Defence, Safety & Security
Kampweg 5
3769 DE Soesterberg
P.O. Box 23
3769 ZG Soesterberg
The Netherlands

www.tno.nl

T +31 88 866 15 00
F +31 34 635 39 77

TNO report

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Enhancing Human Resilience: monitoring, sensing, and feedback

Date	November 2016
Author(s)	O. Binsch T. Wabeke G. Koot W. Venrooij P.J.L. Valk
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Contents

1 Summary

The development of miniaturized monitoring technology represents the greatest opportunity for advancing Resilience and Mental Health in over a century.
All experts of the Resilience- and Mental Health domain are contending with a significant mental health burden, e.g. almost half of all work disability across different branches is now related to psychological, psycho-physiological and psychosocial factors, which increased by 30% between 1998 and now; leveraging technology will be part of a concentrated effort to mitigate this impact. One goal of TNO's Early Research Program – 'Human Resilience' (ERP-HR) is to develop a resilience monitoring approach using state-of-the-art and leveraged technologies to reveal insights into the individual psychological, psychophysiological and social psychological factors that determines resilience. Such a monitoring approach requires insights into the availability and feasibility of wearables in workload contexts, their reliability, sensitivity and sensor accuracy, but also how to manage the data stream, storage and analysability. Furthermore, the program aims to feedback the results of the monitoring approach. As such, the work includes the study how to feedback selected results to the employees, their managers and/or associated researchers. To these aims, the collaborative ERP-HR' work packages 3 and 4 explored in its initial research year the possibilities and gaps of evolving monitoring and sensing systems. Consequently, the two teams focused on the information available about the state-of-the-art advances in technologies to monitor, sense and stream the current individual status and load, and to explore the possibilities for reflection on the results for employees and organizations using dedicated feedback technologies. This report describes the results of this initial exploration divided into 5 chapters, including a brief introduction of the multi-dimensional prospective model for human resilience (WP1), as this model is used as the basis for our resilience monitoring approach.

2 Introduction

This report describes the combined progress of work and results of the work packages ‘Monitoring & Sensing Platform’ (WP3) and ‘Data Modelling and Feedback Platform’ (WP4) that was achieved in the initial year 2015 of the “Early Research Program - Human Enhancement”, research line Human Resilience (ERP-HR). The main goal of this 4 year ERP-HR program is to develop a multi-dimensional prospective model for human resilience and to convert this model into individual monitoring instruments and organisational interventions. This goal is based on the notion that adequate resilience tools and interventions for employees are lacking, consequently resulting in large personnel and organisational costs (e.g., Asscher, 2014; Kallen & Korteling, 2012).

In 2015, The ERP-HR was organized in 6 work packages. The aims of the WP 3 and 4 were interrelated as these WP’s were confined to develop a monitoring & sensing platform to operationalize and measure identified resilience factors (WP 3) and to develop a data modelling and feedback platform to provide effective resilience feedback for end users (WP 4). The most leading work package for the ERP-HE work packages was – at least in the initial year – the WP 1, as this package was selected to start developing a framework that should result in a *generic* multi–factor and –level model of employee resilience (MFMLHR). Consequently, WP1 built and defined a framework consisting of main and interaction variables that shed light into the different aspects (i.e., demands, recourses, outcome; see below) of employee’s resilience. This framework and MFMLHR model of WP1 (Paradies et al. 2016) primed also the in– and output of WP 3 and 4 for the conceptual development of context specific resilience measurements, monitoring tools, sensor-, data modelling and feedback platforms.

The MFMLHR model is based on dominant work-psychological models like Karasek’s demand-control model (1979) and the job demands-resources model (Demerouti et al. 2001; Schaufeli & Bakker, 2004) as the MFMLHR model seeks to distinguish between demands, resources and outcomes. The MFMLHR model is applied to the domain of resilience according to the work of Kamphuis et al. (2012) and Delahaij et al. (2012). According to this work, the framework of the MFMLHR includes factors from different disciplines within the individual domain (i.e., physical, cognitive, energetic, stress-physiology, socio-emotional) and in the social environment of the individual (team, organization, private life). Figure 1 shows the concept model and its factors and variables. The first column is used to describe the demands and possible human resources. *Resources*, on which employees may rely on to deal and resolve the *demands*. This demands and resource field is followed by the next column, that describes the initial part of the appraisal process, when individuals ‘weight’ (i.e., appraised) their current skills, abilities, social environment, (Lazarus, 1966; Lazarus and Folkman 1984). During this cognitive (i.e., un- and conscious) process, a comparison between demands and currently available resources is attained by the individual that perceives the demand (Figure 1; first and second column). Depending on how the demand is appraised together with the current physical, cognitive, and emotional status, the demand is classified as irrelevant, challenging and/or even threatening (for a more detailed description of the appraisal process see Lazarus & Folkman, 1984; and related to this report see also Paradies et al., 2016). If the demand is appraised as challenging or threatening (i.e., low vs. high risk), the initial appraisal process is followed by a mental-cognitive process that seeks for available and applicable coping strategies.

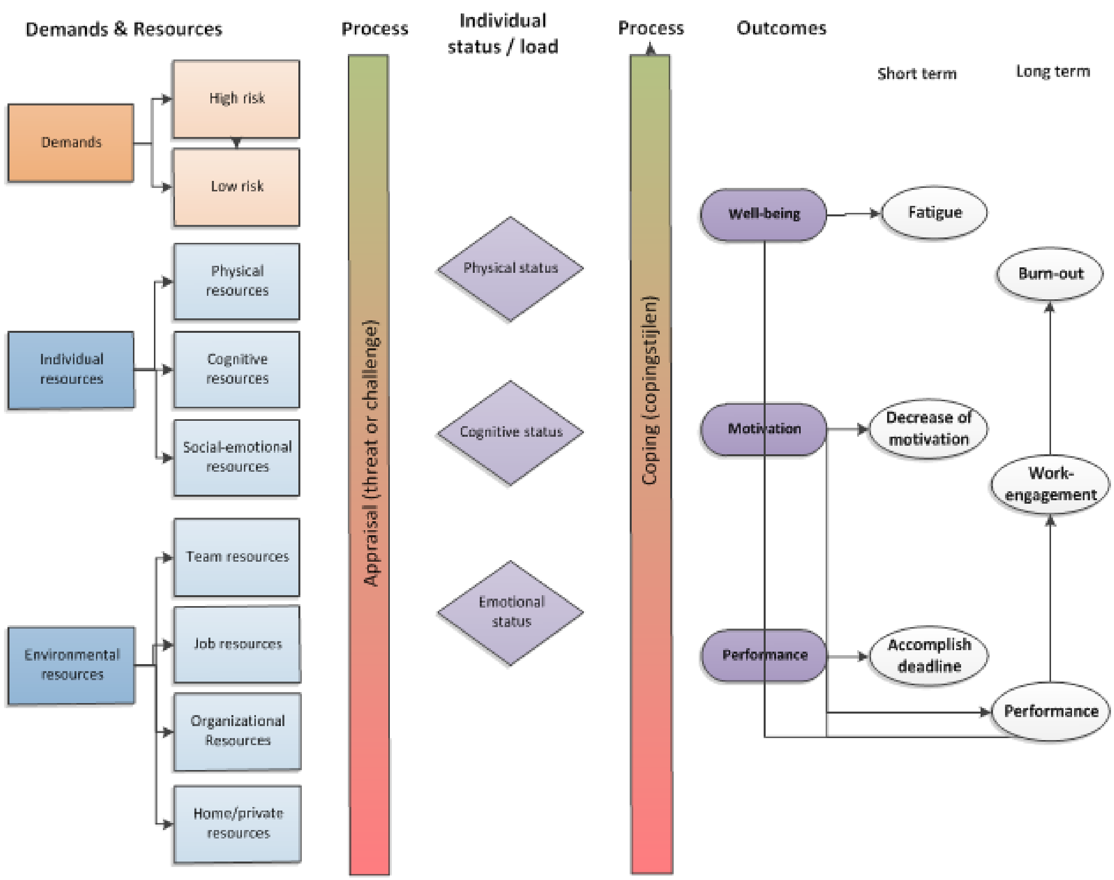


Figure 1 The initial MFMLHR descriptive concept model, which seeks to distinguish between demands and resources, individual status and load, and outcomes.

After the individual applied an available coping strategy, the demand may be appraised again, to see whether the demand is levelled, deceased or is even resolved (see the mechanistic process model of resilience (Paradies et al., 2016). The individual physical, cognitive and emotional status and available coping strategies are responsible for the short term and long term outcomes in terms of health, motivation and performance (see Figure 1, third column). For example, a change of the demand could lead to an increase of motivation, it might even lead to flow (Csikszentmihalyi, 1990) to get more engaged in the task execution with an expected increase in task performance and positive performance state. Whereas, the threat appraisal would lead to overload and negative stress response, and thus, to an expected decrease in task performance, as e.g., anxiety and worry might be involved and tax attentional resources necessary for optimal task execution (e.g., Wegner, 1992, 1994).

As showed above, the model comprises individual physical, cognitive and emotional state factors as the cross-link between demands (high, low) & trait resources (individual, environmental) and outcomes (well-being, motivation and performance; see also Figure 1, core of the model). The state factors are the core variables of the model because of their value to provide information about how the employee may appraise a perceived demand. It is expected that if the state outcome is low or positive, the demand is appraised as irrelevant or rather perceived as a task that can be achieved with accessible resources. In contrast, when the demand is appraised as threat, i.e., the (trait) resources are perceived as insufficient, the state outcome is expected to be negative with an increase of physiological/social psychological stress responses. Although, the trait resources and outcomes are important, the focus for WP 3 and 4 is on exploring the possibilities to measure, store, analyse and feedback the state factors by using new and feasible technology, as this will be the major challenge of the initial year. In a later stage of the ERP-HE, all measures are supposed to feed the model.

To these aims, it is important to realize that the progressive development in the miniaturisation of recent sensor technology offers incredibly and increasingly new possibilities to measure, monitor and feedback different physiological, mental and cognitive proxies/aspects of the current individual state. Sensor systems like the Apple-Watch, Microsoft Band and smartphones with incorporated accelerometers, magnetometers, gyro's, photo-plethysmographs, galvanic skin response, ultra violet light, and global positioning sensors may be applicable to assess the physical status during day and night and over a longer period. Next to this, developing and applying easy-to-use app's installed on smart-phones are able to yield and analyse the current cognitive status of the individual. These are sensors and platforms that would allow to monitor internal processes that manage the response of the demand appraisal, but also to sense directly to some extent external demands.

