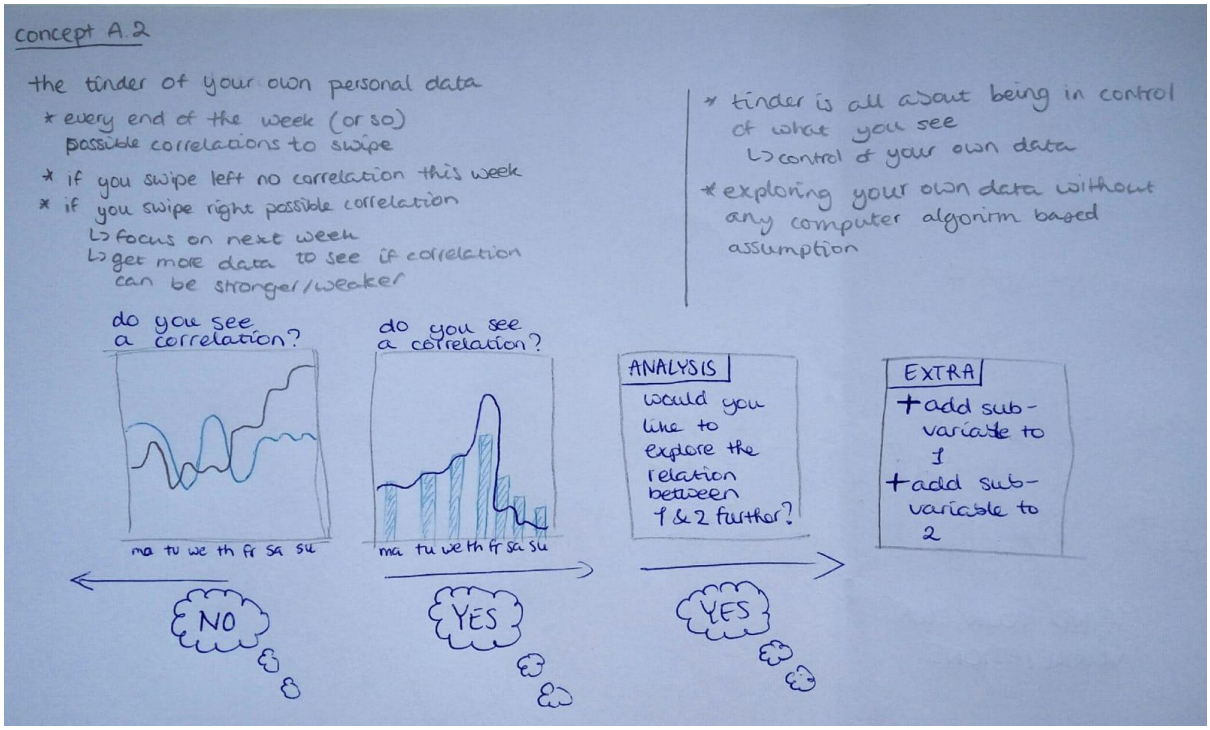


Figure 13, Drawing and explanation of concept A2

3.2.3. A3: Compare your personal data over time

The concept A3 gives the user the possibility to select and compare data of specific periods of time from already tracked data. For example, the user can select the data of the month of November 2018 and the data of February 2019. Once selected, the user selects which self-tracked variables he or she would like to visualize, and the application creates a data visualisation of the selected variables for both selected periods in one graph. The data visualisation thus overlays the selected variables of both periods. See Figure 14 for more details.

This concept will give the user the possibility to discover if his or her behaviour differs during different periods of time. For example, if the user exercises more during the winter or during the summer.

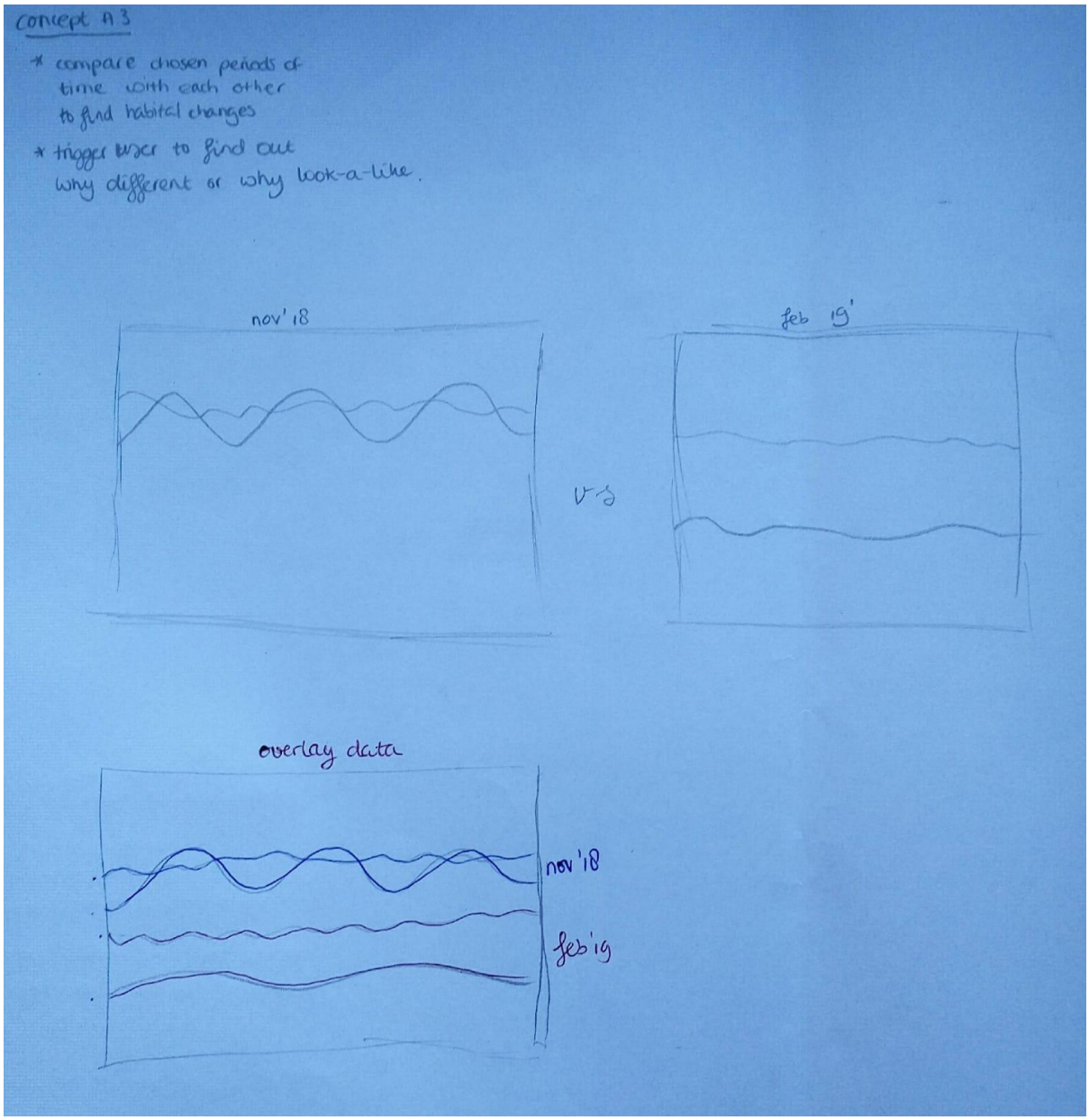


Figure 14, Drawing and explanation of concept A3

3.2.4. A4: Kitchen Discovery Coach

Concept A4 is based on the Glance Clock[17]. This concept is a physical object on its own that can display a data visualisation while being part of the user's surroundings (for example part of the kitchen interior) instead of an application that can only be displayed on your phone or computer. By using an external object to visualize the self-tracked data set up in the daily environment of the user, the data has the aim to become part of the user's daily life.

The data visualisation is combined with a mobile application where the user can select two variables he or she would like to compare throughout the week. At the end of every day, the data visualisation gets updated, such that the user discovers the relation every day of the week a little more. The concept is drawn in Figure 15.

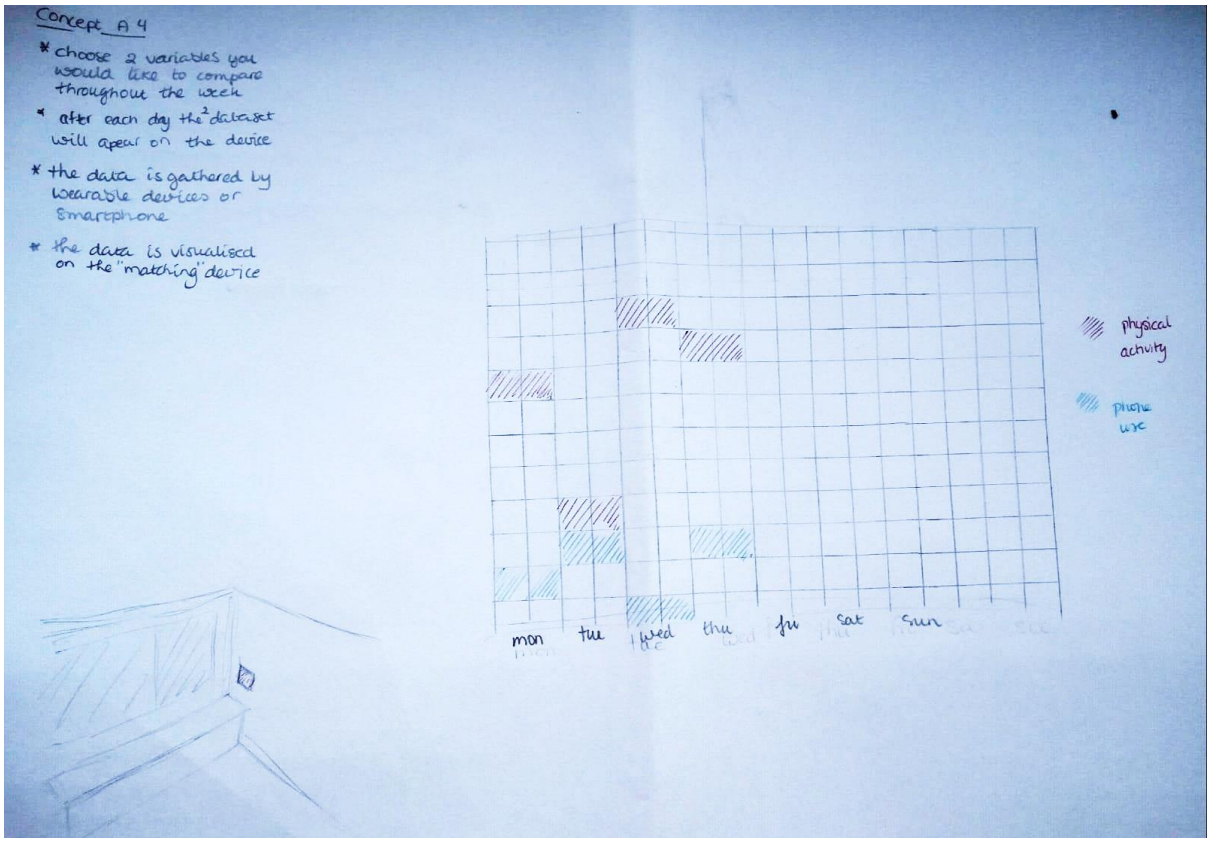


Figure 15, Drawing and explanation of concept A4

[17] The glance clock is a smart clock that display information from all your wearables, smart home devices, and web services. https://glanceclock.com/pages/features

3.3. Concept B – Contextualize your data

In the concepts of segment A, all data visualisations are visualised over time. While time can give a good impression of activities for one week, the activities are more difficult to interpret and understand once the user glances at the data from four weeks ago. Therefore, the four concepts of segment B have the aim to add an extra layer on top of the self-tracking data. Adding an extra layer will give context to the data and make the data easier to understand.

3.3.1. B1: Quantified Self data displayed in Calendar

Concept B1 is the first sub-concept that adds an extra layer on top of the already existing data visualisations. The concept is based on the configuration of Google Fit to Google Calendar (See Table 10 of Section 2.2.3.). As the user displays his online calendar almost every day, the concept enables the user to see the Quantified Self variables embedded per activity of the day. Thereby the user can see if he or she, for example, has a low number of steps once working or has a high heart activity once performing a sports activity. The integration of the Quantified Self variables in the Calendar is visualised in Figure 16 with the use of text. The variables can for example also be displayed in different colours or patterns.

This concept allows the user to easily look back on his or her behaviour during past activities while looking at his or her calendar.

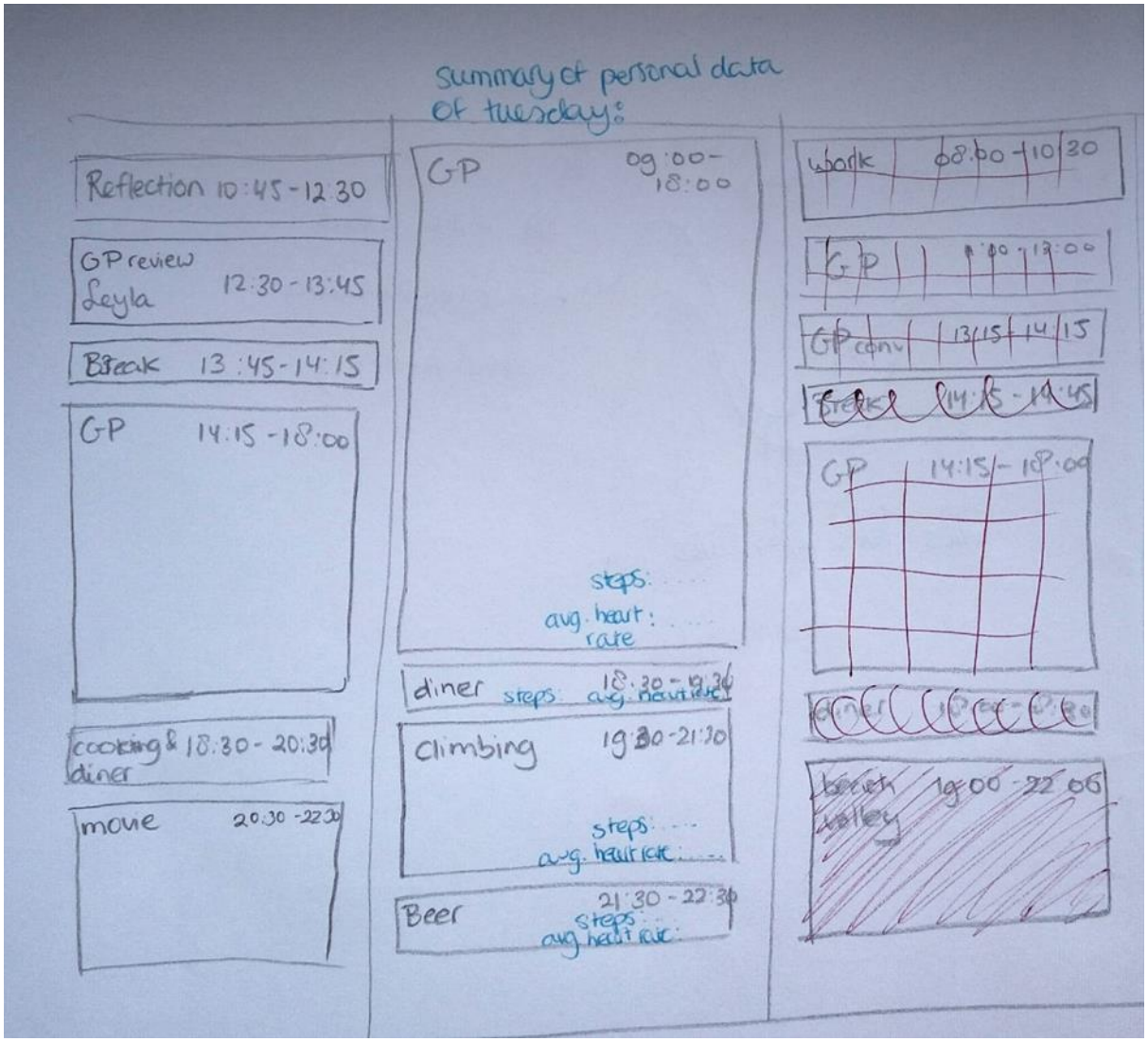


Figure 16, Drawing and explanation of concept B1

3.3.2. B2: Tag your own data

This concept enables the user to tag the activities performed, such as step counts. By tagging a growth in the number of steps, for example, 1500 steps to do groceries or 6000 to go for a run, a data visualisation can be made per activity rather than only over time. Such a data visualisation makes it possible for the user to analyse his or her behaviour per activity. Thereby this tagging function thus gives the Quantified Self data a context and enhances the possibility to let the user discover his or her habits during various tags. Substantiating drawings are made in Figure 17. The

concept is inspired by the data visualisation of the heart activity from fans during a football game by Fitbit[18].