These monitoring and sensing applications seem to be rather simple achievable by applying some settings, tapping and streaming data platforms, and storing, saving and analysing data from easy to wear wearables. These platforms also allow to assess subjective data from easy-to-apply questionnaires or rating scales including tapping general health, physical, cognitive and emotional status; also achievable within some fingertips. Furthermore, these systems are available at affordable prices and are developing and improving quickly.

In summary, new wearable monitoring and sensing systems and platforms are increasingly available and offer possibilities to measure real-time physiological, cognitive responses on appraised demands. However, the models, algorithms and structures that drives such systems are limited evidence based. Therefore, the aim of WP 3 and WP4 is to explore the applicability and usefulness of evolving monitoring and sensing systems. First, it is important to gather and explore the information available about the state-of-the-art technology to monitor and sense the current individual status/load (Chapter 2: Sensors and sensor platforms for monitoring the current individual status; and, Chapter 3: Health platforms).
And second, to explore and describe possibilities for evaluation of the results for individuals and organizations using dedicated feedback technologies (Chapter 4: Providing effective resilience feedback; and, chapter 5: Developing a prototype monitoring mechanism for enhancing resilience).

3 Sensors and sensor platforms for real-time monitoring of the individual status

Measuring and monitoring the individual status has a long history. Different measurement and monitoring tools have been developed and validated over decades. Tools that, for example, measure physical status and performance (e.g. non/-invasive heart rate-, oxygen-, blood pressure-, and muscle contraction monitors; Cacioppo, et al., 2007), perception and motor skills (e.g., gaze-, and noise trackers or accelerometers), body composition (e.g., anthropometry, weight impedance methods) but also cognitive status. These tools may vary from pencil-paper and computerized performance teststo questionnaires and physical applications for monitoring the emotional state (e.g. galvanic skin response, saliva measurements; see for an overview Cacioppo, et al. 2000; Gross, 2007). As the human factors domain is and remains very complex, professionals need to carefully decide which tools to beapplied, depending on context and population characteristics(e.g., personnel of different branches, sportsmen, military, etc.; Binsch et al., 2014, 2015). However, in the past two decades, easy to use tools[1] with incorporated high tech sensors promise a simplification to this complexity. As the number of the tools increases rapidly, their applicability for the resilience domain needs to be examined. In this chapter we describe briefly the literature and web- search that was performed to create an overview of the available tools and their specifications. Next, we describe the web based platform that has been developed as a demonstrator to store, update and share tool information.

3.1 Tools and Platforms: Literature and Web- Search

The catalogue of the assessed tools is presented in Appendix A of this report. The catalogue contains a list separated in 5 columns, distinguishing between the (1) domain, (2) sub-domain, (3) tool, (4) experiences and (5) context. The 'domain' (e.g., physiology, psychophysiology, psychology, etc.) describes in which research field the tool is mainly used or could be applied. The 'sub-domain' describes whether the tool is an app, software or hardware, or where the sensors are placed (e.g., chest-belt system, watch, etc.). This column also provides additional information whether the tool is non/invasive, mechanical, or has other specifications. The 'tool' column provides the name and/or abbreviation and a picture of the tool. The 'experience' column refers to the experience the researcher in question had by using/applying the tool in his/her research (e.g., easy-to-use or wear, data frequency, data storage system, filtering, etc.). The final 'context' column provides information how sensitive, generic, robust, qualitative (etc.) the tool and its output is. The catalogue is dynamic, and thus, still in development as (new) tools develop fast. It is necessary to share the catalogue in a way that researchers in the field can acquire easily which tool is reliable and measure the right factor, and also to contribute to the catalogue new tools and/or their experience. Therefore, we developed a web-portal to meet the defined requirements for contributing and sharing.

[1] The term 'tool' and 'tools' refers throughout the report to all types of wearable systems, incorporated sensors, incorporated software and software interactions that are used and/or might be applicable in future mental health and resilience monitoring approaches and research.

3.2 Web Portal for Resilience Tools

The main requirements for the usability of the web portal is two-fold. First, it should be accessible for all researchers in the field of the resilience domain. Colleagues in this domain should be able to use this portal to assemble an optimal toolset for their (future) research. Second, this portal should be (partly) accessible for a selected group of researchers that is able to augment the tool information. Figure 2 shows the first version of the web based application.

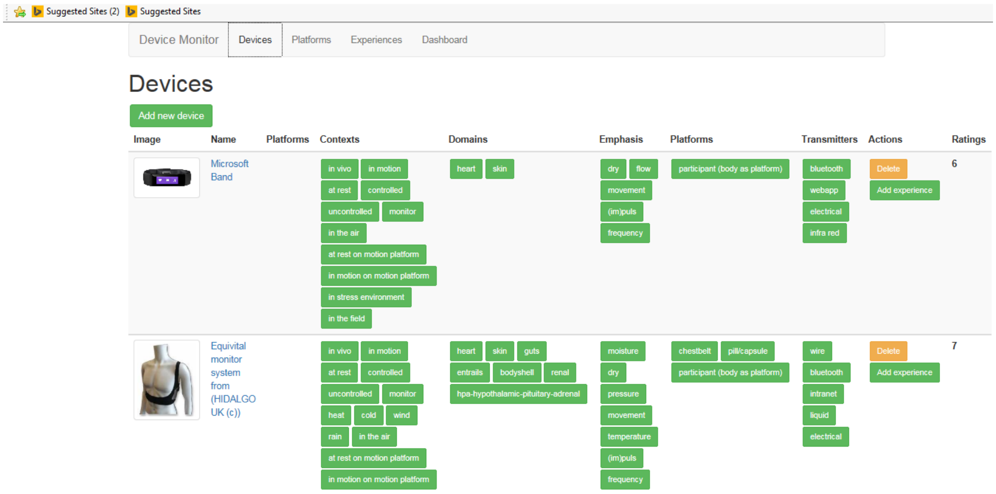


Figure 2 Screenshot of the Web-application to store, describe, evaluate and rate existing and future measurement tools.

The web portal has different work-tabs and provides information about the measurement platform, its sensors, data exchange protocols, data accessibility and feedback modes (see Figure 2). Table 1 shows the extended tab- sheets of the web portal. The tabs contains the information that was gathered from the literature and web search and that was stored in the tool catalogue. For the sake of clarity and simplicity, the columns of the catalogue were re-structured for the web portal, but the information provided in the catalogue and the web portal are the same. Furthermore, the web-app also incorporates a communication entry, that enables an inquiring researcher to contact the author of the tool information to get additional information. The first prototype of the web portal is developed and will further be operationalized in the second year of the ERP-HR program.

Table 1 The tabs and structure of the web portal designed for providing information about applicable measurement tools.

sensor device	connection	data exchange protocol	sensor	data accessibility	Feed-back mode
chestbelt	wire (usb)	ANT+	Optical heart rate sensor	raw sensor data	noise
wrist band	bluetooth	http	3-axis accelerometer	processed data	visual
electrodes	WiFi	https	Gyrometer	descriptive	haptic
pill	wire (ethernet)		GPS	not	
	radio		Ambient light sensor		
	pencil paper		UV sensor		
	infra-red		Skin temperature sensor		
	mobile (internet)		Capacitive sensor		
	mobile (telephone)		Galvanic skin response		
			light sensor		
			3-axis gyroscope		
			3-axis magnetometer		
			microphone		
			camera		
			temperature		
			core temperature		
			humidity		
			force		
			Saliva		

4 Health platforms

In this chapter we present an inventory of several applications or services applied in the health (mHealth) market. This inventory has some intrinsic value, but is also performed to provide input for the prototyping of the application we set out to develop in WP 4 (see Chapter 6) as a means to further knowledge development with respect to e.g. predictive modelling, monitoring and sensing, and providing feedback to users. This chapter consists of three sections. After a short introduction we first describe more general characteristics of the platforms or applications that we have reviewed. In the second section we elaborate on data communication and integration aspects. Finally, in the third section we briefly discuss privacy and security aspects.

Health is often cited as “the most important thing in a person's life” (WHO, 2015). It has also become one of the biggest economies in the world. In the Netherlands, the percentage of the gross domestic product (GDP) spent on health is about one-eighth of the total and is still increasing (see Table 2). In addition, the health economy has been considered inefficient, prone to monopolies (Havighurst & Richman, 2011) and non-rational behaviour (Rice, 2011). The industry is dominated by slow moving giants, and structure has been largely fixed over the last decades (The Economist, March 2015).

Table 2 Percentage of the gross domestic product (GDP) that is spend on health in The Netherlands (Worldbank Netherlands, Data).

Year	***2011***	***2012***	***2013***
Health expenditure (% of GDP)	12.1	12.7	12.9

Not surprisingly then, the high economic value, the potential for efficiency gains and perhaps also the iconic value has persuaded both established tech giants and other industry of start-ups to “try and 'disrupt' the health economy” (The Economist, March 2015). In November 2015 alone, approximately 300 new start-ups in the Healthcare market subscribed on ‘AngelList’ offering a range of products from a virtual healthcare system (“Nectors Healthcare” 2015) to 'Deliveroo' for pharmacies (“PharmaTruck” 2015). Many of these initiatives focus on mobile applications for health, a field also known as mHealth. As noted by WHO in their report "New horizons for health through mobile technologies" (“WHO, 2015, Global Observatory for eHealth Series - Volume 3”), over 85% of the world's population is now covered by a commercial mobile phone subscription, making this a particularly democratic channel for innovations in health.

As may be noted, the distinction between applications, services, databases, perhaps even systems or start-ups is not entirely clear in this context. As a part of the research program, another inventory has been performed that focusses on mobile applications, commonly known as *apps* (for more information see Paradies, Wabeke, & Korte, 2016). However, the domain of health platforms comprises apps, as health platforms are supposed to deal not only with usability aspects, but also with long term data storage, analyses, and the possibility to send adequate feedback and offering interventions to stabilize and/or improve health.

4.1 Platform characteristics

A brief literature review and web search were performed to provide an overview of the potential of existing platforms (see appendix B) and their value for developing an integrated application for monitoring, predicting and improving well-being (see Chapter 6 for the description of the developed prototype). In general, the review and search revealed that the applications and platforms are divers. The diversity is mainly caused as that the industry started independently and apparently unguided to focus on applications that themselves aim to improve well-being, by developing general platforms and some products that are mostly build around hardware (e.g., wearable hardware). As such, the selection of these different platforms, companies and products is not following any specific methodology other than the aforementioned.

These mHealth applications typically comprise of a fairly complicated architecture. While the user is often dealing with the mobile application or a wearable, data is analysed, shared, integrated with other services and stored with the help of various other technologies, all referred to, for the sake of this study, as 'the back-end'[2]. The services that make up the backend are sometimes dedicated only to the app at hand, but increasingly they integrate with a more general service, which we might call a platform, that can deal with more than just the data needed for this particular app. These platforms each have their own focus and capabilities. An example of a “common” platform is shown in figure 3. In this figure, you find the smartphone (1), as the pivotal centre of any mHealth application[3]. From here, things may vary, but an "app" that runs on the mobile device, such as the depicted "Seven Minute Workout" for example (2), interacts with the mobile device itself, and with a wearable device connected via Bluetooth. The data that the app collects is synchronized with a database in the cloud (3) and feedback is provided by using dashboards (4). It is for this last integration step that the app has to rely on a data platform (5). This may be a general data platform, such as Amazon Web Services (https://aws.amazon.com) or Microsoft Azure (https://azure.microsoft.com), that are not specifically targeted at health data. Alternatively, apps may exchange data with a service such as Sense Health (2015), or, integrate with an operating specific data synchronization service such as iCloud (only available for iPhone). Lately, the tech giants are trying out different business models to gain a stake in the mHealth ecosystem by creating more specialized services integrated within the devices’ operating system (e.g. Apple Research Kit, Samsung Digital Health). All these latter integration developments depend on the internet protocol. Several additions exist for this common architecture. Often, users are able to inspect their account using an HTML5 application through a web browser. Also, apps are increasingly integrating, not only through the operating systems of the devices (i.e. iHealth), but also through API's that are exposed directly on their backend. For example, This Then That (2015) allows users to create chains of simple conditional statements, called ‘recipes’, which are triggered based on changes to other web services or applications.

[2] Whereas a ‘front-end’ approach is more focused on what you direct can see (design, typography, colors, etc.), back-end development using specific languages (MySQL, PHP, other database languages, etc.) and therefore is more focused on how ‘it’ works.
[3] As it is today, it might change in the (near) future.

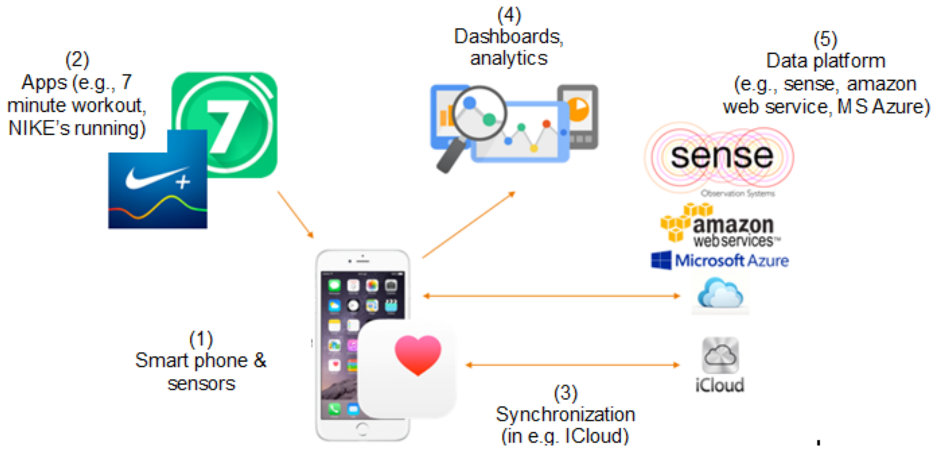


Figure 3 Data streams in a common setup for mHealth applications.

4.2 Data communication and integration

As can be seen from Figure 3, the applications and platforms we are considering can consist of many parts; a mobile apparatus, a server and wearable sensors. Some of the developments we will be looking at in the next section address only one piece of this puzzle, while others deliver a complete set that integrates into one application, at least from the perspective of the user.

Table 3 A list of typical communication patterns used by health applications and platforms. The sending and receiving party, the connection type/protocol and data that usually communicated is described for each pattern.

From	To	Protocol	Data
Wearable	Smartphone	Bluetooth, ANT or proprietary	Measurements
Smartphone	Server	Wifi or mobile data, HTTP, json	Measurements
Server	Database	Ethernet, HTTP, SQL, other	Queries and data
Web-based application	Server	Wifi or Ethernet, HTTP	Application and data

Data communication is an important factor for a successful combination of the above mentioned example of applications. More typical communication patterns and protocols are listed in the Table 3. Other protocols and connections do exist, but these are uncommon and do not apply to the examples described in this chapter. In addition to these communication patterns, health platforms can often also communicate with products of different vendors. This type of communication is called integration, which happens typically on the so-called application layer (Wikipedia, 2015). Integration is relevant for our use case, as we want to integrate third-party services and wearables into our own application. The four most common ways for applications to gain access to health related data are the Software Development Kit (SDK), application programming interface (API), operating system (OS), and Direct Interfacing. This four possibilities are further described in Table 4.

Table 4 A summary of the three most common ways for applications to gain access to health related data.

Type of integration	Description	Examples
SDK	Libraries that allow a mobile app to communicate with the device	Google Glass (Google Developers, 2015), Microsoft Kinect (Kinect, 2015)
API[i]	A documented way to access the data on a server, oftentimes also accompanied with libraries that make this access easier	Fitbit (Fitbit, 2015), CommonSense (CommonSense, 2015)
(Via) OS	Mobile apps can request access to several shared databases on the device they are used on, such as contacts data and location. All major vendors, i.e. Apple, Google and Samsung now also include a service for storing health-related data, i.e. calories burnt or steps taken, that's available for all mobile applications (with consent) to store and use data from	Apple ResearchKit (ResearchKit, 2015), GlucoSuccess (GitHub, 2015)
Direct interfacing	Finally, an application can also try and communicate directly with a wearable. This works well with standardized protocols such as ANT+, but may also work by decoding proprietary line protocols as happens often with the Microsoft Kinect	Garmin Heart Rate sensors (Garmin, 2015)

In conclusion, based on our review and web search and the current way to develop mHealth applications, the best way to develop an own health application is to use the modular integration approach (see Figure 3). This approach offers the possibility to integrate different applications independently. The advantage of this approach is that outdated modules of this network are easy to replace without changing the whole configuration. Disadvantages of this approach are the current possibilities to connect the modules (e.g., blue tooth, etc.), but these might compensable by using new releases of the SDK and API to connect technology and/or modules.

4.3 Privacy and security

Privacy issues are a 'hot' and interesting topic in Big Data, particularly when it comes to dealing with medical data. The ‘successful’ hacking of the UCLA Health records in July 2015 has demonstrated that concerns are legitimate, with reportedly 4.5 million people having their medical data compromised. In June this year, another attempt at an implementation of the EPD (Electronic Health Records, Staten-Generaal, 2014), was blocked by the Dutch Eerste Kamer, citing privacy concerns. The privacy and closely related the security of data in the cloud are not only the topic of an emotional or philosophical debate. Even in the tech-community, there are no widely accepted practices that make data in the cloud completely safe.

Despite promises ("Cloud security at AWS is job zero.", Koldijk et al., 2014), this year has seen some fundamental security breaches such as the prolific Heartbleed bug in OpenSSL (Hoebman, et al., 2014). This bug rendered virtually all cloud services vulnerable to complete takeover by anyone, or at least, their servers have been vulnerable in the past.

What should a developer do, building an app with the best of intentions, but also dealing with potentially sensitive information? As mentioned in WHO (2015), "necessary precautions" must be taken with regard to firewall and antivirus capabilities, password protection, network protection, message transmission security etc.. These requirements are also unforgiving: a single 'bug' or oversight can easily leave all other measures moot. Security and privacy are therefore precarious subjects, requiring serious expertise and devotion, which is sometimes at odds with the idea of a Minimum Viable Product that we have been trying to achieve in this project in 2015. Nevertheless, we are aware that this is a vital aspect of any application's design, and it can also be an impactful area of research in itself. As we progress our prototype, the application of advanced security practices will become an important topic. For this, the so-called 'privacy design strategies' (Koldijk et al., 2014; Hoebman, et al., 2014) that have been considered before in the related SWELL project, can be an interesting starting point.

5 Providing effective resilience feedback

Resilience feedback should empower and engage individuals to improve their resilience autonomously. As described above, one goal of work package 4 is to develop a method for effective resilience feedback. Therefore, the research has also focussed on questions like: How to make feedback that works and that has value for end users? What kind of feedback mechanisms/interventions do we use? When to give feedback?

The first part of this chapter describes a study that investigated the effectiveness of different dashboard designs that inform coaches about a resilience measure of several individuals. In the second part, the results of a brief literature review is described, in which two studies that examined the contexts in which users are available for interruptions are highlighted.

5.1 The effect of dashboard design guidelines

One of the objectives of this ERP is to develop knowledge about methods to provide feedback to a manager or a coach about the resilience of a group of employees (on the individual level). Graphical data visualizations, like dashboards, can be used to provide effective feedback on personal resilience data. However, these data visualizations should be designed in such way that they both effectively and efficiently convey the relevant information for the end user. Nowadays, an increasing amount of guidelines on dashboard design is available, but scientific evidence is often lacking.

In this project, an experiment has been conducted to evaluate several possible dashboard designs to inform coaches about a resilience measure of several individuals. Each dashboard design is based on at least one design rule proposed by Few (2004). By comparing the performance of the different designs, the applicability of the design rules for a coaching dashboard can be evaluated. Results of this study will be used to design more effective and efficient resilience dashboards for coaches.

5.1.1 Method

In order to evaluate a number of dashboard design guidelines, seven different dashboard designs have been evaluated on both effectiveness and efficiency.
All the seven dashboards were designed to provide correct answers in a situation where a coach has to look up a resilience score of an individual and evaluate whether he or she meets a specific reference score. This is believed to be a frequently occurring task in resilience dashboards.

The effectiveness of the dashboard design was expressed in the accuracy of performance (% correct). The efficiency was measured by the amount of time required to perform a specific task (milliseconds).

The seven designs are displayed below and vary in the degree of application of several frequently used design rules like logical ordering, application of charts, adding additional numeric representations and alerts.