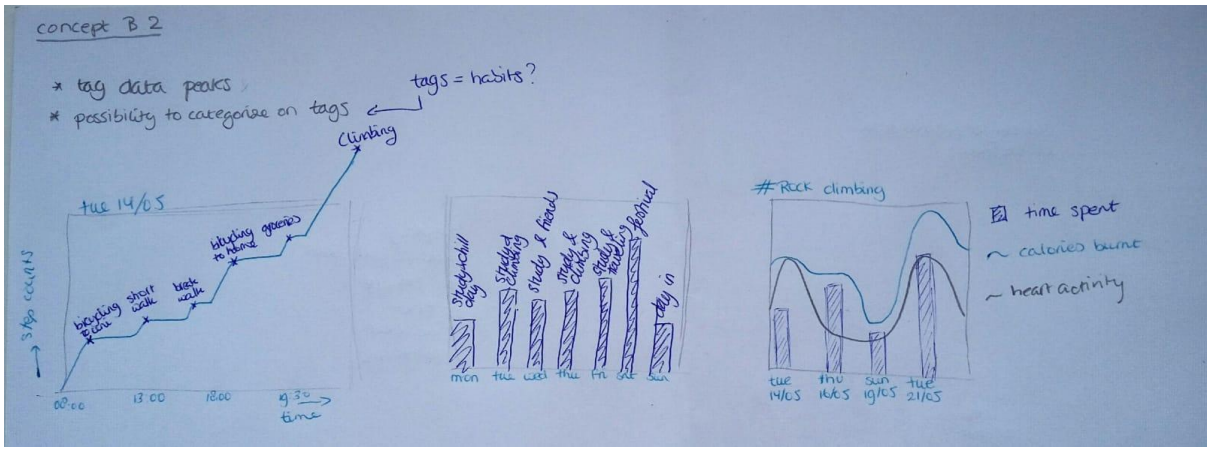


Figure 17, Drawing and explanation of concept B2

3.3.3. B3: Connect own data to your location

The third concept, concept B3 also gives context to the data. The user gets the option to track his or her activities throughout the day based on his or her location. Every time the user enters a new place the application will send the user the question if he or she is currently in the place the device thinks he or she is. If entered "yes", the application will track the possible Quantified Self variables and attach these values to the location. Collecting these datasets per location can give the user an insight of system-driven averages (time spent, steps taken, productivity, minutes active on phone) of each location, by using, for example, a heat map as data visualisation. This overview enhances the user to think about his or her behaviour in different places.

[18] In this data visualisation the viewer can clearly see that the activities, such as break time or touch down, during the game influence the heart activity of the fans watching the game. https://blog.fitbit.com/heart-racing-moments-from-the-big-game/

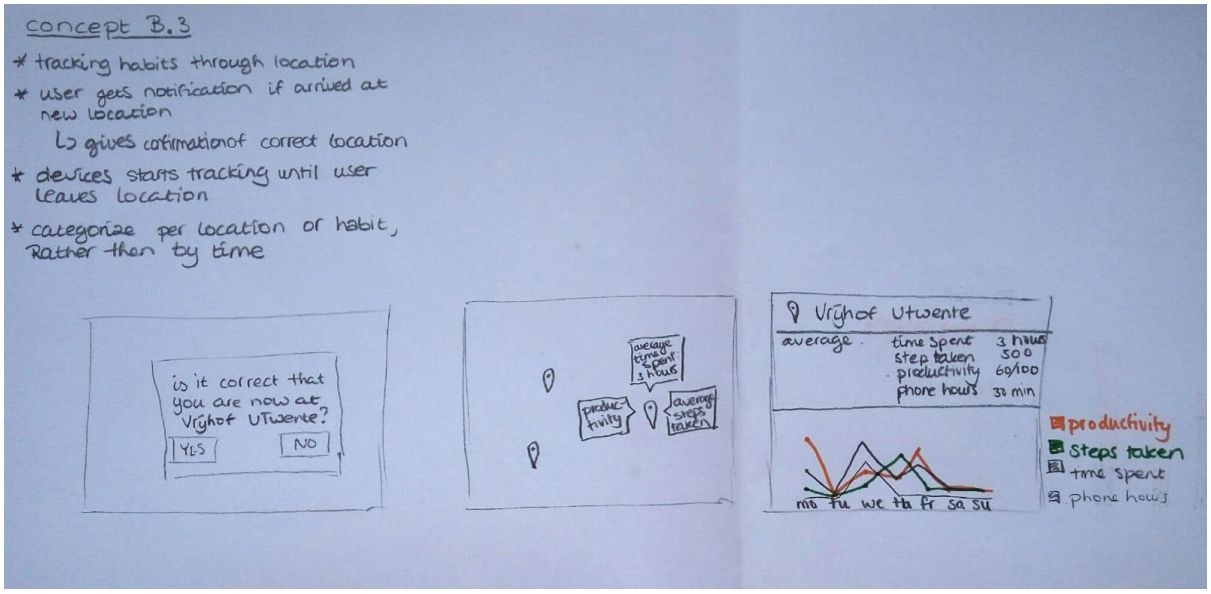


Figure 18, Drawing and explanation of concept B3

3.3.4. B4: Connect emotions to own data

The last concept is B4. This concept enables users to connect emotions to a Quantified Self variable, inspired by the application Moodjam[19] and artwork of Laurie Frick[20]. The user can formulate his or her feelings in colour, during random moments of the day. These feelings can then be combined with a self-tracking variable, such as step counts. For example, the combination of these data sets can be made into a data visualisation where the length of the bar in the histogram visualises the number of step counts and the colours of the bar indicate the mood of the user (See Figure 19).

This data visualisation enables the user to discover whether his or her mood changes his or her behaviour.

[19] Moodjam is an online application that allows users to track his or her mood during the day. The user can give his or her mood a colour he or she finds appropriate. The data visualisation of each day, week or month is thereby displayed in various colours. http://moodjam.com/

[20] This artwork is a physical and colourful representation of the mood of the artist based on the personal data collection of the artist using Moodjam. https://www.lauriefrick.com/mood-quantify

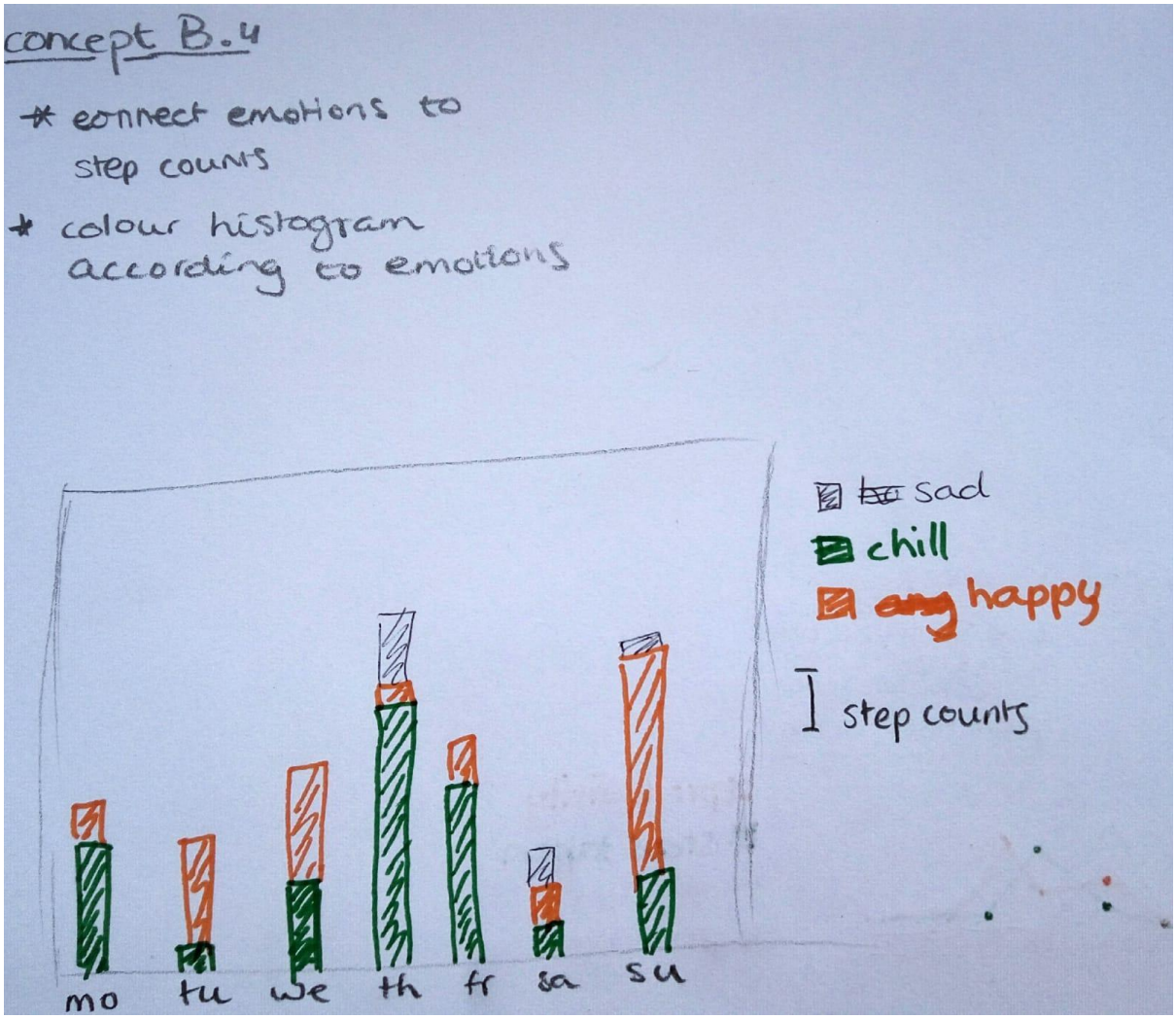


Figure 19, Drawing and explanation of concept B4

3.4. Conclusion

Although all concepts do have the potential to create the transition from Quantified Self to Qualified Self as they meet the set objectives discussed in Section 3.1, only one final concept will be made during this graduation project. So, a decision must be made. To make this decision Chapter 4 will first specify the needs of the target group and identify the variables that will be used to create the Quantified Self of the target group (university students). Secondly, the requirements of the Quantified Self of the university students will be validated against the eight concepts, in order to find the most fitted elements of the different concepts to ultimately form the final concept. The elements are descriptively described in Table 12 as a summary of this Chapter and to give an overview of the differences and correlations between the concepts.

Table 12, Overview of the concepts

Elements	A1	A2	A3	A4	B1	B2	B3	B4
Discover self-tracking data in a **goal-oriented** system. A data visualisation of user-driven combined variables that aims for finding **correlations**.	√							
Discover self-tracking data by **liking or disliking** system-driven found **correlations** of variables. Once a correlation is liked the correlation can be further explored by collecting more data based on a user-driven questionnaire.		√						
Compare various variables **of two periods** of time in a data visualisation to find possible **correlations**			√					
Make the data visualisation **part** of the **habitat** of the **user** by installing a device in e.g. the kitchen.				√				
Integrate the self-tracking **data** per **activity** mentioned in the personal online **agenda** of the user.					√			
Tag self-tracking **data peaks** with activity labels, to create habits and later **visualize variables per habit**, instead of over time.						√		
Visualises the self-tracking **data** per **visited location**.							√	
Combine self-tracking data of **physical activity** with the **mental condition**. Creates a data visualisation of the variables coloured in the **colours** of the user's inserted mood.								√

4. Specification phase

So far, the transition of the Quantified Self to the Qualified Self has been expressed in a rather abstract terminology. Namely, only examples of Quantified Self variables or Qualified Self expressions have been described, consequently, no concise details of what data will be used or what data visualisation will be made have been described. The aim of this chapter is to specify both these details with the use of a target group, a key factor and a corresponding user scenario. These specifications can then define the functionalities of the final concept based on the concepts described in the Ideation phase.

4.1. Choice of data to create Quantified Self

The data visualisation will be designed for university students. In order to make the visualisation useful for students and enable the transition from the Quantified Self to the Qualified Self, the students will need to be able to learn from his or her visualised behaviour. Apart from being personal, the displayed data in the visualisation also needs to be relevant for all students. So, stress will be used as the key variable in the data visualisation, as stress is a common struggle among university students. Most students experience stress in a certain period of their student life (Campbell et al., 1992; Abouserie, 1994). The students are insecure or uncertain about how to prevent or handle stress. So, using stress as the key variable in the data visualisation will give the students the opportunity to learn from his or her behaviour while experiencing stress.

4.1.1. Possible factors related to stress

The idea of the data visualisation is, therefore, to combine the user's level of stress with the other Quantified Self variables in one data visualisation. The Quantified Self variables of the students will be expressed in factors that can be possibly related to stress. Multiple research studies have described various factors as being related to the stress experienced by students. A summary of the found factors is defined in Table 13. In this table, the factors are categorized in dimensions and there is explained how these factors can be transformed into useable quantified data. The quantification is necessary in order to display the factors as Quantified Self in the data visualisation.

The essence of combining these factors with the user's level of stress in a data visualisation is that the user can get an idea of his or her behaviour during for example a stressful week. Moreover, the visualisation will give the student the possibility to explore if his or her behaviour differs when experiencing stress or when not experiencing stress, so if correlations between the factors and the level of stress can be found.

Table 13, Correlated factors of stress among university students

Factor	Data-Input	Dimension	Source
Headaches	Self-report	Physical	(Bhargava & Trivedi, 2018; Thawabieh & Qaisy, 2012)
Tense muscles, sore neck and back	Self-report	Physical	(Bhargava & Trivedi, 2018; Thawabieh & Qaisy, 2012)
Physical activity and exercise	Tracking	Physical	(Pierceall & Keim, 2007)
Sleeping behaviour	Tracking	Physical	(Bleasdale & Humphreys, 2018)
Heart activity (ha)	Tracking	Physical	(Thawabieh & Qaisy, 2012)
Boredom	Self-report	Psychological	(Bhargava & Trivedi, 2018)
Anxiety	Self-report or tracking	Psychological	(Bhargava & Trivedi, 2018)
Restlessness	Self-report	Psychological	(Bhargava & Trivedi, 2018; Thawabieh & Qaisy, 2012)
Tired	Self-report or tracking sleeping behaviour	Psychological	(Thawabieh & Qaisy, 2012)
Inability to concentrate on study	Self-report or tracking of computer behaviour	Psychological	(Sharma & Kaur, 2011)
Humour	Self-report	Psychological	(Abel, 2012)
Ability to 'let go' of emotions	Self-report	Psychological	(Bleasdale & Humphreys, 2018)
Mood	Self-report	Psychological	(Bhargava & Trivedi, 2018; Wang Et Al., 2014)
Problems with relations	Self-report	Social	(Thawabieh & Qaisy, 2012)
Contact with family and friends	Self-report or tracking calendar	Social	(Thawabieh & Qaisy, 2012)
Inability to balance study and leisure time	Self-report or tracking calendar	Social/ Academic	(Sharma & Kaur, 2011)
Worried about academic progress	Self-report	Academic	(Thawabieh & Qaisy, 2012)
Amount of self-study	Self-report	Academic	(Thawabieh & Qaisy, 2012)
Less vacation/breaks	Self-report	Academic	(Sharma & Kaur, 2011)
Upcoming examination and deadlines	Self-report	Academic	(Sharma & Kaur, 2011; Wang Et Al., 2014)
The load of work that needs to be done	Self-report	Academic	(Sharma & Kaur, 2011)

4.1.2. Choice of possible factors related to stress

The factors mentioned in Table 13 are only an indication of possible factors that could give the user extra information about why and how he or she is experiencing stress. As not all factors can be visualised in one data visualisation nor are interesting enough for the students, a user scenario is used to see which factors are useful to use as variables for the data visualisation. A user scenario is a tool to sketch the data visualisation in the environment of a potential user. The utility of a user scenario is to get to know in which situation and for what reason the user would use the application. For this project, the user will be Christina a twenty-one-year-old student of the University of Twente.

Based on this user scenario a factor of each dimension will be chosen. So, eventually, four factors of all found factors defined in Table 13 will be used for the data visualisation of this graduation project.

User scenario

Christina is busy studying for her exams, which are part of the last module of her second year. The exams are in two weeks and Christina is nervous about whether she will have enough time to learn all assigned materials by heart. Therefore, she has made the decision to have no sport commitment for the upcoming weeks, such that she can completely focus on her exams only. However, her concentration to study is nowhere to be found. And as the time flies by, she is busier with checking the newest video clips on YouTube and scrolling through her Facebook than actually following her intended plan: studying. On Friday, after the first week, she is wondering why she still needs to study so much while the only thing her calendar says she has done this week is spending time in the library to study. She is even more tired and stressed than last Monday, even though she spent her time focussing on one thing only; studying.

Christina is confused and would like to know if the fewer days remaining before the exams are the only factor influencing her stress. She thus would like to reflect on her behaviour and learn what other factors might involve the increase in stress, such that she knows what to do differently in the last week before the exams. To do so, she uses an application of a data visualisation displaying her stress level in relation to possible related factors. She first answers the questions with an 8 out of 10 for her stress level of Friday and 'irritated' as her mood in the application (as she has been doing every day for the past week).

Then she views her dashboard. In this dashboard, a graph is displaying her behaviour in multiple factors for each day of the last week. She can see that her stress level increased from a 5 on Monday

to an 8 on Friday. She can see that she spent a lot of time studying, a short period of time having social activities and no time performing sports activities. Furthermore, she sees that her number of step counts is significantly lower than during a 'normal' week. And finally, she sees that her mood of this week is best described as tense or irritated.

Although she expected most of these outcomes the results are different compared to a non-stressful week. This makes her wonder whether this deviation in behaviour, compared to a 'normal' week, can be the cause of her stress. She starts interacting with the data visualisation and discovers while comparing multiple factors to her stress level that her stress level reduces once she has a social activity in the evening and increases once she has a social activity during the day. Also, she discovers that while her intentions were to study every day for 8 hours, she only managed to study 4 hours every day.

So, the reflection of her behaviour using the data visualisation makes her conclude that she would like to plan her social activities only in the evening and try out small walking breaks by herself instead social activities while studying. In this way, she also increases her physical activity and hopes that these walks will help to reduce her stress and feeling of being tensed.

The next week she sees a small decrease in stress and improvement in study efficiency. However, it does not completely satisfy her needs. Thus, in the future, she explores different methods aiming to understand her stress better and better.

The user scenario sketches four factors that could be used as the factors for the data visualisation. It is also considered that these factors are most practical to use as Quantified Self variables, as they can be measured. In Table 14 the factors that will be used for the data visualisation are concluded.

Table 14, Filtered factors related to the stress of university students

Factor	Dimension	Source
Physical activity and exercise	Physical	(Pierceall & Keim, 2007)
Mood	Psychological	(Bhargava & Trivedi, 2018; Wang Et Al., 2014)
Contact with family and friends	Social	(Thawabieh & Qaisy, 2012)
Upcoming examination and deadlines	Academic	(Sharma & Kaur, 2011; Wang Et Al., 2014)

4.2. Choice of concept to create Qualified Self

The four chosen factors and stress level as discussed in the previous section will be displayed as variables in the data visualisation. How the concept of the visualisation will be chosen will be discussed in this section. The choice of the concept is of importance because the concept sets the fundamentals of the design of how personal data will be interpreted by the user.

4.2.1. Analysis of concepts

The various concepts described in Chapter 3 will be recruited on functionality to assure that insight of data can be created by the user, as the main objective of the concept is to extend the Qualified Self. The Qualified Self can be extended by the user if he or she can learn from his or her data. In this case, the function of the data visualisation will be to display how the data of the user changes relatively to experiencing stress. Thus, the data visualisation should enable the option for the user to compare his or her stress level directly to other possible factors. With stress as the key factor (See Figure 20) the data visualisation should deviate from the common data visualisation.

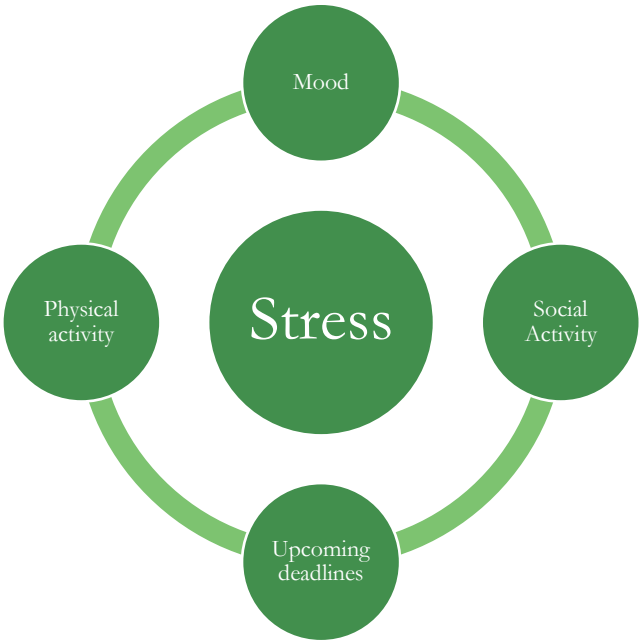


Figure 20, All factors to be displayed in the data visualisation

In the State-of-the-Art data visualisation (such as Fitbit or Google Fit) of factors, the factors are correlated to time, e.g. step counts on y-axis and period of time on the x-axis. As the aim of the visualisation is to correlate the stress level to the factors. The period of time should be replaced with stress level to make the correlation possible (e.g. step counts on the y-axis and stress level on the x-axis). Furthermore, the chosen factors and stress level will need to be collected as quantified variables in order to make the visualisation of the stress level and factors and possible. These

quantified variables are described per factor in Figure 21 (see Section 5.1.1. for detailed explanation). Most importantly to notice is that the quantified variables are either stored as an integer of string. An integer can be defined as a whole number and a string can be defined as an object that represents sequences of characters. The design of the data visualisation is dependent on this technical detail if correlations in stress level and factors want to be found, because mood and activities can otherwise not be compared to the stress level of the user[21].

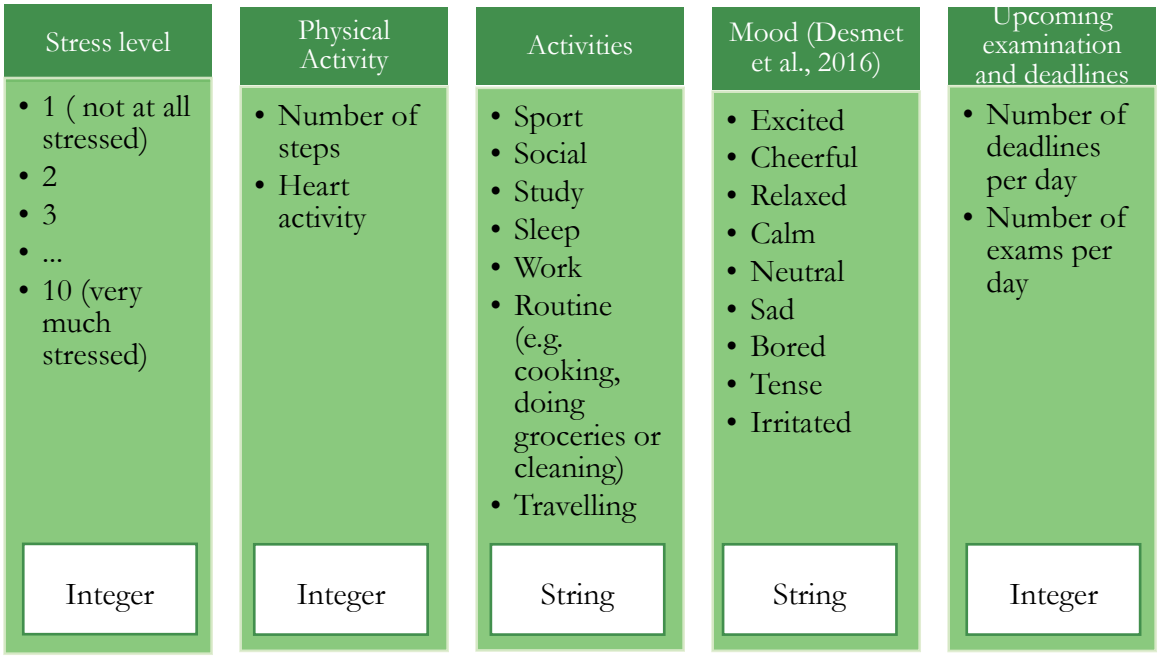


Figure 21, Quantified variables of stress level and factors

[21] For example: If the measurement of the stress level on Monday where 6 and 7 and the mood on Monday was Exited and Cheerful. The values of the integer stress level can be displayed as a line chart; but the values of the string mood cannot be displayed as a line chart.

4.2.2. Conclusion of the final concept

To sum up the analysis Table 15 is made. In this table, each concept is evaluated based on the requirements concluded from Section 4.2.1. The evaluation states that concept 'A1: Find your own correlations' and concept 'B2: Tag your own data' fulfil all requirements and are therefore used as essential parts for the final concept.

Table 15, Fulfilment (coloured green) or non-fulfilment (coloured red) of the requirements of the concepts

	Possibility to let the user compare all multiple factors	Possibility to compare stress level directly to a different factor	Possibility to compare categories (strings) to numbers (integers)
A1: Find your own correlations	x	x	x
A2: Tinder your own personal data	-	x	x
A3: Compare your personal data over time	-	-	-
A4: Kitchen Discovery Coach	-	x	-
B1: Quantified Self data displayed in Calendar	-	-	x
B2: Tag your own data	x	x	x
B3: Connect your own data to your location	-	-	-
B4: Connect your own data to your emotions	-	x	x

The final concept will thus have the functionality to let the user discover the correlation in data his or herself by interacting with his or her data (concept A1) and will have the option to visualise and compare each data set of a factor with another (concept B1).

5. Realisation phase

This chapter will consist of the realisation of the data visualisation. Firstly, an explanation of how the data will be gathered along with the functionality of software used to make the data visualisation will be explained. Secondly, the design of the data visualisation will be explained. In this section, it will be explained how the dataset will be displayed inside the data visualisation made with Tableau Desktop.

5.1. Technology used

In order to realise the data visualisation, the collection of data in a dataset first need to be defined and realised. So, the construction of the dataset will first be explained, followed by a description of the software used to design the data visualisation.

5.1.1. Dataset

The dataset designed for the data visualisation will exist of the stress level and the four chosen factors as described in Section 4.1.2. As the factors are established with extensive questionnaires or literature reviews in the found academic literature and are thus not designed for self-tracking, the factors need to be adapted in a way they can be expressed as Quantified Self variables. The adaptations of these factors to variables are given in Figure 22. Additionally, the values of the variables are also given. The adaptations are further explained below the figure.

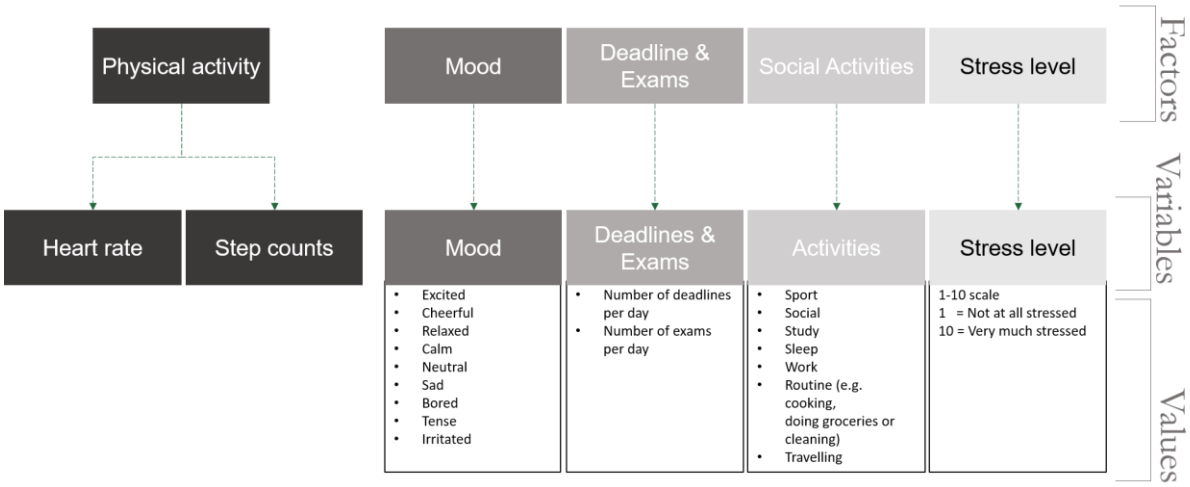


Figure 22, the adaption of factors to Quantified Self variables

The factor of physical activity will be expressed in heart activity and step counts. Both these variables can be accurately measured by every self-tracking device. The used variables give the user an impression of the insensitivity of the physical activity (heart activity) and the quantity of the physical activity (step counts). The factor of mood will be expressed in nine values; each value is

an expression of mood taken of the pick-a-mood expression board designed by Desmet et al. (2016). These nine expressions offer a comprehensive choice of mood for the user. To continue, the factor of deadlines & exams will be expressed in values giving the number of deadlines and exams per day. The factor of social activities will be expressed as a value in the variable activities. Each value of the variable activities will categorize every hour in a type of activity, such as sleep, study or social. The factor of social activity is thus only a value of the variable activity.

The last factor is stress level, the stress level will be expressed in a value scaling from 1 to 10. For this scale, number 1 will indicate not stressed at all and number 10 will indicate very much stressed.

Next, the Quantified Self variables will need to be collected inside a dataset such that the factors can be visualised. The collection of variables will be described according to the steps given in Figure 23. The first step will be to measure the variables with a self-tracking smartwatch and a daily self-reporting questionnaire. Secondly, the measurements will then be collected by Google Fit (self-tracking) and by SurveyMonkey[22] (self-reporting). If the data is collected it will be stored in the Google data archive (Google Fit) and the SurveyMonkey database. The data of the Google data archive can be downloaded in a comma separated file. This comma separated file will be used as the main database. The data in this file is classified on an interval of 15 minutes per hour per day (e.g. 12:00 17-05-2019; 12:15 17-05-2019; 12:30 17-05-2019). Lastly, the data of the SurveyMonkey will be manually combined using the timestamp as a joined field in the comma separated file. The combined file will be used as a database for the data visualisation in Tableau Desktop. Note that the creation of the dataset will not happen autonomously, it requires the action of a human to download the data of the online databases and merge the data into one dataset.

[22] https://nl.surveymonkey.com/dashboard/ SurveyMonkey is an online platform for making, sharing and storing questionnaires.

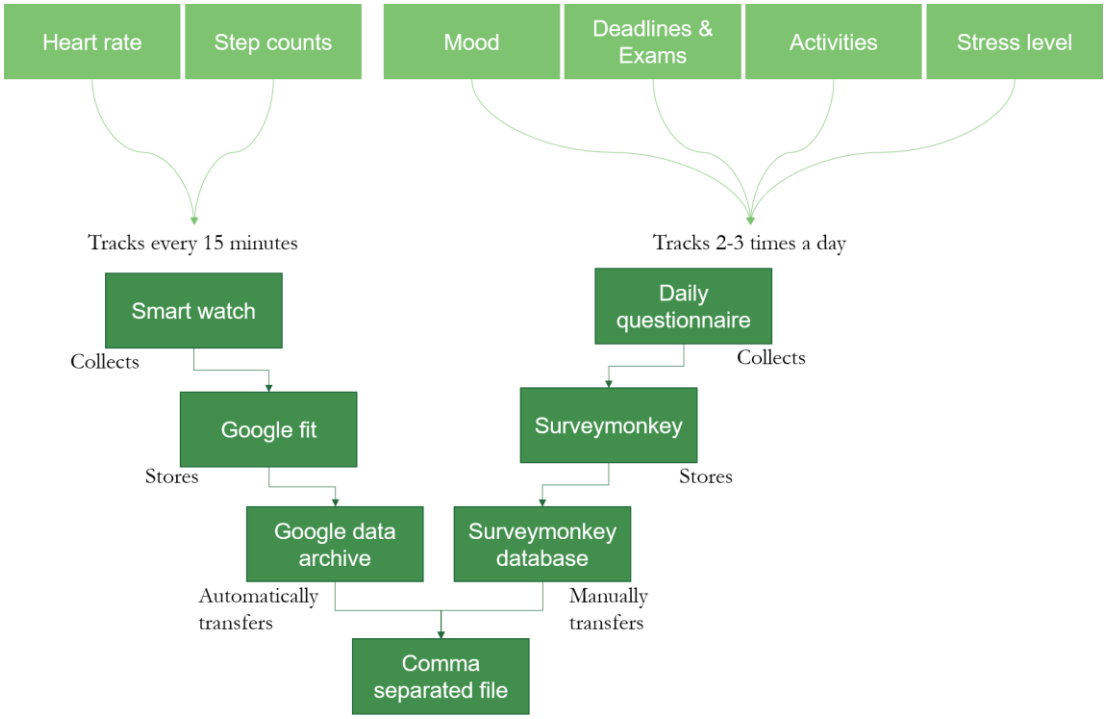


Figure 23, collection of data for the data visualisation

5.1.2. Software

To make the data visualisation the software Tableau Desktop[23] will be used. This software is specially developed to create insightful data visualisations of variables taken from a synchronised dataset. Tableau Desktop allows the designer to configure the final data visualisation in three steps (See Figure 24).