1. Variables ordered randomly

Target: 1550

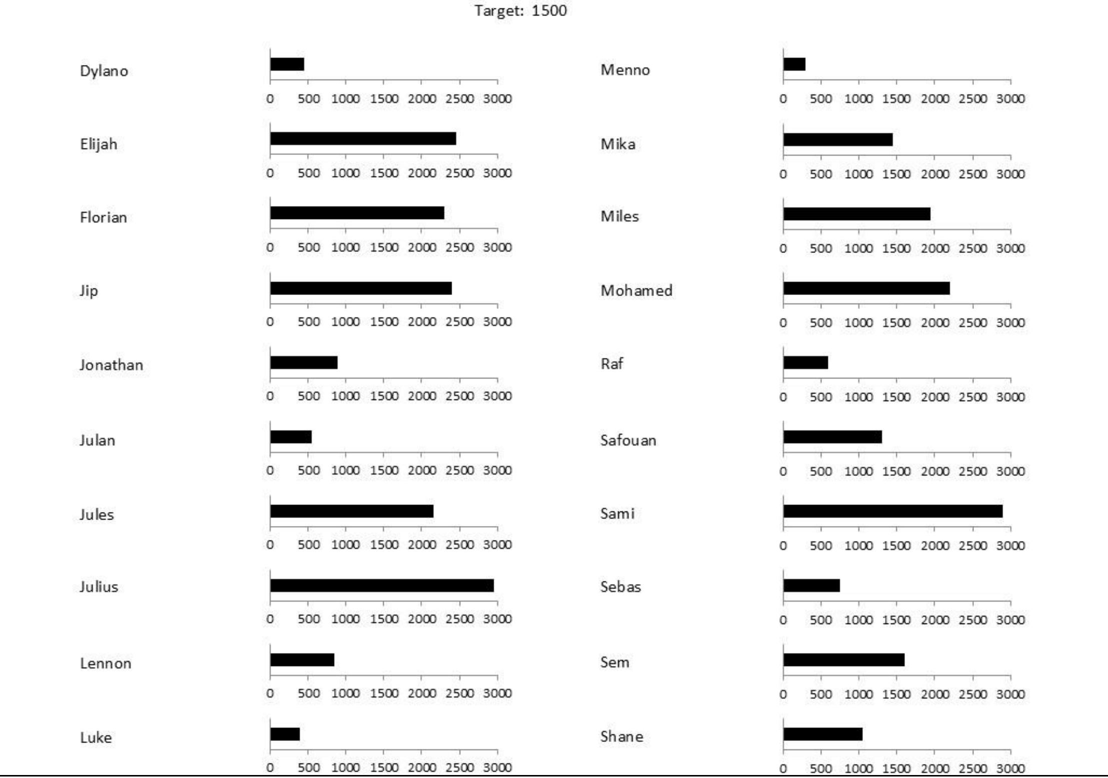
Tieme	800	Abraham	3000
Duncan	850	Bilal	1750
Brent	150	Bram	550
Marnix	1850	Rijk	900
Muhammad	1350	Boet	1550
Thom	2550	Djayden	250
Quinten	2900	Ian	1050
Tijs	2400	Manuel	700
Hessel	2700	Benjamin	2300
Kasper	1950	Glenn	1300

2. Variables listed in alphabetical order

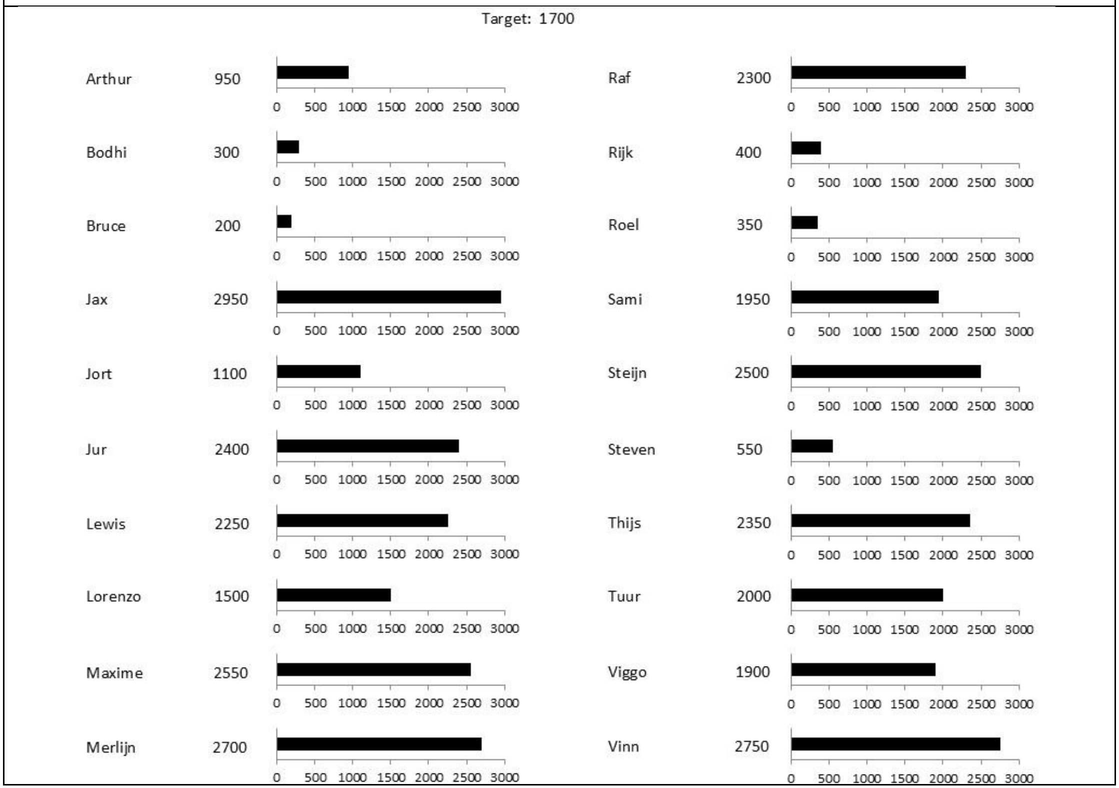
Target: 1500

Adam	700	Jop	2350
Adriaan	1000	Jorn	800
Bentley	2600	Jur	1450
Björn	450	Marius	3000
Delano	1150	Mitch	1050
Evert	2550	Oliver	2800
Ferre	2050	Oscar	1200
George	1850	Tom	500
Jake	1350	Vinz	150
Jayson	600	Wesley	2300

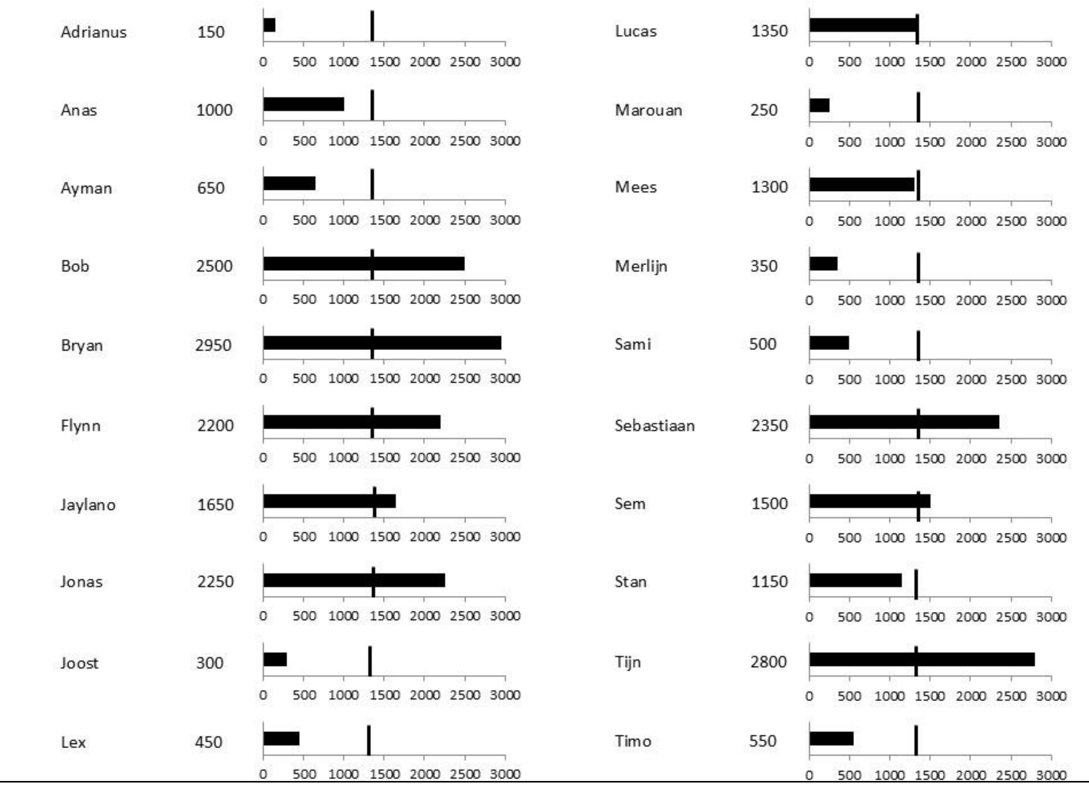
3. Replace numbers by charts



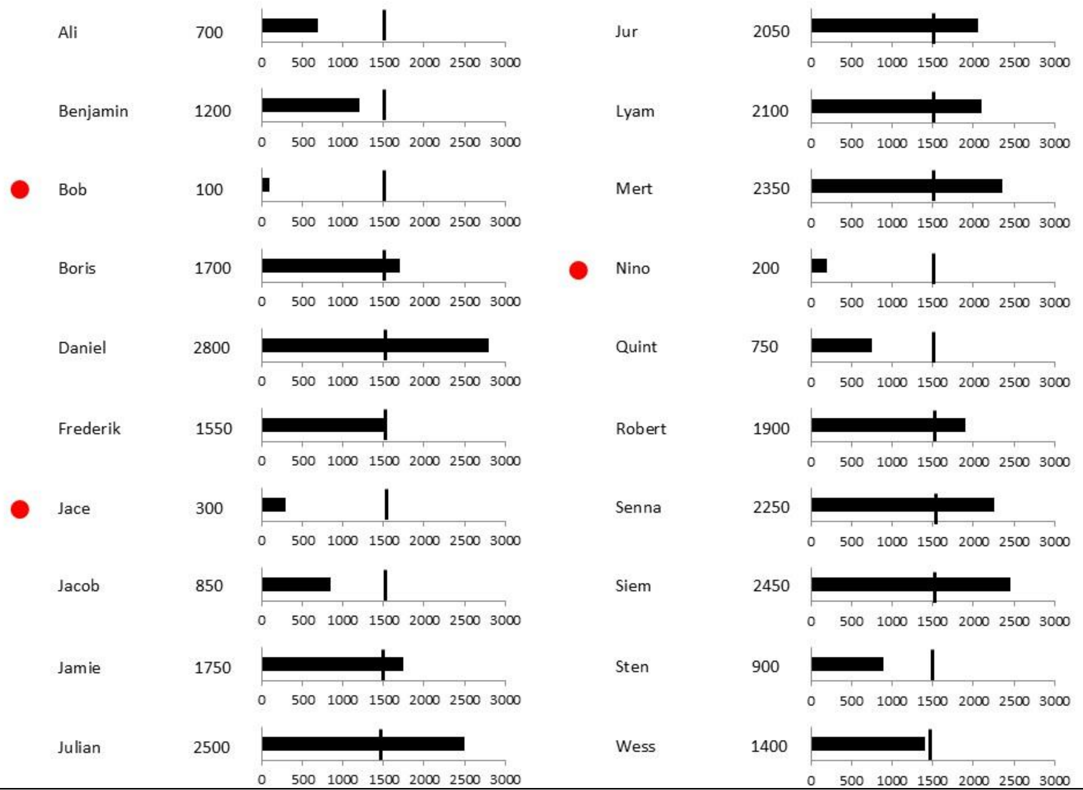
4. Combine chart with numbers



5. Add target line



6. Add alerts (score <500)



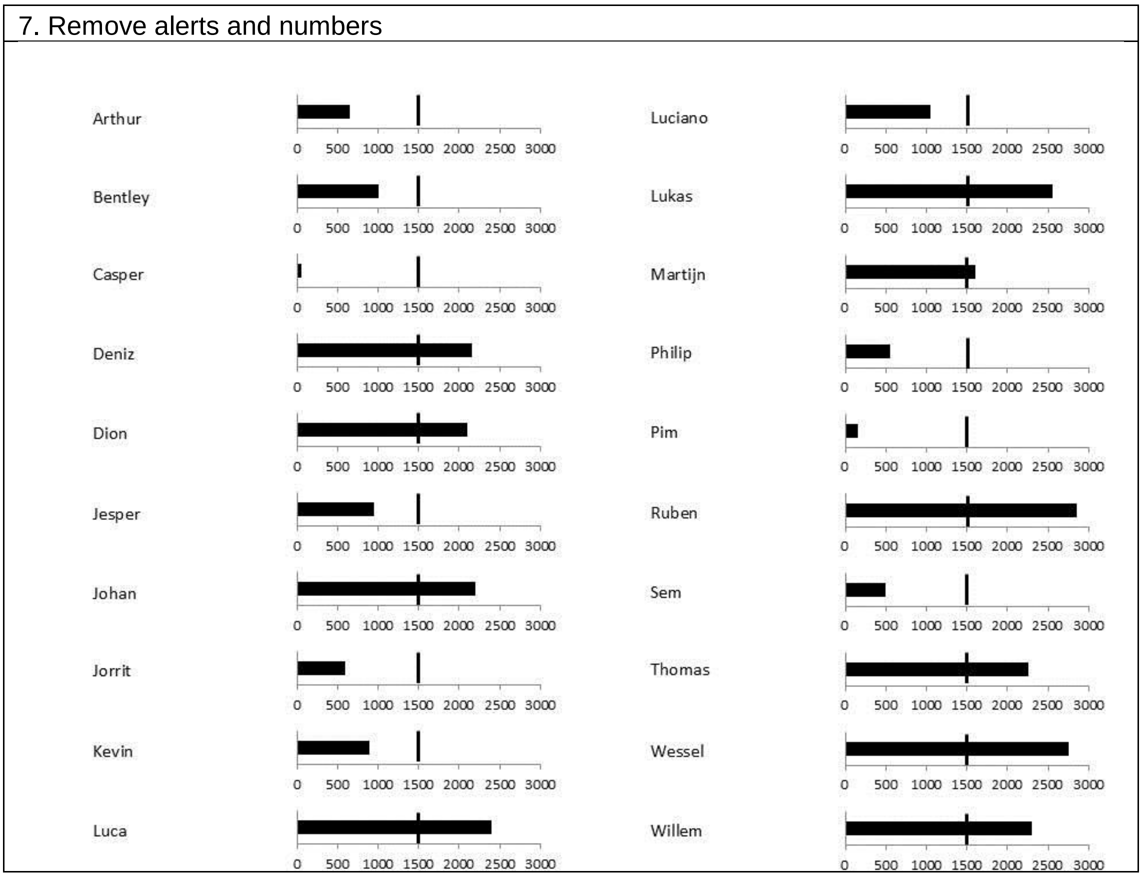


Figure 4 The dashboard designs which were evaluated in this study.

Design 1 represents the most basic form of a resilience dashboard. It consists of a random list of names of individuals with their resilience scores expressed in numbers. The target or reference value is expressed in a number in the right upper corner. Design 2 equals design 1, but adds an alphabetical order to the list.
In design 3 the numeric scores are replaced by bar charts. In design 4, the bar charts are accompanied by numbers reflecting the same score as the chart. Design 5 adds a vertical line to the bar chart replacing the target that was mentioned in the right upper corner in designs 1-4. Design 6 adds red dots to alert a user when the score of an individual drops below a specific value. This specific value is in this study not related with the target variable to investigate the effect of alerts that represents other cut-offs. Finally, design 7 has the bar chart with vertical line, but lacks the alerts and additional numeric scores.

It was expected that design 7 would perform best since it provides a single chart without numerical values and alerts that could cause clutter in which individual values can quickly be compared to the target. Design 1 was expected to perform worst due to the lack of ordering.

Twenty people participated in this study. Each of the seven designs were randomly displayed 20 times and every time the participant was asked to look up a specific name and evaluate whether this person met the target. The participants received training before they started the experiment.

5.1.2 *Results*

The results are presented in the graph below and suggested that participants have the lowest average reaction time using design 7 (3335 ms) and the highest using design 3 (4784 ms). Although participants spent more time answering questions using design 3, they also make the most mistakes (9,6%). The other designs have average reaction times between those of design 3 and 7. Design 5 and 6 have a slightly higher percentage of answers correct than design 7 but this difference is not significant.

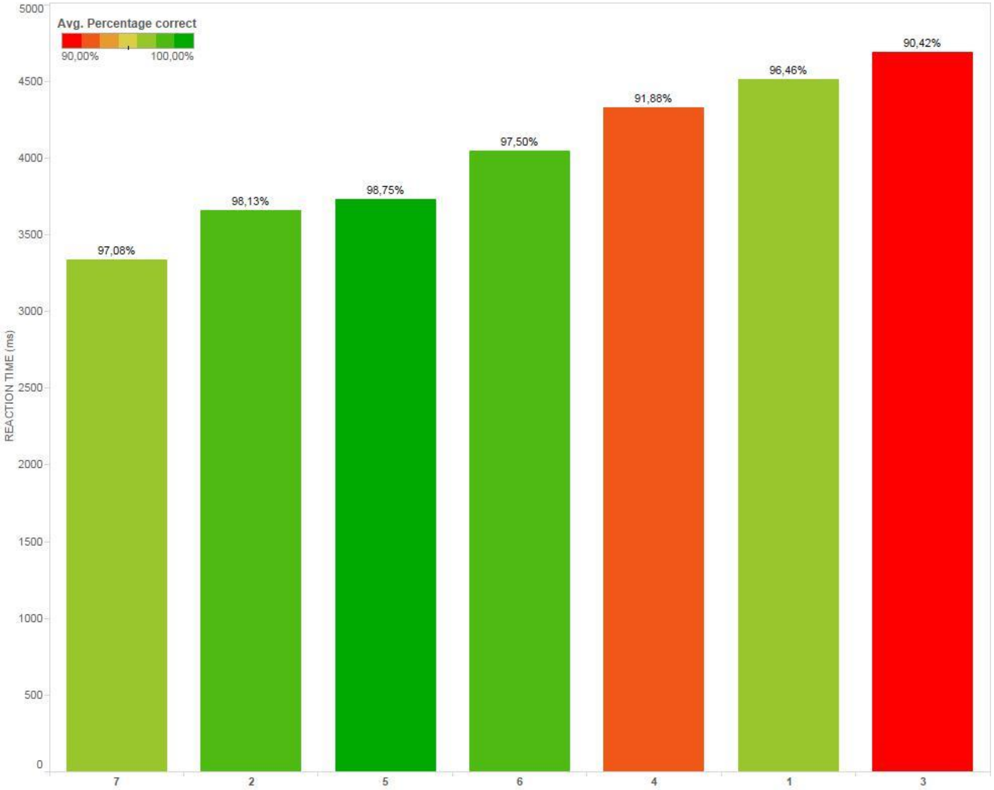


Figure 5 Results of the different designs expressed in reaction time and percentage of answers correct.

By testing the different designs statistically, design 7 proves to be considerably better than design 3 on both reaction time and percentage correct.

5.1.3 *Discussion*

In the worst performing dashboard design (number 3) the names of the individuals are placed in an alphabetical order and their resilience scores are displayed in a bar chart. The information on the target is displayed as a number in the right upper corner. In the best performing design (number 7), the names are also placed in alphabetical order and the resilience scores are also displayed in a bar chart. But the numerical target used in design 3 is replaced with vertical line in the bar chart.

The difference between these two designs that lead to the significant improvement in both reaction time and percentage of answers correct is the replacement of a numerical target value in a vertical line. The decrease in reaction time can be explained by the reduction of the scan path required to evaluate whether an individual scores below or above the reference score. Adding a target line near the same chart that represents the score reduces the required scan path and leads to a lower reaction time. The improvement in percentage of correct answers can be explained by the similarity in style of the representation of both the score and target in design 7. In design 3, users have to interpret a score in bar chart and compare it with a target expressed in a numerical value. This is a more complex cognitive process that apparently leads to more errors.

Besides the conclusion above, comparing the other conditions on reaction time and accuracy provides additional insights in effectiveness and efficiency of several dashboard design rules. The results show that applying design guidelines like alerts and additional numeric scores does not always lead to a significant improvement. The effectiveness of these design choices depends on the context in which the dashboard is used and the specific tasks of the user. Due to the fact that the alerts in this study were not related to the target variable, they probably caused clutter instead of being useful and therefore increased reaction time.

A design to use in this project might be based on design 7 which is displayed below (see Figure 6). Scores on resilience measures could be expressed in bar charts combined with vertical reference lines to increase usability.