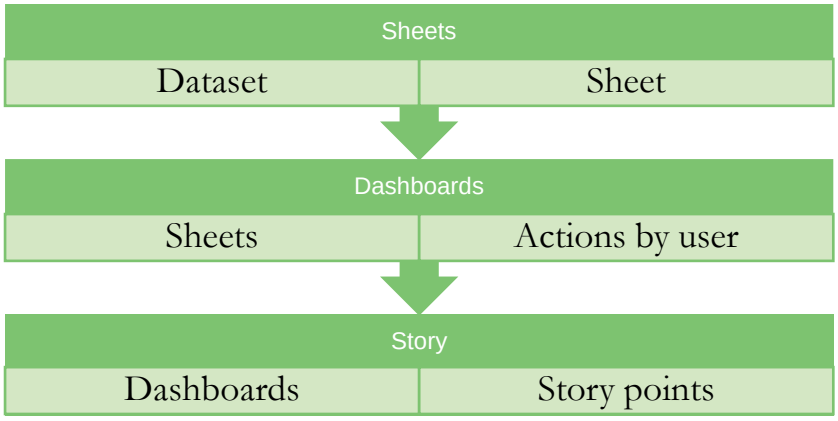


Figure 24, Steps to create a data visualisation with Tableau Desktop

[23] https://www.tableau.com Tableau Desktop is a software that enables the designer to transform data sets in interactive and insightful data visualisations. The software is made in a way to "help people see and understand data".

In the first step, the designer can create multiple sheets by using the variables synchronised from the dataset. The designer can create a sheet by making use of the options available in the interface or by coding. The sheet exists of a graph, this graph can range from a histogram to a detailed dual combination graph including labels and various colours. Any imagined graph can be made in a Tableau sheet if the dataset is interpreted correctly by Tableau and the designer has the required programming skills. (See the tree map inside the red square of Figure 25 for an example of a sheet)

The created sheets can be combined in a dashboard. This dashboard allows the designer to program actions between sheets. For example, the designer can create an action between sheet 1 and sheet 2 in a dashboard with as consequence that the variable of sheet 2 will be highlighted when the user clicks on a correlated variable given in sheet 1 (The explained action is visualised inside the green square of Figure 25). So, the dashboard allows the designer to give the user a view of multiple sheets on one page and thereby also discover correlations between the variables given in the different sheets.

The final step in Tableau is the creation of a story. This option gives the designer the opportunity to display the dashboards as a virtual booklet. In the story the designer can add story points, or chapters so to say, that will visualise the dashboard. The story function thus allows the designer to create a story out of multiple dashboards, by displaying the dashboard one by one to the user in any desired order. The story will be the final prototype that will be displayed to the user. (An example of the first page of a story is given inside the blue square of Figure 25)

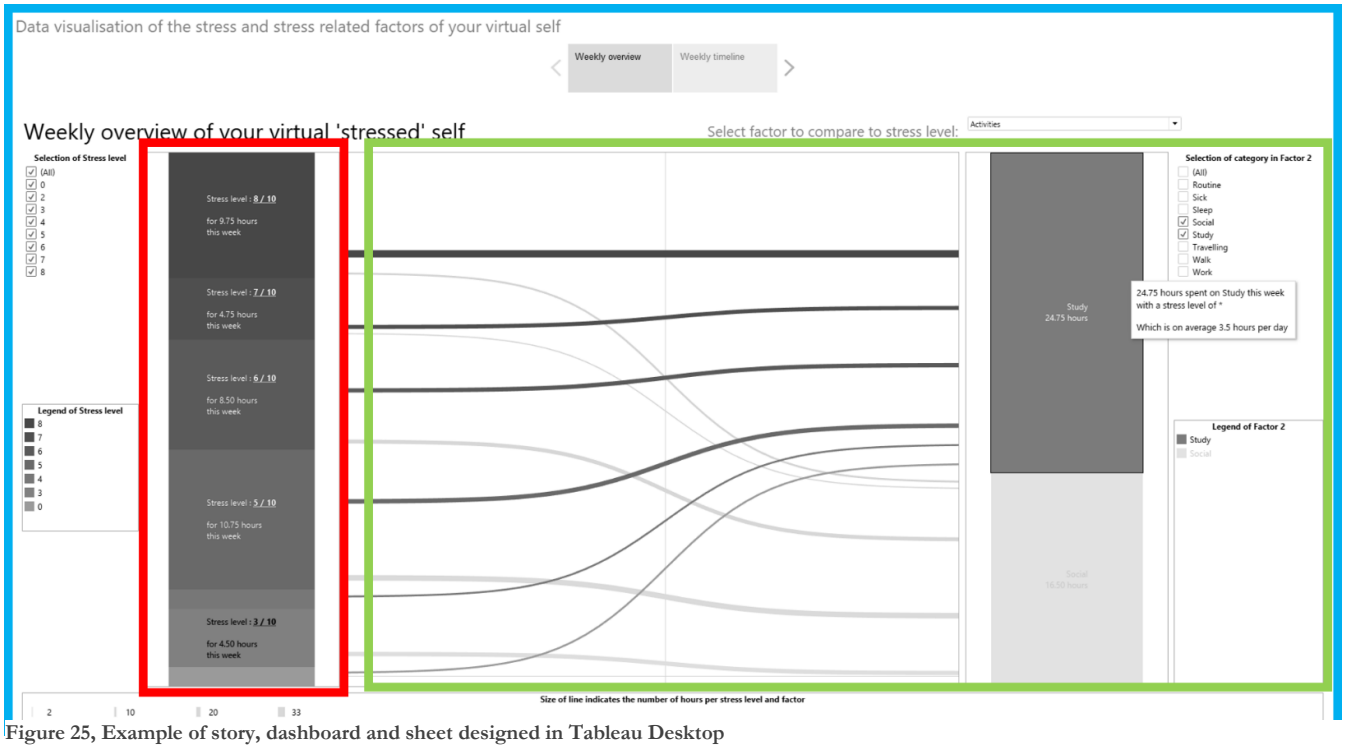


Figure 25, Example of story, dashboard and sheet designed in Tableau Desktop

5.2. Design of the final data visualisation

The data visualisation will be a story created in Tableau Desktop. The story will have the title: "Data visualisation to explore the behaviour of your virtual self in relation to stress" and will visualise Quantified Self variables of one week of one user. The data visualisation will enable the user to interact with his or her personal data in three, so-called, story points. The story points will be described in the following three subheadings of this section. The last subheading will describe the noteworthy elements of the final data visualisation.

5.2.1. Story point 1

Story point 1 will have the title: "The weekly overview of your virtual 'stressed' self". In this story point, a dashboard is created with the objective to compare the stress level with each other factor while excluding time. The dashboard allows the user to select one of the four factors to compare to his or her stress level, for example, mood. Consequently, the data visualisation will visualize the relation between the mood and the stress level of the user. Further, the data visualisation gives the user the option to include or exclude values of the stress level and the chosen factor, for example, the user can select stress level "10" and see which expression of mood he or she usually has if experiencing very much stress. Or, for example, the user can select the variable heart activity and include the values "very high heart activity" and "light heart activity" of the variable heart activity and compare how these values are related to the values of the level of stress and see if there is a correlation.

The relation between the stress level and the selected variable will be displayed in a Sankey diagram. A Sankey diagram is a diagram designed to visualise relations between values based on the Sigmoid function[24]. This function connects two points in space with an "S"-shaped curve. So, the Sankey diagram will connect every value of the stress level to every value of the chosen variable if they are related (See Figure 26). The values are related if they appear in an equivalent 15-minutes timeslot, as this timeslot is the joined field[25] (See section 5.1.2.).

Furthermore, the size of the curve (the relationship between the stress level value and the chosen factor value) will indicate how many times both values appeared in an equivalent timeslot. In other

[24] $S(x) = \frac{1}{1 + e^{-x}}$

[25] An example of related values can be "very high heart activity" to stress level "10" as the dataset indicates: 19:00-19:15 17-05-2019 stress level: "10" and heart activity: "very high heart activity"

words, the more often related values appear in an equivalent timeslot the thicker the size of the curve between the two related values. Thus, the Sankey diagram also allows the user to discover the strongness of a correlation between the two values.

As the last option, the data visualisation will give the user the possibility to highlight the connection of the value between the related values on the other side. The aim of enabling this interaction is to make a comparison of values easier. The user can highlight the connection by hovering over a value or curve.

All described interactions are displayed in Appendix B.

Figure 26, Screenshot of story point 1, with Mood as selected factor

5.2.2. Story point 2

The second story point will have the title: "Weekly timeline of stress level and selected factor: x. The dashboard created in this story point will have the objective to let the user discover how his or her behaviour in relation to stress is classified per weekday. The main sheet of the dashboard is a timeline displaying data per day for seven days. In this timeline, all chosen variables can be related to the stress level of the user. The stress level will be displayed in a line graph while the chosen variable will be displayed in a bar graph per day in this timeline (See Figure 27). Dependent on which factor is selected by the user, the data visualisation will show the related values in different coloured bars per day. The longer the length of the bar, the more hours spent on the value.

In addition, the user can also relate the stress level to timeline of the deadlines and exams of the week, as a sheet consisted of this factor is displayed underneath and aligned with the main sheet.

So, for example, the user can select 'activities' as a variable with 'study' and 'sleep' as values (As displayed in Figure 27). If so, the data visualisation will give the user the possibility if the number of hours spent on sleep or study per day influences the level of stress. This possibility allows the user also to discover which day he or she spent the most time on studying and if the amount.

Apart from this, the user can also see if the scheduled deadlines or exams influence his or her stress level. In this way, the user can discover that the stress level increases when a deadline is nearby and decreases when the deadline has been passed (See Thursday in Figure 27).

Lastly, the user can interact with the data visualisation by clicking on, for example, the value 'study' in the legend of the chosen variable 'activities'. By doing so, the user can discover how much time he or she spent on average on studying per week and which day he or she spent the most or fewer hours on studying of the displayed week.

All interactions explained are displayed in Appendix C.

Figure 27, Screenshot of story point 2, with activities as a selected factor

5.2.3. Story point 3

The last story point of the data visualisation will have the title: "Compare your stress level to selected factor: x and selected factor: y of the selected day: z". This story point will be the last point of the story and will be the most detailed. The objective of this visualisation is to let the user discover if the two chosen factors are dependent two each other if they are both related to stress. To make this comparison of two factors possible, it is chosen to filter the data on a selected day. In this way, the user can display the two factors of one day related to the stress level per hour (See Figure 28).

So, for example, if the user selects 'heart activity' as factor x and 'step counts' as factor y. The user can discover whether the increase in heart activity (See 19:00-20:00 in Figure 28) is due to physical activity or due to the stress level for example. In this case, it is more likely that the increase in heart activity is due to the increase in stress level than due to physical activity since no steps were taken between 19:00-20:00.

The user can highlight per hour both chosen factors in relation to stress by hovering over the values. Furthermore, the user can again include and exclude values of the chosen factors in the

timeline. As an addition, the deadlines and exams of the chosen weekday are also visualised in a sheet next to the other two sheets.

(The described interaction steps are displayed in Appendix D)

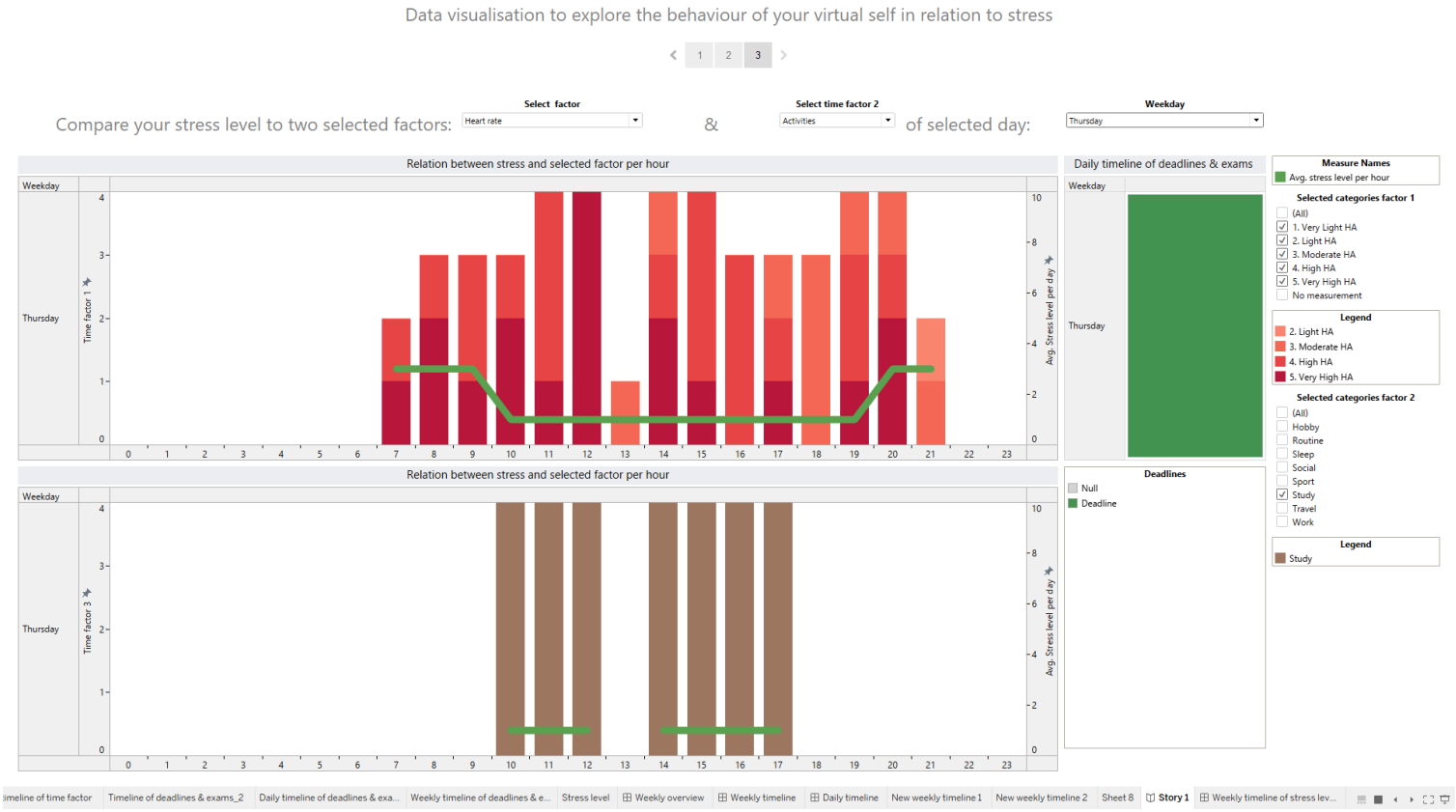


Figure 28, Screenshot of story point 3, with heart activity and step counts as selected factors

5.2.4. Noteworthy elements

The first noteworthy element in the final data visualisation will be indicating the stress level of stress in the colour green, as academic study indicate that the colour green is seen as a relaxing and comforting colour among students (Naz & Epps, 2004). This is intentionally decided to prevent the outcome of the user experiencing extra stress once seeing his or her stress level in a data visualisation.