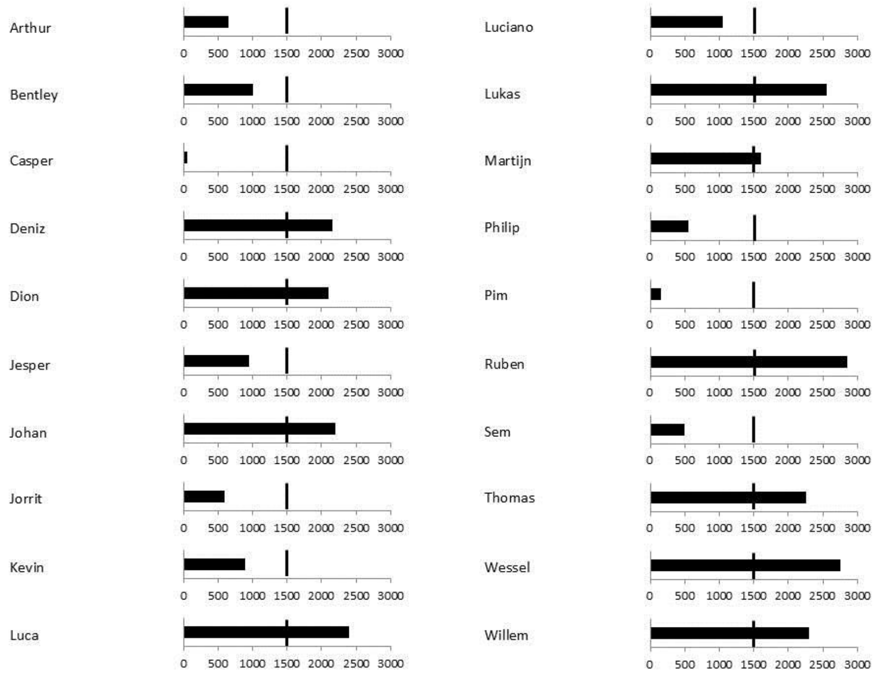


Figure 6 Example for a resilience dashboard based on the design 7 tool.

Further details can be found in dissertation thesis of Koen van der Leer.

5.2 Assessing opportune moments using smartphone sensors

Two different ways of providing feedback can be discriminated: push versus pull feedback. Push-feedback is automatically sent to a user without the need of any user interaction. A prime example of such feedback are smartphone notifications. Pull-feedback on the other hand does require user interaction; feedback is only presented to the user when he demanded it, e.g., by browsing to a webpage containing some graph of a resilience measure. The moment of sending push-feedback is very important, since even the most valuable feedback can easily be rejected if the user is not available. More specifically, imagine an individual who receives a smartphone notification asking him to perform push-ups while s/he is giving a sales pitch. Although push-ups may enhance the individual’s health, s/he will almost certainly not accept the provided feedback at this moment.

Several research has stressed the importance of timing when it comes to providing feedback (Fogg, 2009; Intille, 2004). The importance of timing was also found in a previous TNO study which investigated the effectiveness of personalized recommendations (Wabeke, 2014). Knowledge workers that participated in this study received personalized tips throughout the working day with the aim of improving their well-being. Results indicated that 60% of the tips were rejected, because the moment of recommendation was somehow inappropriate.

The right moments to persuade a user are often called *opportune moments*. These moments do not only depend on the actual/clock time. Rather they seem to depend on the ‘interruptibility’ of an user. In turn, this interruptibility has a lot to do with the context of a user. Where is the user? What is his primary task? What is his behavioral attitude? Context-aware algorithms are designed to automatically infer what a person is doing and can be used to accurately define whether a moment is an opportune moment. The following paragraphs describe two recent studies that investigated the contexts in which users are available for interruptions using a data-driven approach. The insights revealed by these studies help to design effective resilience feedback.

5.2.1 Classifying opportune moments for issuing notifications

Poppinga et al. (2014) conducted a study in which they investigated opportune moments for issuing notifications. For their purpose, the researches created a smartphone application that notified participants at different moments during the day about two questions. Firstly, participants were asked about their mood. Secondly, participants indicated whether the notification was obstructive.
The notification looked and behaved similar to traditional SMS notifications. Around each notification, data from different smartphone sensors was monitored to construct a snapshot of the participant’s context at these moments. See Figure 7 for an overview of this procedure.

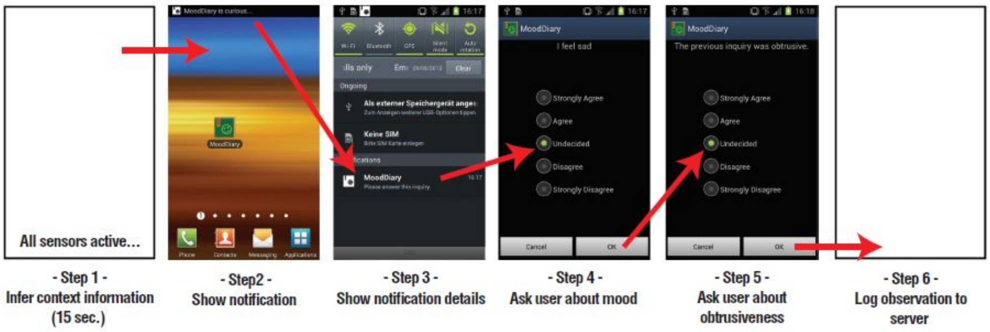


Figure 7 The six-step process for issuing and answering a notification used by Poppinga et al. (2014). For each step requiring user interaction, the notification can be rejected. In both cases—answering and rejection—the context information was transferred to the researchers' servers.

Afterwards, Poppinga et al. (2014) analyzed when questions attached to notifications were accepted. It turned out that most questions were answered when the phone was pitched towards the user at the time of notification. On the other hand, notifications that were sent when the smartphone screen was covered were often ignored and not opened later on. These findings suggest that notifications are more effective when a user is already using the smartphone. Future resilience enhancing technologies may thus want to postpone notifications if the user's smartphone is covered. For example, because the smartphone is in a bag or pocket.

5.2.2 *Predicting opportune moments for health related interventions*

The previous study focussed on opportune moments for issuing notifications. The topic of a notification can be very broad. For example, one can receive a notification for a new e-mail or a software update. It could well be that findings about opportune moments in general differ from opportune moments for resilience feedback. Hence, the following paragraphs cover a study that is more in line with resilience feedback.

Sarker et al. (2014) focussed on predicting opportune moments for health related interventions, which are aimed at improving the user's health and require appropriate engagement of the user. The design of their study is similar to the study described previously. There are, however, four important differences:

- Firstly, the created smartphone application notified participants about health related questions instead of general questions.
- Secondly, the notifications did not behave like traditional SMS notifications, because the phone beeps for 4 minutes. If the participant started answering or pressed the delay button, this sound stopped.
- Thirdly, a wearable sensor that measured the participant's ECG, respiration and acceleration at notification times was used in addition to smartphone sensors.
- Finally, the authors aim to predict the probability of answering the first questing attached to a notification within *124 seconds*, whereas the study described previously aims to classify whether a notification was answered or not (without a time restriction).

Results indicate that participants are least available at work and during driving, and most available when walking outside (Sarker et al., 2014). The predictive model that was trained achieved an accuracy of 74.7% in 10-fold cross-validation and 77.9% with leave-one-subject-out. In addition to these machine learning analyses, the authors also defined the 30 features with the highest information gain for predicting an opportune moment (see Table 6).

Table 6 Features ranked (R) according to information gain for predicting an opportune moment.

R	Feature	R	Feature
1	Detailed Location	16	Stress probability
2	Coarse Location	17	Stress count in 5 previous window
3	Weekday	18	StressChange-300
4	Outdoor?	19	StressChange-240
5	Sleepy?	20	ActivityAll-120
6	Happy?	21	StressAny-180
7	Energetic?	22	StressChange-180
8	Commute Mode?	23	StressAny-240
9	Recreation?	24	StressAny-60
10	Activity type	25	StressChange-30
11	Weekend?	26	StressDuration-30
12	Talking on phone?	27	ActivityAll-180
13	Taken Alcohol?	28	ActivityAll-240
14	Elapsed hour of day	29	ActivityAny-300
15	Time spent in current location	30	EMA Index

The features in the table above can be used to accurately define whether a moment is an opportune moment, because they have a high information gain. One can observe that many informative features are already detectable using sensors. For example, features related to the location of a user can be measured easily using a GPS sensor (Table 6, features 1, 2, 4, 8 and 15) and features holding information about the current date and time are always available (features 3, 11 and 13).

6 Developing a prototype monitoring concept for enhancing resilience

The insights generated by the project work in the initial year were integrated in a prototype that was developed to test assumptions about wearable applications that aim to enhance employee resilience, and to gain additional insights for further development. The application focused on the resilience of young TNO employees. The concept and development process of the prototype are discussed extensively in Paradies, De Hoogh, Preenen, Wabeke, Van Zwieten, Kamphuis and Delahaij (2016). Next to this, the advice coming from the literature review and web search (see chapter 3) is used to develop a prototype. The present chapter gives an overview of the technical components the prototype consists of. Furthermore, it describes some of these components in more detail.

6.1 System setup

The resilience prototype is a tool that supports both young TNO employees (coachees) and their coaches in enhancing the coachee’s resilience. The prototype contains four technical components which are related to each other; namely a data platform, dashboard, smartphone application and a Microsoft Band. These components and their relationships are displayed in the Figure 8.

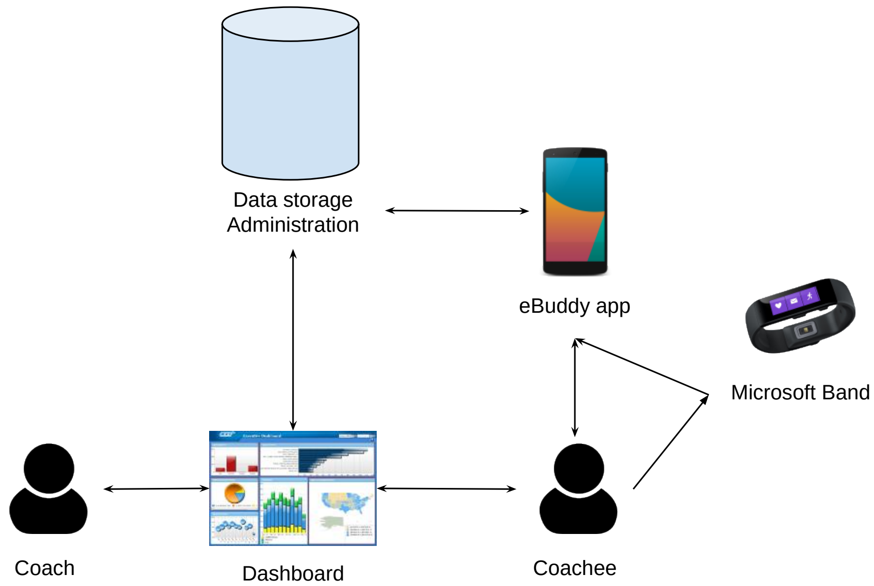


Figure 8 The prototype that was developed contains four technical components which are related to each other and the user. This figure displays these components and the relationships.

The coachee installs a smartphone application called eBuddy on his smartphone. This application connects with a Microsoft Band to gather data that is monitored by this wearable device (e.g., heart rate measurements). Furthermore, the smartphone application provides the coachee with questionnaires about topics he is working on. Examples of such topics are improving scheduling skills or motivation.

The questionnaires are prompted at a daily or weekly interval and contain five questions at maximum. All data of the coachee is sent to a TNO server using a HTTP internet connection. See Section 6.2 for more details about the smartphone application.