The second element is the range of heart activity. The heart activity of the user is categorized into five ranges; Very Light Heart Activity; Light Heart Activity; Moderate Heart Activity; High Heart Activity and Very High Heart Activity. This range is made to be able to give the user an indication of the meaning of the measured heart activity, as a number ranging between '60' and '100' will be difficult to interpret by a user with no prior knowledge of heart activity.

Lastly, step counts will be excluded as a selected factor in story point 1, since the variable will exist out of too many values to visualise in a Sankey Diagram. This is so because the number of step counts is recorded every 15 minutes and is dependent on this interval. The dependency of the interval will lead to a high number of values, as a different number of steps is recorded every 15 minutes.

5.3. Conclusion

The three story points form the final data visualisation. The final data visualisation is designed to enhance the transition from the Quantified Self to the Qualified Self. However, the design will need to be evaluated in order to check whether the data visualisation functions as intended. This will be done in the next chapter. In this chapter, a usability test will be performed to find possible design flaws and discover if the Qualified Self of the user is extended with the gained insight into the Quantified Self data visualisation.

6. Evaluation Phase

The evaluation phase will consist of a usability test. In this chapter the protocol and set up of the test will first be described, followed by a description of the diversity of the participants. The results of the test will be explained in the last section of this chapter. In this section, the results will give an indication of the usability of the data visualisation and if the participants have learned about their stress level by displaying the data visualisation.

6.1. Usability test

A usability test gives the researcher the possibility to improve their data visualisation based on the advice of various participants. The objective of this test is to find out whether the data visualisation will be easy to use for the user and will support the user with the reaching of the Qualified Self by interpreting the Quantified Self.

6.1.1. Testing protocol and set up

In order to test whether the data visualisation enables the user to extend the Qualified Self using the Quantified Self a usability test will be performed since the fulfilment of this aim is reliant on the usability and usefulness, understandability of the data visualisation. The usability test will be user-based constructed with a semi-structured interview with the participants. The participants will form a diverse group of five university students. The method of the usability test is based on the research study of Lazar et al. (2017) and will have the following protocol:

Table 16, Protocol of usability test

	What?	**How?**
General	Number of participants	5
	Diversity of participants	The participants will have different genders, average stress level and progress in their studies
	The goals	1. To check whether the data visualisation enables the transition from Quantified Self to Qualified Self 2. To improve the quality of the user interface of the data visualisation by finding flaws in it. These flaws can be discovered by the participants and prevent future users from having problems with the data interface design.

	Privacy	The study is complied with the General Data Protection Regulation (GDPR)[26] and approved by the ethics committee EWI[27]. Also, the participants have read and signed the Information Brochure (See Appendix E) and Informed Consent (See Appendix F)
Preparation	Preparation of the data	The participants will collect the self-tracking data (consisted of the variables discussed in Section 4.2.) for seven days, by wearing a smartwatch[28] and filling out an online questionnaire (See Appendix G) following a time schedule (See Appendix H).
	Preparation of the data visualisation	The collected data will be inserted into the data visualisation using the Wizard of Oz method. This technique enables the researcher to pre-set the data visualisation of the personal data of the subject manually.
Usability test	Introduction	The usability test will take approximately 45 minutes. In the first five minutes, the researcher will explain the structure of the testing session to the participant.
	Setting	The researcher and participant will discuss the data visualisation together. However, the researcher will only ask questions and will not make any statement about the personal data itself.
	Structure	10-15 minutes of letting the participant interact with the data visualisation following a task list (See Appendix I) 25-30 minutes of reflection of the interaction with the data visualisation of the participant. The researcher will ask the participant reflection questions following the structure of a questionnaire (See Appendix I).
	Focus point	It needs to be made very clear to the participant that the interface is being tested, not the participant.

[26] Publishing number: WBP19ME0059

[27] Reference number: RP 2019-65

[28] The participant will wear a Motorola 360 (2nd generation) or a Huawei Watch 2 Sport

6.1.2. Diversity of participants

To reach the participant a request on social media was posted. The registrants were asked for their level of average stress experience and study year. Based on this information and the time of registering five university students were selected (See Table 17). Furthermore, only students with no self-tracking experience with self-tracking wearables are selected to assure that the results of the usability test will lead to the improvement of the data visualisation for a more understandable design for all users. Note, all participants do have experience with either Apple Health or Samsung Fit considering the measurement of their daily step counts.

Table 17, Overview of the diversity of the participants

	Gender	**Age**	**Study**	**Study year**	**Level of average stress experience**	**Experience self-tracking wearables**
Participant 1	Female	20	Bachelor	First	Low	No
Participant 2	Female	20	Bachelor	First	High	No
Participant 3	Male	20	Bachelor	Third	Low	No
Participant 4	Female	21	Bachelor	Third	Medium	No
Participant 5	Male	25	Bachelor	Second	Medium	No

The group of participants is relatively small. However, this will not have a significant influence on the sufficiency of the results because a usability test focusses on finding flaws in the data visualisation.

6.2. Results of usability test

The usability test will consist of first a task list session and second a reflection session (Appendix I). The task list session will consist of the researcher asking the participant to fulfil a task while thinking out loud. For example, the task can be: Interact with story point 2 while thinking aloud. During this session, the user will be asked to observe and interact with all story points in chronological order. The results of this session will be written in an observative style, as the researches have observed how the participants performed the tasks while thinking out loud.

The reflection session results will be written from the user perspective, as he or she provides a reflection on how he or she found the interaction with the data visualisation. The results will be gathered by the researcher by writing the answers of the participants on paper during the test. The

results will be analysed by summarizing for each participant their opinion in general, of the data collection, of the interface and of the results.

As the participant group size is relatively small, inferential statistics will not be possible. Therefore, the results will be analysed qualitatively. So, a short summary, including quotes, will be given for each interviewed participant. (See Table 18 till 22 for the results of the usability test of each participant)

6.2.1. Results of participant 1

Participant 1 is a 20-year-old female, who is currently in her first year of her bachelor. She has a low level of average stress and has no experience with self-tracking.

Table 18, Results of the usability test of participant 1

	Summary
Task list	To start, the user was asked to observe the Story Points (SP 1, SP 2 and SP3) without interacting with the data visualisation. The user seems confused about where to start and does not read the title of the visualisation straight away but starts reading whatever noticed first. She understands that in SP 1 a factor will be related to her stress level. SP 2 is more difficult for her to understand as she guesses that she can choose the time interval in which the data will be visualised, rather than choosing a factor to display over the seven days tracked. SP 3 is where she immediately starts to wonder if the data visualised will be corrected, as her mood will be displayed per hour while it was not asked per hour. "Oh, only now I read the titles of every SP." Once interacting with the SP's, she understands how to change the visualisation according to her desire. The first goal she has is discovering whether the data visualised in the data visualisation is true. And the second goal is to place the data into context; what she was doing during a social activity; why she felt irritated during the day. She understands SP 1 completely and finds the visualisation very interesting. Equally for SP 3, namely the function to relate her stress level to her activities. However, SP 2 does not draw her attention that much, as it only confirms what she thought. "I am curious to find out why I say my mood is calm while my stress level is relatively high" "I can clearly see that I do not stress while I am studying and only stress a little while not studying in the evening. I then remember what I still need to do." "I do find it weird to see that my heart activity is high while studying. It makes me wonder if I think something else then my body says."

	"The emotion exiting is related to stress. This is funny to see, as apparently, I experience positive stress while I look forward to fun activities." "I think my heart activity during work on Sunday was so high because it was really hot. Not because of the fact I was working."
Reflection: *General*	She rates the usefulness with a 9 out of 10 and the possibility to learn her behaviour in relation to the stress of the data visualisation with a 7/10. She substantiates the grades with the explanation that she finds the SP's easy to understand and funny to see. Furthermore, she says that it is a new way for her to see her behaviour in relation to stress. However, she is still questioning why her stress level is relatively lower than her heart activity indicates.
Data collection	She did not find it any problem to fill in the questionnaire, let even alone annoying. She would do it again if asked. But noticeable was that she later indicated to not always take the stress level question that serious: "Once asked for my stress level, I always asked myself once more how bad was my stress really? And consequently, rated my stress level lower." The values of activities felt not complete once asked to categorize activities such as; "Netflix" or "Driving lessons". She advised adding the values Netflix and professional meeting.
Interface	She found it hard to interpret her mood correctly while she found it easy to interpret her activities. She found the data visualisation clear and graded them with an average of a 6.5/10. She found the data good, not too detailed nor too general. She found SP 1 the easiest to read and SP 2 to most difficult.
Results	She did not feel judged by her viewing her own data. Also, she would not change her behaviour according to her findings. She found the data visualisation interesting, however not relevant for her: "I feel okay with how I handle my stress". The data visualisation is more relevant for people who fluctuate in stress level, according to her, since these people can discover a trend in the factors related to stress and see how to change their behaviour respectively.

6.2.2. Results of participant 2

Participant 2 is a 20-year-old female, who is currently in her first year of her bachelor. She has a high level of average stress and has no experience with self-tracking.

Note, the smartwatch did not synchronise with the phone of participant 2. This means the user did only compare the factors activity, mood and deadlines & exams in relation to stress.

Table 19, Results of the usability test of participant 2

	Summary
Task list	Participant 2 did not take the effort to read the headings of the SP's, consequently, she found it difficult to understand what the intention of the data visualisation was. Once interacting, she easily understands the possibility to select different factors and compare the values of these factors to the stress level. However, she finds it awkward to try to understand SP 1, as she thinks this story point is too complicated for her. She does try some things out, but she is not motivated to actively engage with the data. SP 2 is the visualisation that draws most of her attention. She immediately starts to put the data in context, by explaining why her mood and activities are related to her stress level. She discovers some relations. Also, she retains some memories while displaying her behaviour and is a reflection on her behaviour. She cannot make any sense of SP 3 as she says it is confusing and consists of too many different colours. She finds it hard to compare the 2 factors in 2 different graphs. The data visualisation lets her discover the following: "I can clearly see that once I have a short social activity during a study day, my stress level is decreasing. While my stress level is actually increasing if my social activity during my studies lasts for too long."
Reflection: *General*	The usefulness of the data visualisation is graded with a 7/10. She can make sense of the data and see how her stress level is related to her activities. She sees that she is most stressed during studying, while other activities decrease her stress level. Once asked if she has learned from her behaviour in the data visualisation in relation to stress, she grades the data visualisation respectively with a 7/10 too. She says: "I would like to find the perfect balance between hours spent on social activity and hours spent on study activity. The amounts indicated per value per day in SP 2 help me discover this."
Data collection	She found the questionnaires the minimal effort to fill in and indicated that she would do it again in order to get such results displayed. She does not have any comments on the chosen values categorizing the variables. The only comment she has is to split study two sub-categories, namely study in class and self-study, as she has the feeling that she feels less stressed if she is studying in class in comparison with when she is studying by herself. "If I study in class, I feel not responsible for my time management, this is outsourced to the teacher. However, once I study by myself, I feel more pressure to spend my study time well."

Interface	She found SP 1 & 3 difficult to interpret because there were too many lines and colours displayed and consequently graded the usability with a 5/10 and a 6/10. She repeatedly indicated that these are too complicated for her. She found SP 2 the easiest to interpret and graded the usability and amount of data with an 8/10. "The maximum for different variables in one graph is three for me."
Results	She did not feel judged by her own data and expected the results. She will not change her behaviour accordingly to her findings of the data visualisation, as she says: "This is the way I stress, I know it and I am fine with that." But she does mention that she finds her discoveries of the data visualisation useful as it makes her reflect on her week. With the data visualisation, the reflection on her behaviour in relation to stress is possible because of the gathered data during the week.

6.2.3. Results of participant 3

Participant 3 is a 20-year-old man, who is currently in his third year of his bachelor. He has a low level of average stress and has no experience with self-tracking.

Note, the heart activity measurements did not synchronise with the Google Fit of participant 3. This means the participant was only able to compare step counts, activity, mood and deadlines & exams in relation to stress.

Table 20, Results of the usability test of participant 3

	Summary
Task list	While observing, he views the option to select different values at first and lastly reads the titles of every SP. He views the SP's from left to right and discovers all functionalities as intended, he even understands the objectives of every SP. Once interacting, the first thing he does is judging whether the data visualised is correct or not. He then thinks about the story behind the data if discovering a peak or another noticeable aspect. It is clear he understands the intended order of the data visualisation, as he uses the conclusion found in SP 1 to discover why in SP 2. This discovery he then tries to confirm by looking into the data of SP 3. He is attracted to the data peaks and other notable data. Once noticed, he tries to find out why the data is different from other 'normal' data. "I am mostly stressed once I am doing a hobby or am studying, as I am than most aware of my study load."

	"I would like to use the visualisation to discover how much my thoughts are correspondent with the measurements of my body."
Reflection: *General*	He rates the usability of the overall data visualisation with a 7.5/10 because he is convinced the data visualisation allows the user to compare the different factors to stress and to each other. The visualisation can sketch a representation of your body versus your thoughts. However, he rates the functionality to learn from his behaviour in relation to stress with a 5/10, as he is convinced that he already knew that these factors are related to his stress behaviour. Furthermore, he finds the interval of a week too small to conclude a correlation as a fact. He does not have the feeling that stress is more tangible in relation to before he saw the data visualisation, since he says, "Stress is a feeling you have".
Data collection	The self-reported data of the online questionnaire is indicated as truthful as he did not find it much effort to fill in the questionnaire. He found the values of activities ok, but he did miss a category for his "driving lessons". He advised an addition of the value "serious activity". Noticeable, was his comment on stress level and emotion: "I see stress more as an emotion, as it is a feeling. Therefore, I was sometimes what confused how to choose my emotion relatively to my filled-in stress level."
Interface	He found the interface of the data visualisation easy to understand. He found SP 2 & 3 the simplest and SP 1 the most difficult. This can also be related to one of his comments he indicated later in the interview: "I found it most difficult to understand which category of which factor is most related to your highest stress level". Overall, he would rate the usability of the data visualisation with an 8/10 and the displayed data with a 6. He notes that the data visualisation is missing a graph in his point of view. He would have liked the possibility to see the two graphs of SP 3 in one graph, to make the SP easier to interpret.
Results	He would not change his behaviour accordingly to the results he found in the data visualisation. He did not feel judged by the data displayed. The data visualisation was of interest for him, as he would normally not remember a stressful week this detailed. This makes the data visualisation interesting for him to reflect on his behaviour of the tracked week. He convincingly says he does not feel like this data visualisation could support him during his studies, however, he also indicates he would use it again if offered to him. He thinks this data visualisation is of relevance for people who say are not easily stressed, as this data visualisation will offer these people to look more critically to their behaviour (as the body can say something different than the mind).

6.2.4. Results of participant 4

Participant 4 is a 21-year-old woman, who is currently in her third year of her bachelor. She has a medium level of average stress and has no experience with self-tracking.

Note, the heart activity measurements did not synchronise with the Google Fit of participant 4. This means the participant was only able to compare step counts, activity, mood and deadlines & exams in relation to stress.

Table 21, Results of the usability test of participant 4

	Summary
Task list	The first thing she says once observing the data visualisation is "A lot of different small texts, I am not going to read them all.". As she is distracted by these texts, she reads the titles of every SP as last. She is quickly done with observing and continues with the interaction. In the beginning, she finds the interaction complicated, as she does not know what to expect as visualisation. What is apparent is, how she interprets her stress level. Her stress level is not higher than a 5/10 but she does say: "I am comparing my high level of stress to my activities once clicking on the 5/10 stress level box" while she totally forgets she did not experience a high level of stress during the week. She checks if her data is correct while discovering and explains the context behind the data she sees. She does not have a specific objective to discover certain factors in relation to stress. She is rather just playing with the visualisation and attracted to deviations in her data. She finds her relation to activities and stress level weird in comparison with, in her eyes, 'normal' persons. "What I can clearly see in the data visualisation is that my mood is correlated with my stress level. I hereby indicate that I know the consequences of my stress on my mood."
Reflection: *General*	The usability of the data visualisation is rated with a 7.5/10 as she sees her behaviour changing dynamically in figures and not in the text. She does say the data visualisation requires some time to understand the interaction possibilities. The amount of data displayed is ok. It could be more detailed by adding body temperature or skin conductivity. This, because she is interested in comparing her subjective data to her objective data and compare her interpretation of her behaviour to the objective data measured from her body.

Data collection	She found it sometimes annoying to fill in the questionnaire and sometimes she did not find it any effort. However, she indicates that this not influenced the truthfulness of the data visualisation. In activities, she missed a category that would fit "moving".
Interface	The interface was easy and good to interact with once knowing the possibilities. She rated SP 1 with a 7/10 on usability, in SP 1 she found it unclear that the lines indicated the relationship between the values. SP 2 was rated with an 8/10, as this SP had a "good flow and was designed to your intuition". Whereas SP 3 was rated with a 5/10 on usability because the bar charts did not have any function. Consequently, she found SP 2 the easiest to interpret and SP 3 the most difficult.
Results	The user indicated that she found it somewhat awkward to wear a wearable that constantly measures your behaviour. This made her more aware of her behaviour during the day. She would not like to use the data visualisation or track the data again, as she did not gain new insight into her behaviour in relation to stress, only confirmation. Also, because she is convinced that she would become more stressed once seeing that her behaviour indicates that she was really stressed. She, however, did find it amusing to discover that the results of stress in relation to mood are as expected. "I do think the data visualisation is useful for people who are struggling with stress management."

6.2.5. Results of participant 5

Participant 5 is a 25-year-old man, who is currently in his second year of his second bachelor. He has a medium level of average stress and has no experience with self-tracking.

Note, the smartwatch did not synchronise with the phone of participant 5. This means the user did only compare the factors activity, mood and deadlines & exams in relation to stress.

Table 22, Results of the usability test of participant 5

	Summary
Task list	During the observing task, the user starts with reading the headings and gives the impression he will understand what will happen once he can interact with the data visualisation. Once interacting, he does not seem very interested. "I expected these results; I am more interested to find something I did not know yet."

	But he is happy to see that his mood is calmer once he is less stressed. He is trying to discover his data, only does not seem to take the time to do so. He seems to understand SP 2 and places the data into context. It is noticeable that he sees stress as a cause of mood. The one discovery he does has: "I do can see that I am more stressed in the evening than during the day. I think this is because I then always realise what I still need to do."
Reflection: *General*	He gives the usability of the data visualisation a 2/10, as he already knew what he saw. He does indicate that the factors are clearly displayed and recognizable. As he gained only one insight into the data, he rates the possibility to learn from your behaviour in relation to stress a 4/10. Once asked if he finds stress more tangible after seeing the data visualisation then before, he says: "I find stress not something that can be tangible, as it is a natural occurrence and therefore out of your power".
Data collection	He finds it no effort to fill in the questionnaire. He did comment that it would like to indicate his activities per 15 minutes because it is otherwise hard to make sense of the heart activity in relation to stress if, for example, he studied for 30 minutes and bicycled for 30 minutes in one hour.
Interface	He finds SP 1 (4/10) confusing to interpret in relation to SP 2 (8/10) and SP 3 (9/10). SP 2 is the easiest to understand as it flows naturally to your expectations. The amount of data visualised is ok. Not too detailed nor to general. "All data measured is displayed in the data visualisation. I do not miss any data."
Results	The user found it annoying to wear the smartwatch and would not use the data visualisation again if no objective data is displayed. However, if an autonomous stress level measurement was performed, he says he would have been more likely to: "I would like to discover if my opinion about my stress is correspondent to the measurements of my body indicating stress."

6.3. Conclusion & discussion

In order to evaluate the data visualisation, the usability test had two objectives namely, to test whether the transition from Quantified Self to Qualified Self took place (objective 1) and to test the usability of the data visualisation on possible design flaws (objective 2).

It could be stated that objective 1 is partly met, as all users gained insight into their behaviour in relation to stress and thus extended their Qualified Self using the Quantified Self. Even though most of these insights are small, all users were motivated to discover how the factors could possibly have influenced their stress level. The data visualisation offered this possibility as it was designed to compare multiple variables in one graph. The user interaction made the users more part of the data configuration, as they were required to find their own correlation between stress and their behaviour. All users understood this objective. Yet, only one participant understood that the order of the story points could be used to enhance the fulfilment of the objective.

Secondly, the usability test resulted into the finding that the user needs a timeline in order to be able to give context to the data. This is not as expected, as it was argued in the specification phase that the time will have to be excluded in order to compare different variables directly.

Also it is noticeable how the data configuration of each user correspondingly consisted of three phases; 1. Checking whether the data is correct or incorrect; 2. Connecting the data to their personal context (user 1: "What did I do during this social activity that increased my stress level significantly?") 3. Wondering or (try) answering the question: "why?" if peaks or deviant data is discovered.

These phases of the data configuration lead to confirmation by all users. The users confirmed that the factors were related to stress and that they already knew that and can confirm that now too. Therefore, the Qualified Self is extended with a confirmation of self-knowledge of their own well-being. The data visualisation allowed the user to reflect upon their stress and possible related stress factors.

Secondly, objective 2 has let to findings of multiple design flaws. These are of high relevance because these design flaws can withhold the discoveries of correlations between the various variables of the data visualisation. The discovered design flaws are described in Table 23. Aligned with the discoveries are the possible solution to how the design flaw can be adjusted. It is recommended to change the design flaws accordingly, to enhance the functionality of the data visualisation.

Table 23, design flaws of the final data visualisation

Design Flaws	Possible solution
Most users did not read all text available	This could be solved by displaying the data visualisation on a bigger screen. However, it is strongly recommended to use less and clearer text and/or replace the text with icons
Most users did not read the headings or only read them at the end.	Make headings more appealing. Make the font black instead of grey
Most of the users did not find SP 1 clear	Assure the connection between the values and boxes, by removing the white space in between. Or make use of gradient from value to value. So, start with the matching green level in the transition to the matching other colour.
Most of the users did not find SP 3 clear	Make 1 graph out of the 2 graphs by displaying two values in every bar per hour. For example, the icon displayed on the right. 
Confusion of the possibilities in the beginning and of the objective of the data visualisation	Make use of an exploration phase, in the beginning, to give the user a helping hand to discover the possibilities of the data visualisation.
Only user 3 understood the relation between every SP	The SP's are set in such an order to let the user discover the found aspect in SP 1 more in SP 2 and confirm this information again more elaborate in SP 3. This possibility was however not clear. It could be improved by giving the user the possibility to select an aspect in SP 1, which then consequently already be highlighted once opening SP 2, idem for SP2 to SP 3.
No users were interested in the factor step count. The step counts are only interesting to see per hour (thus SP 3) and still then the user did not see the use of it.	The relation between step counts and stress is too far-fetched. As stress is an indication of your mental well-being, while step counts are an indication of your physical well-being. Step counts could better be combined with heart activity once displaying or replaced with another factor considering the physical activity.
The variable activities missed a value to place 'driving lessons' or 'job interview'	Add 'professional activity' to values of the variable activity

7. Conclusion & Discussion

In this chapter, the conclusion of the graduation project is described by answering the Research Question stated in the introduction. Furthermore, highlighting aspects of the data visualisation are discussed. Subsequently, a recommendation for future work is defined.

7.1. Conclusion

As discussed in the literature research the key challenge with application expressing the Quantified Self, is the disconnection between the user and the technology in means of user and data, user and data visualisation and user and data configuration. This key challenge is also the barrier to extend the Qualified Self of the user using the Quantified Self, as insight regarding well-being by the user is required to extend the user's self-knowledge.

According to Swan (2013), this disconnection could be solved by giving context to the data and according to Li et al. (2010) by involving the user in the data configuration. These two strategies have been applied in designing various concepts and later also in the final data visualisation realised. Accordingly, the final data visualisation has been tested in the usability test.

The results of the usability test indicate that both strategies are of value by giving the user the possibility to create insight into his or her well-being. However, this insight appears to be more confirming then activating. In other words, the insight gained by the users is seen as a confirmation of the correspondence of the data and their expectations. The insight did not surprise the user or impress the user in a way that the user will consciously apply the new knowledge in his or her life.

But the confirmation indicates that the user understood the data visualised in the data visualisation and could apply the data in context, thus some form of Qualified Self is gained. However, as a result of the usability test, it can be said this formation can only happen with the utilization of a timeline in a data visualisation. Since the users cannot give context to the data without the use of a timeline indicating when the variable was measured.

Involving the user in the data configuration by allowing the user to compare multiple variables by interacting is efficient to let the user understand the causations and correlations of the data. It can be said that this is more efficient for the creation of the Qualified Self then only passively displaying the data to the user.

So, to be able to create a data visualisation of the Quantified Self in a way that the user is actively engaged with one's own data and shape one's own Qualified Self the data visualisation will need

to have the possibility to compare various variables to each other. The data visualisation will need to give the user the possibility to interact with the data, such that the user feels in control of the data displayed. Lastly, a timeline is required to allow the user to give context to the data.

7.2. Discussion

The main discussion point of the result from this graduation project is the focus of multiple users to compare subjective data with objective data. It appears that the user is motivated to compare his or her personal data to 'anything' in order to give value to the data. As the data visualisation realised is specified on personal data of the user only, the user intuitively starts to compare objective data against subjective data to see if a correlation or difference can be found in this manner. This is, of course, a logical consequence as the goal of the data visualisation is to find correlations between variables. It can be of interest for, for example, people who think they do not stress while studying but do have a high heart rate during studying, to discover whether his or her interpretation of his or her well-being is correspondent with unconscious functions of the body. However, the discoveries find can be of danger because the subjective data of the user is (thus how the user for example experiences stress) is dependent on the reality while the objective data of the smartwatch (thus the variables that the smartwatch can measure) is dependent on the sensor ability of technology. So, as discussed in the literature as stated by Don Ihde (Verbeek, 2006), it can be that the user is more likely to see the objective data as true and change his or her feeling according to match the subjective data to the objective data.

Another discussion point is the definition of the Qualified Self, as this terminology is relatively new only little research paper exists on the subject. This graduation project has indicated an own definition to the Qualified Self. Namely, the self-knowledge of the well-being of the user by the user. The challenge with this definition is that the Qualified Self is different per person. As every person interpret his or her well-being uniquely. The Quantified Self is thus an addition to the Qualified Self only if the user finds the information of value, or in other words, can connect with subjective experience. The challenge, therefore, makes it difficult to test per person to what extent they learned from viewing their personal data in a data visualisation, as this can divers per person.

Also, it can be discussed to which extent the extension of the Qualified Self is formed in comparison with a State-of-the-Art discussed system. As the usability test used does not classify as a baseline measurement, it cannot be concluded that the data visualisation made is of higher quality then other systems. To would have done so, the participant should have been asked to

observe the same dataset in both an already existing system and the designed data visualisation. These results can then be compared to see to what extent the Qualified Self is extended.

The last discussion point is the reliance of the Qualified Self formed by the Quantified Self data. It can be the case that the user will discover and conclude a correlation between variables in the data visualisation that is more a coincidence than a reliant fact.

7.3. Recommendation for future work

For the future design of data visualisations considering the transition from the Quantified Self to the Qualified Self, it can be recommended to implement an option for the user to let technology remember or hold on to earlier found discoveries of and by the user. In this way, the user will be more motivated to find possible correlations to multiple factors and will have the possibility to substantiate the found correlation over time. Secondly, it could be of value to discover the credibility of the three phases (checking truthfulness, place data in context and discovery of peaks) of data configuration by the user in further research. The increase in credibility will enhance the chance to implement the interaction of the user with the data visualisation and thus enhance user-driven data configuration in future applications.

Overall, it is strongly advised to enable the option for the user to let him or her compare various variables to each other and consequently let the user develop the Qualified Self his or herself, rather than displaying the Qualified Self to the user. However, it should be made clear to the user that the data comparison of these variables is only an indication and not the truth.

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Appendix A – The Creative Technology Design Process

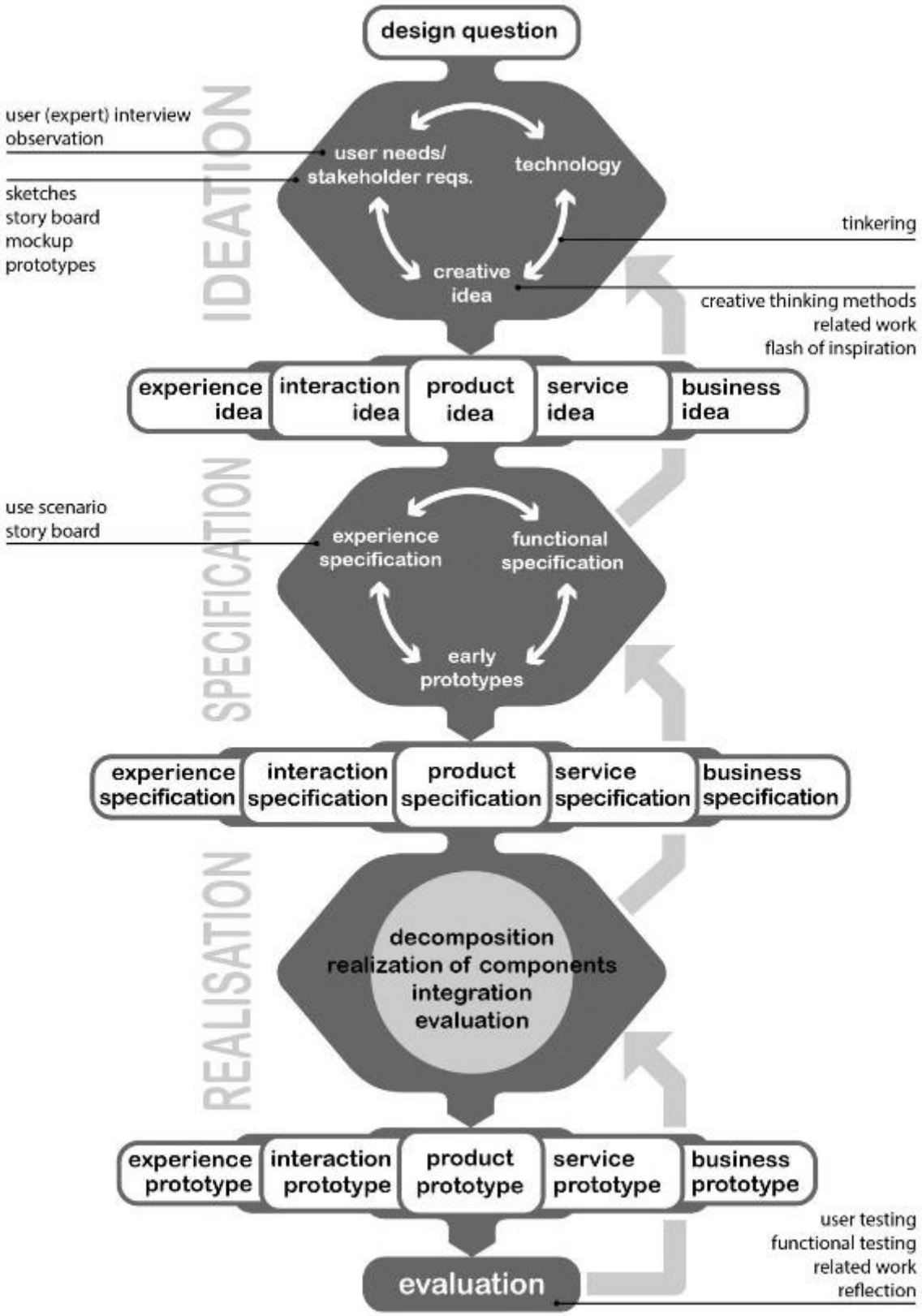


Figure 29: Screenshot of the Creative Technology Design process

Appendix B – Interaction with story point 1

Figure 30, User interaction 1 of Story point 1; the user can select factor to compare to the stress level