The server is responsible for all data storage and administration. For instance, it stores Microsoft Band measurements and keeps a list of users including the topics coachees are working on. Section 5.2 describes the setup and responsibilities of the server in more detail.

The coach and coachee can view all monitored data using a web-based dashboard. This dashboard also enables the coach and coachee to turn topics on and off. Section 5.4 focusses on this dashboard.

6.2 Database infrastructure and management

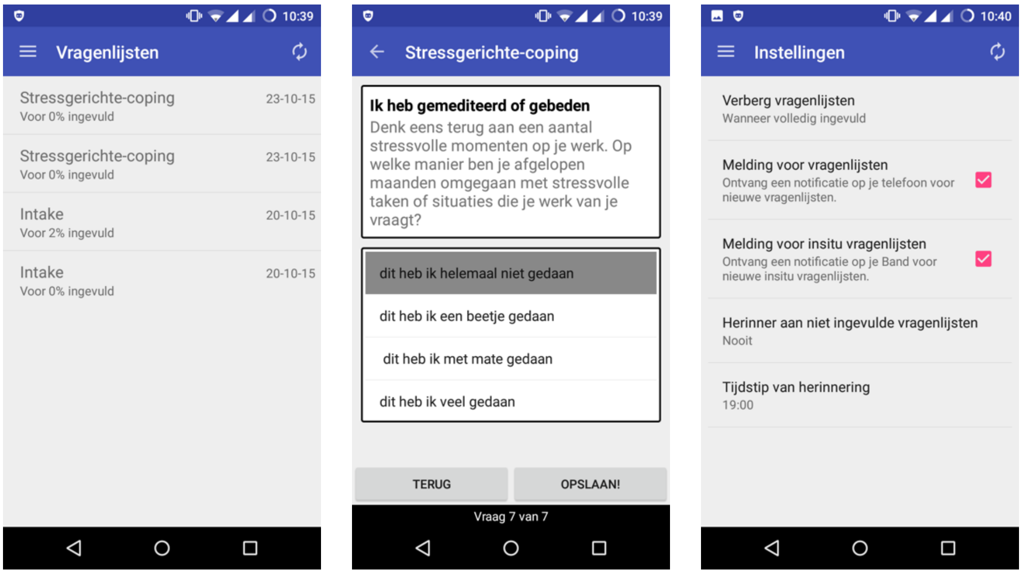
The applications' infrastructure is built with the microservices pattern, utilizing the Docker ecosystem to provide preconfigured database 'containers' as well as images that can be used to host the custom code. For example, there is a container that translates user requests into queries for the database, a container that runs the database itself and a container that serves static files, comprising a web-based app. At the moment, there are two database systems used, MongoDB and InfluxDB. MongoDB is used as a general purpose object store, while InfluxDB is a specialized application for time-series data, that we use to store measurements such as heartrates and data from the device's accelerometers. The containers can communicate amongst each other, and do so, over various networking connections based on TCP/IP. In order to be useful, some interfaces have to be open for users and administrators, mainly:

- an administrative interface for managing users and questionnaires;
- an api that exposes personal data, intended for the smartphone application.

These endpoints communicate in json objects in a REST based architecture.
The security and personalization is based on basic HTTP authentication, a trusted approach although not considered safe if not over a secured HTTPS connection.
At the moment, we are considering moving towards HTTPS with the help of the service Let's Encrypt.

6.3 eBuddy smartphone application

The eBuddy smartphone application enables coachees to fil-in questionnaires and connect with a Microsoft Band. It is thus mainly a data gathering tool and not (yet) used for providing feedback. Figure 9 provides an overview of what the application looks like. The subsequent paragraphs highlight how the applications gathers data from the Microsoft Band.



Acitivty displaying the list of questionnaires. | Activity displaying a single question. | Activity that allows the coachee to change application settings.

Figure 9 Three screen captures of the eBuddy smartphone application.

6.3.1 *Gathering data from Microsoft Band*

- To connect to the Band, coachees first installed the Microsoft Health application on their smartphone and logged in using a Microsoft account. The Microsoft Health app provides the underlying communication between the smartphone and Band.
- Subsequently, the eBuddy application registers at the Microsoft Health application using the Microsoft SDK. This SDK contains several software development tools allowing one to gather data from sensors including heart rate and accelerometer.
- Accordingly, the eBuddy application asks coachees to grant access to their Band data. After carrying out these steps, the eBuddy application is able to communicate with Band using the Microsoft Health application as a proxy and can gather heart-rate and accelerometer measurements.

For more details about gathering data from the Microsoft Band see: https://developer.microsoftband.com

6.4 Feedback and coaching tool

The dashboard is designed for a resilience coach who coaches five employees (see Figure 9). In the tabs the status of their demands, resources and outcomes is directly visible in a small graph. Briefly, when a component is green there are no issues. Based on one or two standard deviations from the mean (green) value, respectively, a component turns orange or red, implying that attention is required. By clicking on the tab, all the information of the employee is presented. Clicking on a specific scale will show additional information and advanced benchmark possibilities.

Figure 10 Resilience coaches can view all collected data using this dashboard.

In addition to this dashboard, an administration panel was developed (see Figure 11). This administration panel allows coaches to activate topics for coachees. Activating a topic means scheduling a set of questionnaires (e.g., questionnaires about autonomy).

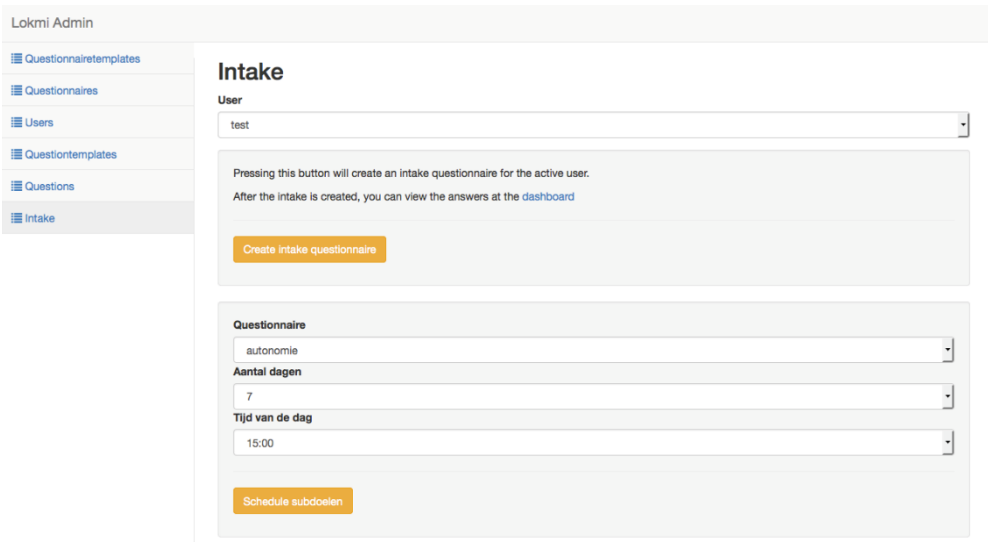


Figure 11 Resilience coaches can activate topics for coachees using this administration panel.

7 Sum-up and way ahead

The aim of WP 3 and WP 4 with respect to monitoring resilience was a) to gather and explore the the state-of-the-art advances in technology to monitor current individual state; and b) to explore and describe possibilities for evaluation of the results for individuals and organizations using dedicated feedback technologies.
To these aims, a literature and web search was accomplished to scan the available tools with incorporated sensor technology appropriate for a monitoring approach. Next, the results of this scan were put into WP3's catalogue and led to prototype of a web portal. The web portal was developed to share the tool information and store the state-of-the-art stats and facts of the monitoring tools. Furthermore, a brief literature review and web search was also conducted to gather information for the development of a resilience monitoring platform and the possibility to provide feedback to organizations and employees. Finally, a resilience monitoring platform was developed within WP4 as a prototype, and the functionalities and specifications are described in this report.

Next to the contribution for leveraging the prototypes, the brief literature reviews and web explorations revealed that the health and fitness industry releases increasingly user-friendly gadget technology. These are also displayable on health applications and, e.g., wearables. These technology develops fast and can be used to develop tailored applications for the development of a comprehensive resilience and mental health monitoring approach. Thought, it seems very beneficial to may pick out of a broad range of tools, however, it is also required to test and validate this technology to select the most applicable, reliable, easy-to-use and easy-to-wear technology. Therefore, in the following year of the research program a number of monitoring and sensing tools will be systematically tested in specific use cases.
In addition, individualized modelling and feedback algorithms will be developed, strategies and methods will be further examined and developed to keep end-users involved and motivated to participate.

More specifically, WP 3 structured its research in the areas of 'monitoring & sensing, 'data management & modelling', and 'feedback platform' and seeks to answer following research questions in the year of 2016:

Monitoring & Sensing:
- What are state-of-the-art developments in sensors and monitoring instruments to assess the determinants/factors from the MFMLHR model?
- How can complex/extensive questionnaires be transformed into simple easy to use rating scales taking into reliability and validity issues into account?
- What are the requirements for a so called stepwise monitoring approach (high sensitivity / low specificity: minimal intrusive vs. low sensitivity / high specificity: more intrusive) to be applied in defined use-case(s)?

Data management & modelling:
- How do we develop an individual based predictive modeling/reasoning algorithm?
- What existing data platform is most applicable to be used in proposed use-cases?

- Can we derive this personalized algorithm from the group modeling approach used in WP1 by using machine learning techniques?
- How do we determine the cut-off points?

Feedback platform:
- How, what and when do we provide feedback, and what role does feedback play to keep users engaged?
- To what extend does the in 2015 developed desktop dashboard version succeed in effectively communicating the gathered data (and context) to the end users (coaches and participants)?
- How can we process all various data types (sensor, questionnaire, context) in output measures that are useful and easy to understand for the end user?
- What are the feedback requirements with respect to timing and self-control?

For work package 4 two prototypes will be developed and enrolled in demanding test environments (use cases) at a sport organization (i.e., national team of the Royal Korfball Association) and a selected unit of the Dutch Police Force.
More specifically, the activities of WP 4 will result in:
1. A first working prototype, consisting of a mobile application and wearable sensing device to be used for expert testing.
2. A trial prototype, consisting of a mobile application and wearable sensing device to be used for a larger test (case study, sample size: 20-50 people). The data of this case study will be used as input to the model validation activities of WP 1 and 2.
3. A trial prototype feedback dashboard, to be used in a larger demanding user group (test sample size: 20-50 people).

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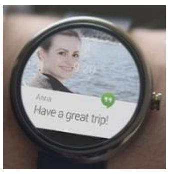
A Inventory list of sensors and sensor platforms

This table starts with a domain column, in which the toolset is linked to the research domain that mostly uses the tool. The next column describes the system specifications and to which sub domain the described tool belongs, followed by the tool column displaying the name and a picture of the tool. In the last two columns the specifity, usability, pros and cons are described.