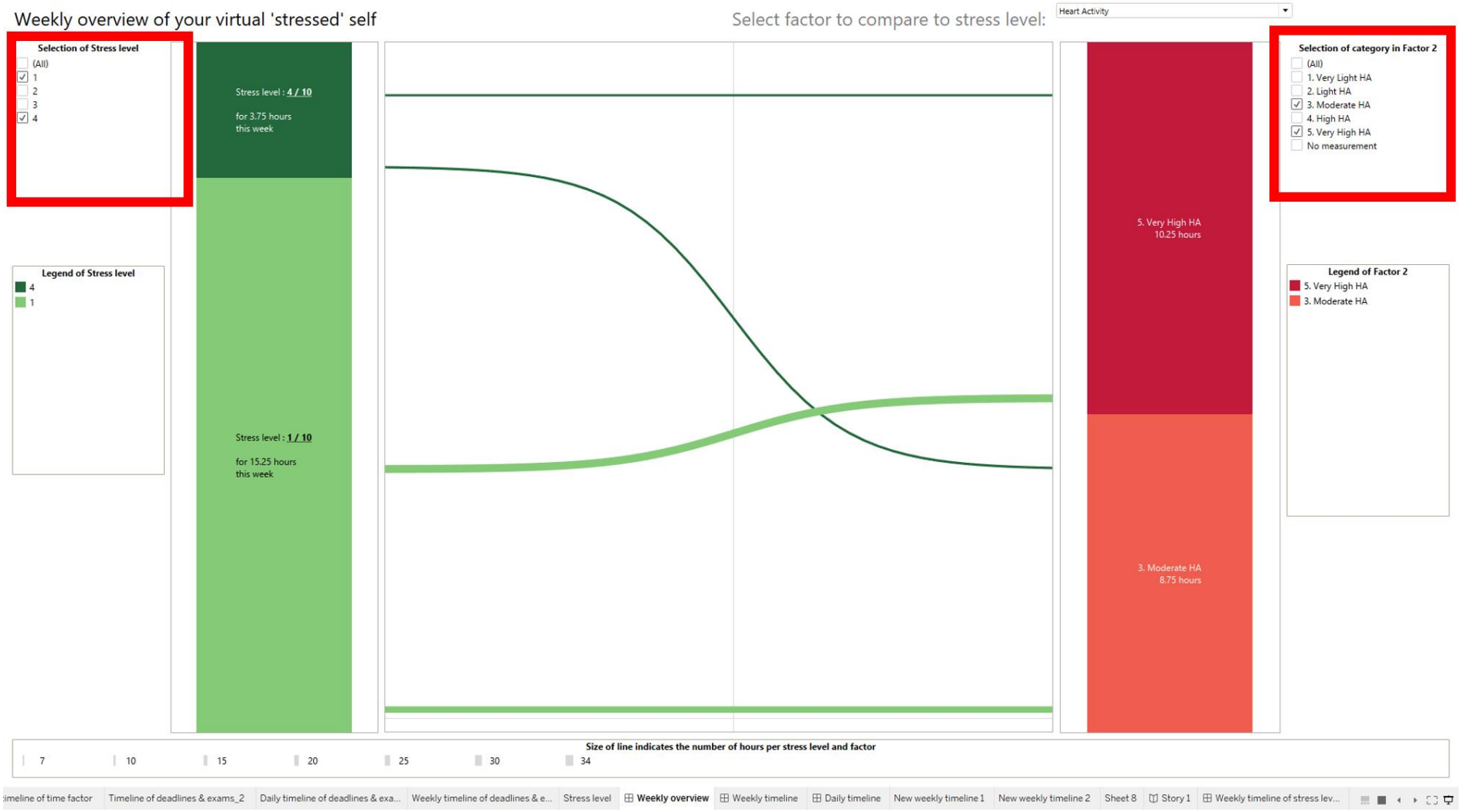


Figure 31, User interaction 2 of Story point 1; the user can select values of factor to compare to the stress level

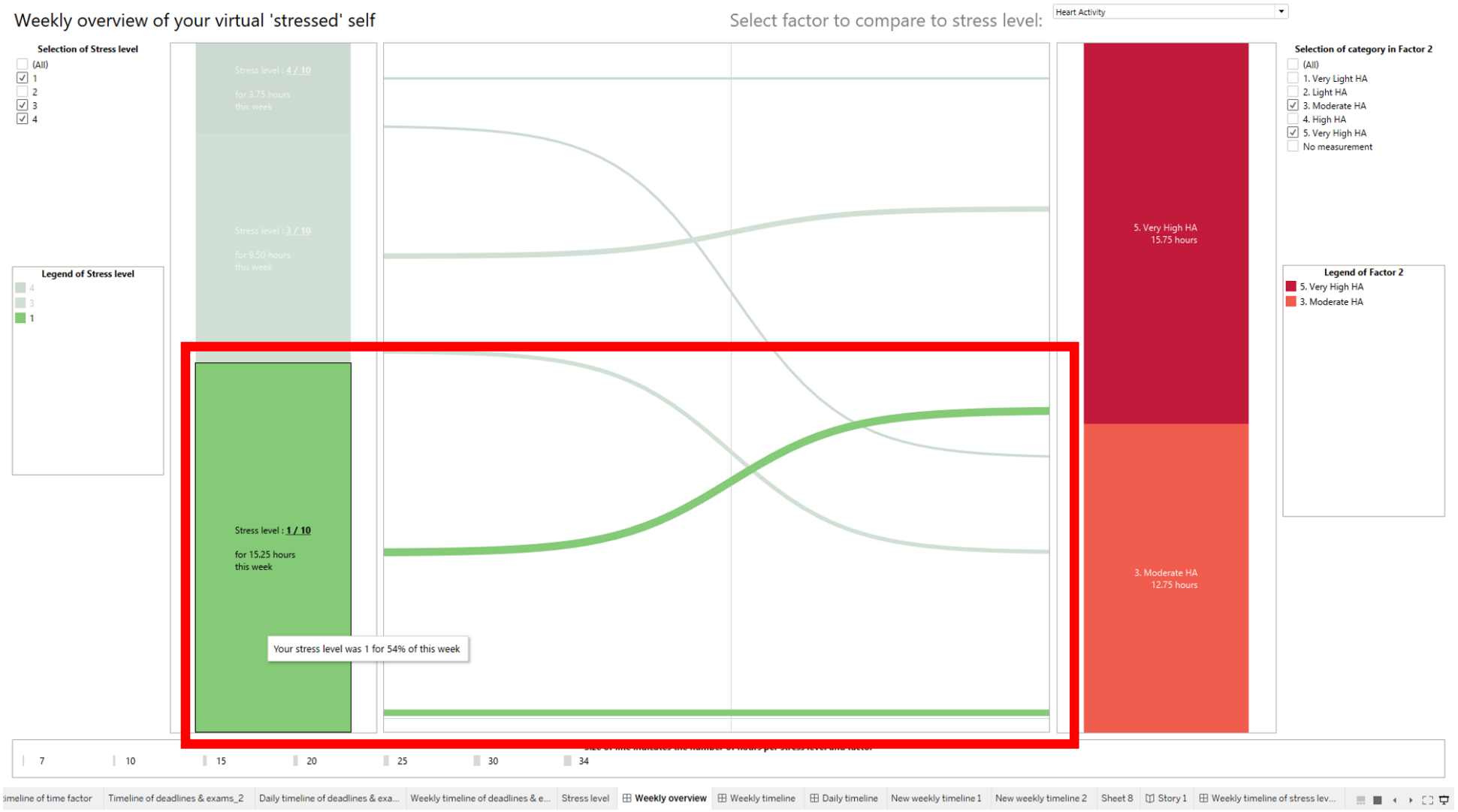


Figure 32, User interaction 3 of Story point 1; the user can hover over the graph to explore the connection

Appendix C – Interaction with story point 2

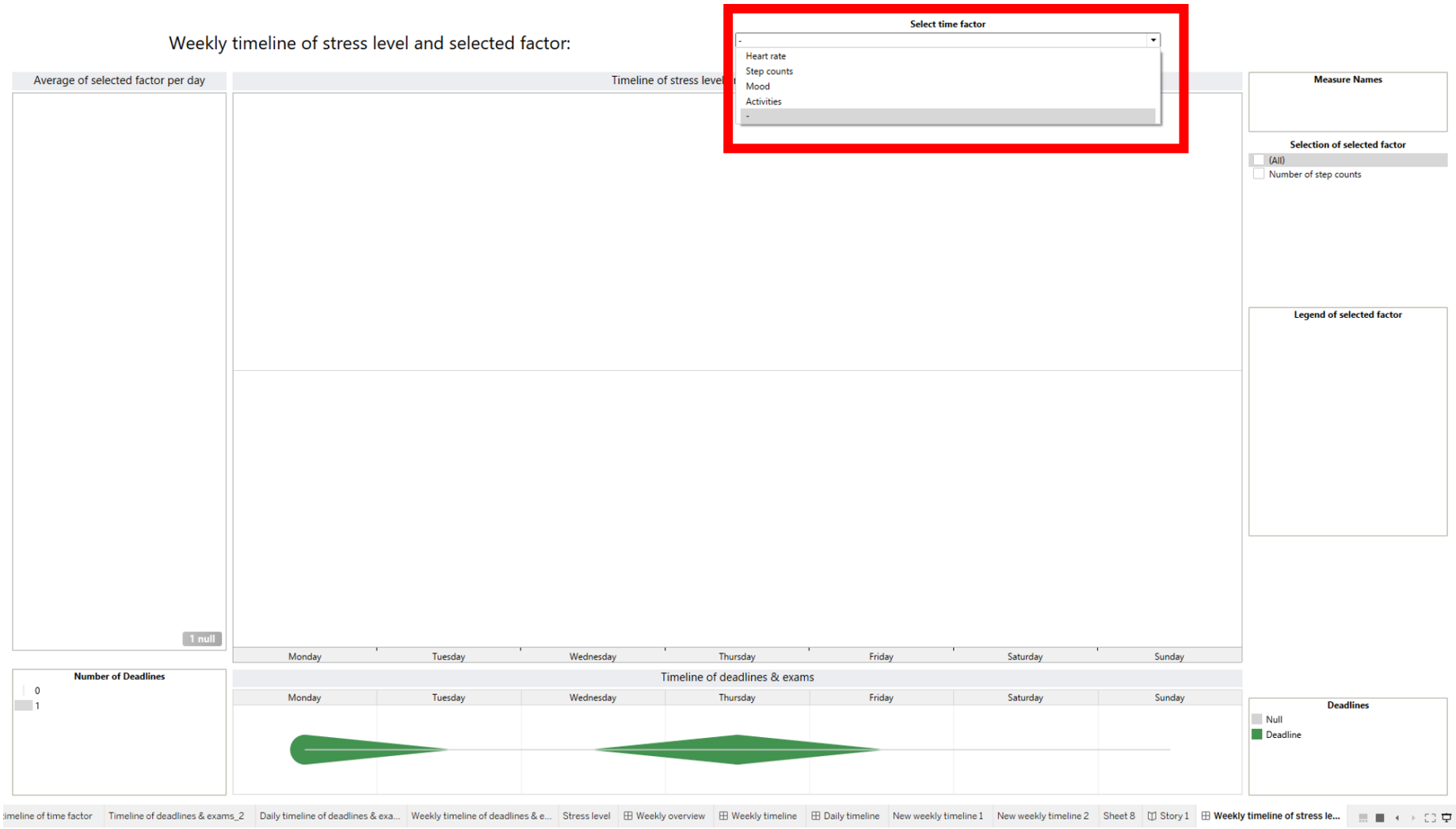


Figure 33, User interaction 1 of Story point 2; the user can select factor to compare to the stress level

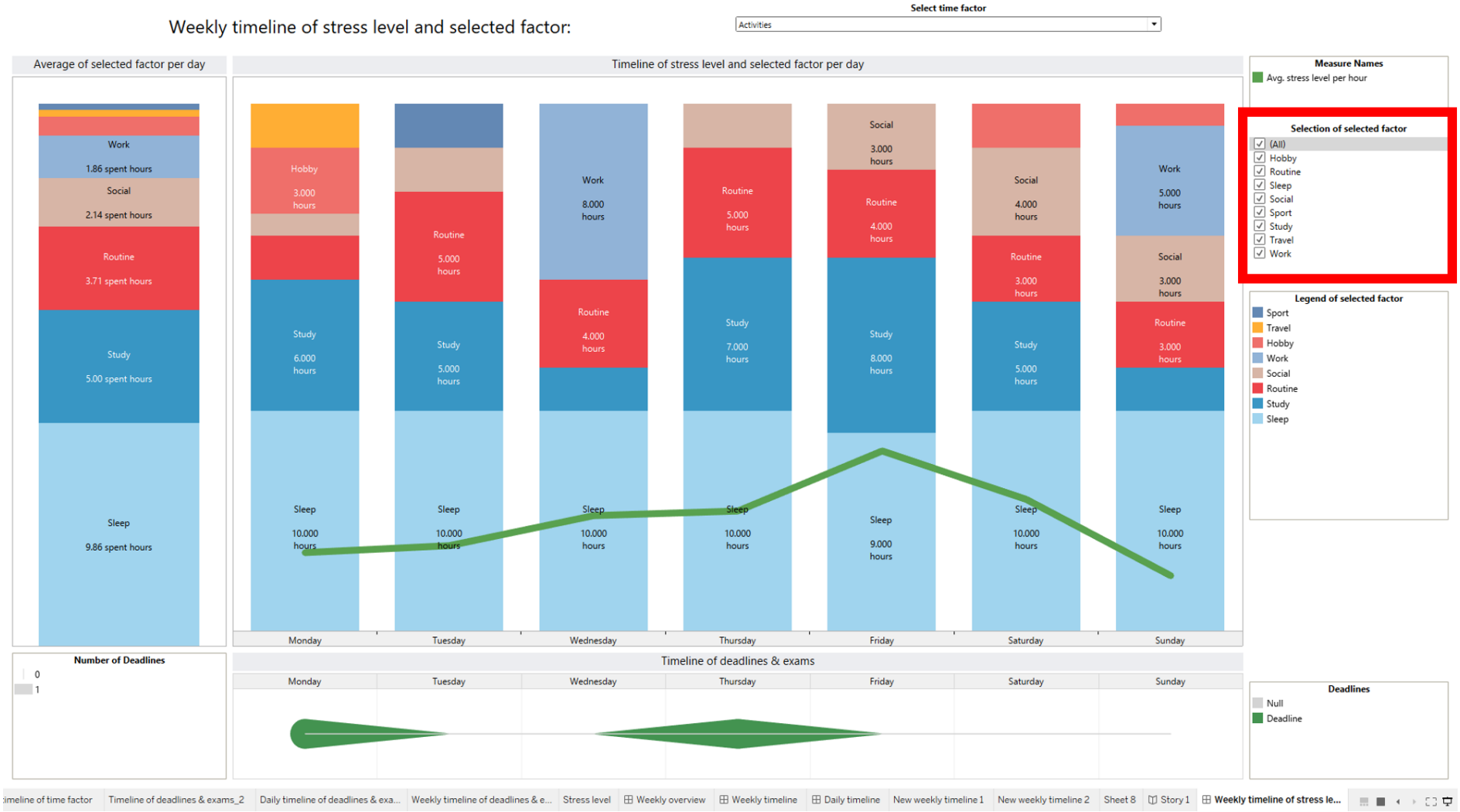


Figure 34, User interaction 2 of Story point 2; the user can select the value of factor to compare to the stress level

Figure 35, User interaction 3 of Story point 2; the user can select a value to compare per day

Appendix D – Interaction with story point 3

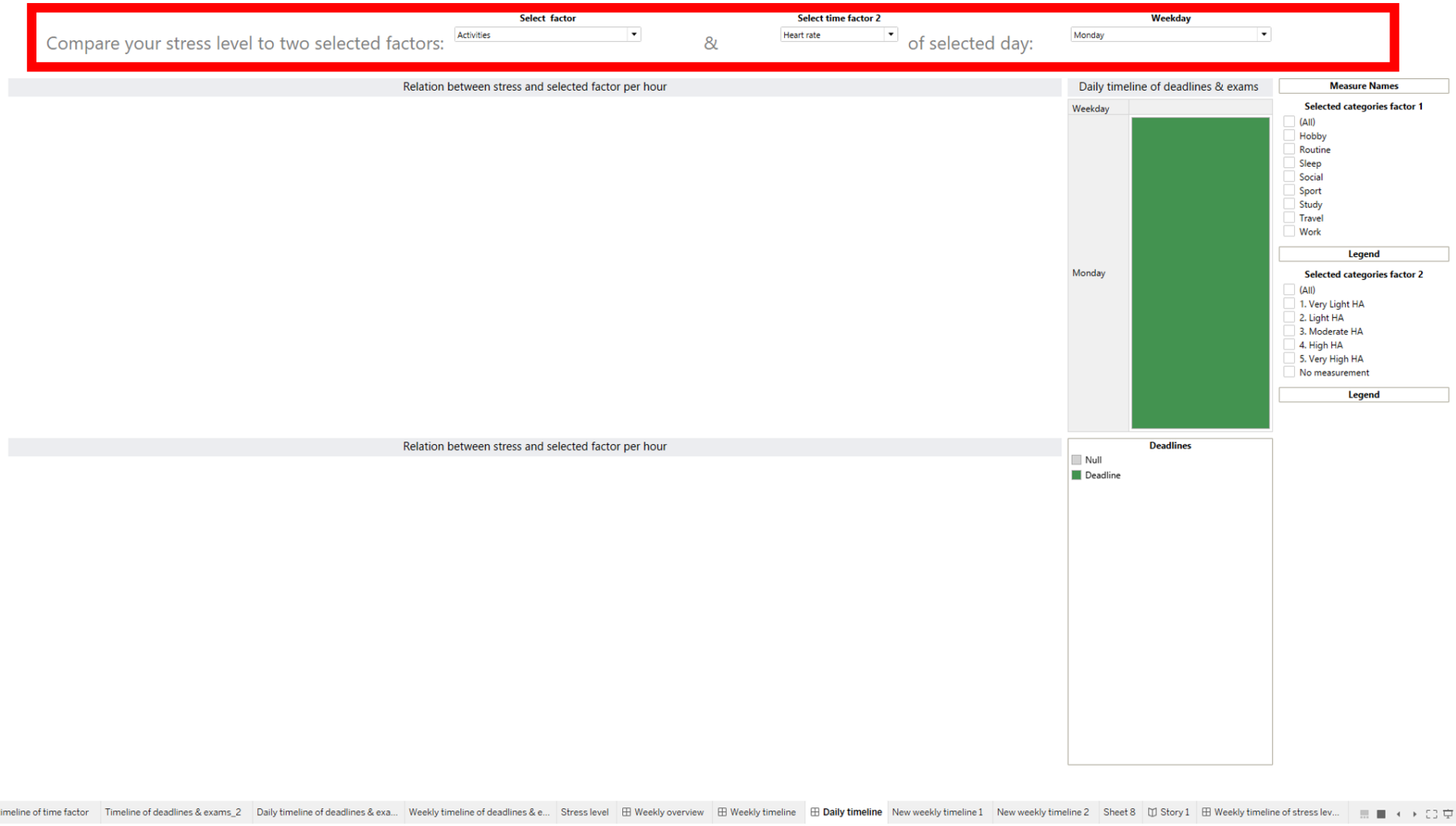


Figure 36, User interaction 1 of Story point 3; the user can select two factors and a day to compare to the stress level

Figure 37, User interaction 2 of Story point 3; the user can select values of factors to compare to the stress level

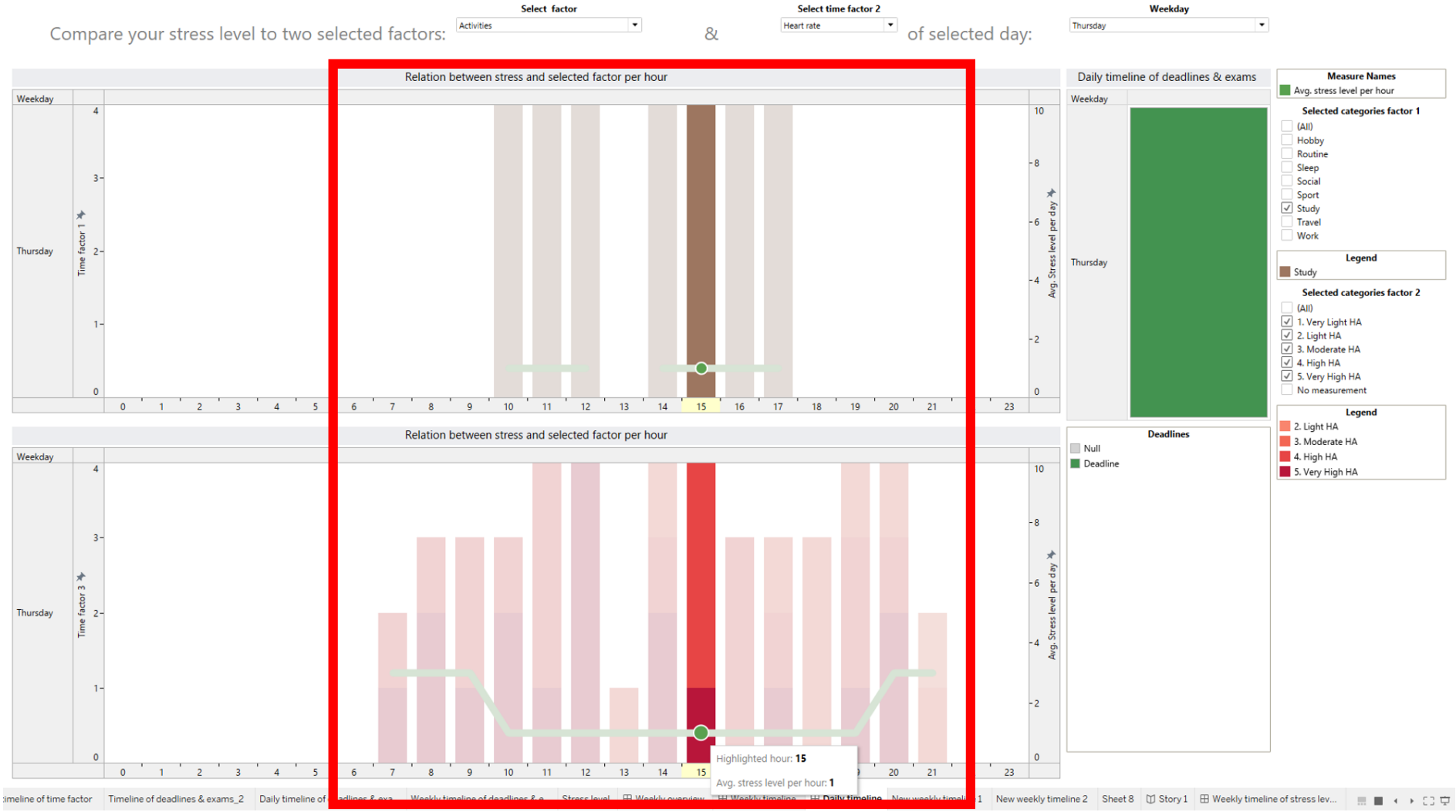


Figure 38, User interaction 3 of Story point 3; the user can highlight variables in the graphs

Appendix E – Information Brochure

Information brochure 'Quantified Self to Qualified Self'

Dear reader,

In this letter, I would like to inform you about the research you have applied to participate in. The research is part of my graduation project called the 'Quantified Self to Qualified Self'. The aim of the research is to discover if my data visualisation can give students the opportunity to discover one's own behaviour in relation to stress. Moreover, to establish how my data visualisation can be improved on functionality and design based on the participant's view. The data visualisation will be made using self-tracking data of the participant; therefore, data of the participant will first need to be gathered in order to let the participant reflect on the data visualisation. To do so, the experiment will be structured as follows:

- From 17-06-2019 until 23-06-2019 the behaviour of the participant will be tracked using the following two methods:
    - You will be asked to wear a smartwatch for a period of 7 days, starting on Monday and ending on Sunday. This smartwatch is synchronised with an anonymous account that stores your tracked personal data. The tracked personal data consist of the measurements of the smartwatch. The measurements are executed over a time interval of 15 minutes, every 15 minutes the device tracks: Step counts; Calories burnt; Distance travelled; Average heartbeat; Latitude and longitude; Speed and Type of physical activity.
    - You will be asked to fill in an online questionnaire two or three times a day during using random intervals. This questionnaire can be filled in using your smartphone and will ask you questions such as 'How stressed are you on a scale from 0-10?' and 'What activities have you done at what time today?'. The data of this only questionnaire will be stored on the same anonymous account as the data of the smartwatch.

  The account will only be accessible to you and the researcher and will be removed once the graduation project is finished.
- On 24-06-2019 you will be asked to participate in an interview with the researcher. During this interview, you will have the opportunity to display and interact with your tracked personal data in the data visualisation. The aim of this interview is to establish the user functionality and glanceability of the data visualisation and to discover whether you can learn from your data using the data visualisation. The interview will last for a maximum of 1.5 hours. The results of this interview will be used anonymously and for this graduation project only.

The total experiment thus lasts for 7 days and will require your attention for a maximum of 3 hours (including the time filling in the questionnaire and attending the interview). It is important to know that most of the subjects participating in similar experiments find it very interesting. At the end of the entire research, you may, if you so wish, be informed about the results obtained by means of a debriefing.

Please note, that we, as part of the University of Twente, are obliged to comply with the General Data Protection Regulation. For this, we take measures with regard to the

processing and inspection of personally identifiable data, such as your name and the data of the smartwatch.

Yours sincerely,
Floor Stolk
Creative Technology graduate student
Tel: +31 (0)6 37 17 52 51 email: e.f.stolk@student.utwente.nl

Appendix F – Informed Consent

Informed Consent

'I hereby declare that I have been informed in a manner which is clear to me about the nature and method of the research as described in the aforementioned information brochure 'Quantified Self to Qualified Self'. I will handle the smartwatch that I will wear during the experiment with great care. My questions have been answered to my satisfaction. I agree with my own free will to participate in this research. I reserve the right to withdraw this consent without the need to give any reason and I am aware that I may withdraw from the experiment at any time. If my research results are to be used in scientific publications or made public in any other manner, then they will be made completely anonymous. My personal data will not be disclosed to third parties without my express permission.

If I request further information about the research, now or in the future, I may contact Floor Stolk (telephone: +31637175251 email: e.f.stolk@student.utwente.nl)

If you have any complaints about this research, please direct them to the secretary of the Ethics Committee of the Faculty of Electrical Engineering, Mathematics and Computer Science at the University of Twente, J.M. Strootman-Baas, Paviljoen 015, 7500 AE Enschede (NL), telephone: +31 (0)53 48 96 719; email: ethics-comm-ewi@utwente.nl

Signed in duplicate:

.....
.....

Name subject Signature

'I have provided explanatory notes about the research. I declare myself willing to answer to the best of my ability any questions which may still arise about the research.'

.....
.....

Name researcher Signature

Appendix G – Online Questionnaire

Questionnaire[29]

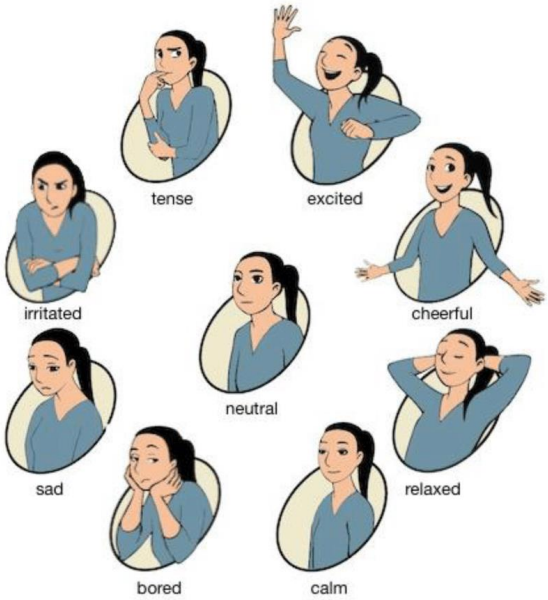
Hi there,

Please fill in the questionnaire as soon as possible and as honest as possible. Please note that the asked time and frequency for filling in the online questionnaire are randomly generated.

Also, do not forget that the research has the objective to test only the data visualisation and is thus not made to test you as a participant.

Questions:

1. What grade (1-10) would you give your stress on the moment of filling in this questionnaire?
    a. Scale from 1 (Not at all stressed) -10 (Very much stressed)[30]
2. Select one of the nine images that describe your mood the best on the moment of filling in this questionnaire:



1. Sad
2. Bored
3. Irritated
4. Tense
5. Neutral
6. Excited
7. Cheerful
8. Relaxed
9. Calm

Figure 39: Pick-a-mood expression board for self-report of mood

[29] Example of online questionnaire: https://nl.surveymonkey.com/r/8HN9TJB

[30] Based on the Visual Analog Scale questionnaire used as self-report stress indicator in the research of Cho et al. (2019)

3. What activities have you performed from 00:00[31] until now?
   (Choose from Sleep; Social; Study; Sport; Travel; Work; Hobby or Routine (e.g. doing groceries, cooking, doing the laundry, cleaning)
   a. 00:00-00:15:
   b. 00:15-00:30:
   c. 00:30-00:45:
   d. 00:45-01:00:
   e. 01:00-01:15:
   f. 01:15-01:30:
   g. 01:30-01:45:
   h. 02:00-02:15:
   i. Etc.

Extra question on Monday:

When and how many deadlines or exams do you have this week? Please also include the time of deadline or exam in the scheme.

Weekday	Number of deadlines	Number of exams
Monday		
Tuesday		
Wednesday		
Thursday		
Friday		
Saturday		
Sunday		

[31] The mentioned time is changing per questionnaire as it is dependent on the last time the participant has filled in the questionnaire.

Appendix H – Time schedule for online questionnaire

This schedule indicates when the online questionnaire will be sent to the user. The schedule is made using a random generator to generate the number of times asked per day (ranging from 2-3) and to generate the time to send the questionnaire to participants (ranging from 09:00-21:00).

Weekday	Number of times asked	Time to send the questionnaire to participants
Monday 17/05/2019	2	10:00 21:00
Tuesday 18/05/2019	3	11:00 15:00 19:00
Wednesday 19/05/2019	3	09:00 13:00 22:00
Thursday 20/05/2019	2	10:00 20:00
Friday 21/05/2019	2	09:00 18:00
Saturday 22/05/2019	3	11:00 17:00 20:00
Sunday 23/05/2019	2	11:00 23:00

Appendix I – Set-up usability test

Task list

- Explain how you feel about seeing your behaviour in a data visualisation (Do you feel comfortable exposing your data to me and talk about it?)
    - If not, the researcher focusses on design tweaks only.
- Tasks to test usability and discover design flaws:
    - Explain what you see (while doing so do not touch the data visualisation)
    - Explain what you think you can do with the data visualisation (while doing so you can interact with the data visualisation)
- The tasks to test if the user experiences the transition from Quantified Self to Qualified Self:
    - Explain if you can find a visible relation between your stress level and other factors
    - Explain if you can find a visible relation between your stress level and activities
    - Explain if you can find a visible relation between your stress level and deadlines & exams
    - Explain if you can find a visible relation between your stress level and mood
    - Explain if you can find a visible relation between your stress level and physical activity

Reflection session

1. General
    a. How useful do you find the data visualisation? 1-10 scale
        1 = I cannot make any sense of the data visualised in the data visualisation
        10 = I can make sense of the data visualised in the data visualisation
    b. Did you learn something about your behaviour using the data visualisation? 1-10 scale
        1 = No, I already knew all data visualised in the data visualisation.
        10 = Yes, I gained various insights about my behaviour in relation to stress
    c. Does the data visualisation make the concept of stress more tangible for you then before seeing the data visualisation? Yes/No, Why?
2. Collecting of data
    a. How much effort did you find it to fill in the online questionnaire? Did this have any consequences on the truthfulness of the data? 1-10 scale
        1 = It took a minimum amount of time and I filled in everything in as truthful as possible.
        10 = It took me too much time, and I found it annoying to do. Even so annoying that I did not always fill in the questionnaire as truthful as possible
    b. What do you think of the categories made for activities?

   c. Would you describe the variables used in the data visualisation as factors influencing your stress? Why/Why not? What other factors would you like to have seen?
3. Interface
   a. What steps in the data visualisation did you find easiest to do?
   b. What step in the data visualisation did you find difficult to do?
   c. Do you find the interface clear or confusing? 1-10 scale.
      1 = Clear
      10 = Confusing
   d. What do you think of the amount of data visualised? 1-10 scale.
      1 = Too detailed
      10 = Too general
   e. Explain what you find difficult to interpret from the data visualisation (Do you think it is necessary to at an instruction set up for the user in the beginning?)
   f. Explain what you find easy to interpret from the data visualisation
4. Results
   a. Do you feel judged or that you judge yourself once looking at your data? (Why?)
   b. Explain if you would like to adjust or enhance certain behaviour after your discoveries
   c. Explain if you find these discoveries useful (How could the visualisation be made more useful for you? What do you miss? What do you like?)
   d. Do you see yourself using the data visualisation again? Do you think it would be a supportive tool to have during the continuation of your studies? Why?
   e. Would you recommend the data visualisation to someone else?
   f. Explain how the data visualisation works to this someone