Domain	**Sub-domain non*invasive tools**	**tool/app/sensoring**	**context/specs/ experiences**
Physical/ Physiological activity	belt systems (chest/finger/hip; mobile)	Equivital (Hidalgo) 	HR/HF/HRV/ d.m.v. ECG
			Kern en Huidtemperatuur d.m.v. pilsensoren
			GSR d.m.v. elec. finger sensors
			Respiratie d.m. van expansiesensoren
			bewegingsactiviteit d.m.v. actographie sensoren
		Polar 	HR/HF/HRV/ d.m.v. Pols/HR sensoren
			Activity door bewegingssensoren/ interne algorithmen
		Eyelink/tobi  	Oogbewegingen; fixaties, saccades, blinks,…
		Portapres 	continous blood pressure in combi with portapres (cBP)

Physical/ Physiological activity	klinische/lab data*acquisitie systems met accessoires	Biosemi (acqi van ruwe signalen)   	electrocardiografie > HF/HR/HRV/ICG*/SV*/CO*
			electroencephalografie (EEG) > alfa, beta, gamma, teta brainwaves
			electromyografie (EMG)
			galvanic skin response (GSR)
			cardiac output (CO)
			impedance cardiografie (ICG)
			stroke volume (SV)
			stroke volume variation (SSV)
			systemic vascular resistance (SVR)
			continous blood pressure in combi with portapres (cBP)
			Pulse transit time (PTT)
		TOBI	oogbewegingen
		g*tec 	Skin temperature
			Respiration effort
			Snoring
			cBP
			Acceleration
			Respiration airflow
			galvanic skin response (GSR)
			Limb movements
			oxygen saturation
			EEG
			pulse
	termo fysiologie	sensoren	klimaatkamer
		veld vs lab	
		…	
	semi klinische parameters	hormonen 	

Physical/ Physio-logical activity	Activity trackers	Shimmer 3 IMU evaluation kit 	Accelerometer, gyro, magnetometer, emg, ecg, gsr; applicable sampling frequencies;
		ViFit 	Voornamelijk geschikt voor lopen/rennen. Kan geen onderscheid maken in typen activiteit.
			Data komt ook in database van producent (geanonimiseerd); kan wel eenvoudig worden verkregen (API)
			Toegepast in TNO studies Zeist (P4@TNO, QuaLiFY)
		Moto 360 	*Capacitive touch *Pedometer (9*axis sensor) *Optical heart rate monitor *Ambient light sensor *Dual microphones xxx
		Apple Watch 	*accelerometer *gyroscope *heart rate sensor *barometer
		Pebble Time 	* 3D accelerometer * Compass * Ambient light sensor * Microphone * Up to 7 days between charges
		Microsoft Band 	*Optical heart rate sensor *3-axis

Physical/ Physio-logical activity			accelerometer/gyro *Gyrometer *GPS *Ambient light sensor* Skin temperature sensor *UV sensor *Capacitive sensor *Galvanic skin response *Microphone
		Mio Link 	*Optical heart rate sensor *Heart rate variability *Bluetooth 4.0/ANT+
		FitBit Surge 	* gps tracking *pulse *All day activity *record multi sport * Long battery life; *noitifications & music * auto sleep monitor; * wireles syncing
		Samsung Galaxy S6 	*Accelerometer; *Gyro; Proximity; *Compass; *Barometer; *heart rate;*SpO2 (Oxygen saturation sensor)
		Activ8 	Onderscheid 6 typen ‘activiteit’ (liggen, zitten, staan, lopen, rennen, fietsen); Data kan afgeschermd worden opgeslagen Gaat toegepast worden in TNO studie (DIY*pilot)
		‘ Actiwatch 	bewegingssenoring en algoritmen die afgestemd zijn om algemene beweging te registreren ingezet in diverse studies om bewegingsactiviteiten te registreren in militaire settingen en/of tijdens studies om slaapkwaliteit/duur/activieit gedurende de nacht in kaart te brengen

Physical/ Physio-logical activity	visueel/camera	visuele camera 	* meten van persoonshouding
		Infraroodcamera  	
		 stereocamera	
		kinect camera 	

Physical/ Physio-logical activity	Vragenlijsten	SQUASH 	§ Vragenlijst naar activiteit in afgelopen maand; neemt ook woon*werk verkeer, huishouden, etc. mee
			§ Ingewikkelde statistiek voor data*analyse
			§ Veel toegepast in TNO studies (Zeist en Leiden)
		IPAQ	§ Internationale, gevalideerde vragenlijst; ook beschikbaar in NL
			§ In mindere mate toegepast in TNO studies (Zeist)
		SF12/SF36	gevalideerde WHO/Health vragenlijst;
			onderdeel (na aanpassing) van de Resilience Monitor (Defensie); onderdeel van de belastingsmonitor fieldlabs Defensie.
			onderdeel van de belastingsmonitor fieldlabs Defensie.
		Dag*/nachtboeken	subjectieve inschatting van activiteiten/slaappatronen/kwaliteit
		HealthQ	Gezondheids schaal WHO gevalideerd
		Belastingsmonitor MOC short&long	2 tot 6 concepten van fysiologische activiteit (mentaal en fysiek) met LEO schaal (pain perceptie) in combi met coping strat.
Physical/ Physio-logical functioning	Motorieke taken test in combi met v*lijsten(?)	Short physcial performance battery	o Veel ervaring mee in TNO Leiden (Astrid Chorus)
			o Alleen gevalideerd bij ouderen
	Handknijpkracht	Handdynamometer 	Meten van de knijpkracht in N.; goede voorspeller voor gerontologen voor licht verval/prestatie m.b.t. de spierkracht/activiteit en cardio output
	Uithoudings*vermogen	Cooper test	12 munuten loop
		Conconi test	Periodischer versnellingsloop
		lactaat test loopband/fietsergometrie	ergometrische lactaat testen
	Kracht max	Maximaal kracht test per spiergroep	SPORT*physiological test batteries

	Krachtuithoudings*vermogen	Duurtest per spiergroup	
	Snelkracht (explosief) test	Explosiviteitstest spiergroupspecifiek	
	Snelheidstest;	sprintvermogen [lopen]	
	Motorieke taken testen	Scholieren <> Ouderen	
	Vragenlijsten (zie ook physical activity)	Vitaliteit; WHO; Health…	
Physical/ Physio-logical functioning		Vita*16	Ontwikkeld en gevalideerd door TNO Leiden (Jorien Strijk)
Body constel-lation	SmartScale	FitBit Aria / Withings	§ Betrouwbare data
			§ Data komt ook in database van producent (geanonimiseerd); kan wel eenvoudig worden verkregen (API)
			§ Toegepast in TNO studies Zeist (P4@TNO, QuaLiFY)
		Medisana SmartScale	§ Betrouwbare data, maar niet gebruiksvriendelijk
	Gewicht Zelfrapportage		§ Verschil tussen weegschalen
			§ Risico op onderrapportage
	BMI (Body Mass Index)	gewicht/lengte2	o Standaard*maat voor classificatie normaal – overgewicht – obees
			o Houdt geen rekening met spier*vet*ratio
	Waist/hip*ratio		o Betrouwbaarder voor inschatting spier/vet*ratio dan gewicht
			o Meet*protocollen beschikbaar (met gewoon meetlint)
	Vet*percentage	impedance	o Meestal gemeten met bio*impedantie; foutmarge van ongeveer 5%
		skinfold (3*6) calippermetrie	o Andere meetmethoden zijn te invasief en vereisen training (bv. skinfold)
	Somatypering	Mesographie	Mesomorph
		Endographie	Endomorph

		Ectographie	Ectomorph
Food	FFQ (food frequency questionnaire	voedingspatroon over afgelopen maand)	§ Risico op onderrapporage
			§ (nog) niet digitaal en open source beschikbaar
	Dietary recall (voedings*dagboekje)	Paper pencil	§ Data moet handmatig worden overgenomen; voedingswaarden moeten handmatig worden opgezocht en ingevoerd
		Online (FatSecret, MijnEetmeter, OPEN platform)	§ Voedingswaarde automatisch gekoppeld
			§ Data kan eenvoudig worden geëxporteerd (m.n. FatSecret en OPEN)
cognitive task: perception, processing, assessing/ evaluating, applying, re-/production of information	Leren	Opnemen, Verwerken, Beoordelen, Toepassen, (Re)produceren	
	Waarnemen	Perceptueel*motor (vinger motoriek)	Purdue pec 
		tobi/ eylink	
	Herinneren/ geheugen	N-back; (two … back)	pc
	Denken	Montreal Cognitive Assessment (MoCA)	
		Brief Cognitiev Assessment Tool (BCAT)	
	Interpreteren	Cognitive function test	
	Geloven		
	Probleemoplossen		
Executive functioning	Plannen		
	Beslissen		
	Foutencorrectie	vigilance	
	Fout-opsporing	vigilance	
Emotions	Facial Expressions analysis		

		Noldus en VicarVision http://www.noldus.com/human-behavior-research/products/facereader 	Binnen MNS veel ervaring mee (SWELL en MIME project)
	stroop test		
Video processing			
o Face detection			
o Person detection			
o Facial expression reading			
o Face recognition			
o Eye gaze detection			
- Audio processing			
o Speech detection			
o Speaker identification			
o Activity detection (e.g. sound of TV)			
- Text analysis			
- Machine learning. It is a generic approach to categorize unlabeled data based on the analysis of previously collected data.			
Volometrix		VoloMetrix extracts and analyzes anonymized, aggregated header-level data from your corporate communication systems. Data provides insight into the subject, timing, and format of collaboration, as well as an understanding of the role and geographic location of individuals involved. Together, people analytics data provides a holistic map of your company's communication and collaboration behavior. Quantified into money. VoloMetrix helps businesses understand how employees spend their time at work, using data from emails and calendar events to streamline operations.	http://static.crunchbase.com/daily/content_20141013_twitter.html; http://www.volometrix.com/people-analytics-how-it-works
SAP Integrated Performance Analysis		Integrated reporting is based on the idea that social, environmental, and economic performance are interrelated, with each realm creating tangible impacts on the others. To achieve an integrated strategy, SAP believes that	http://sapintegratedreport.com/2014/en/strategy/integrated-performance-analysis.html

	they must understand these connections and work to support them throughout SAP.	
IBM - Smarter Workforce	Employee survey programme. Data is gathered by questionnaires and company systems. Combined they create a complete picture of the company which can be benchmarked against others in the industry. This leads to an action plan on how to engage employees. Xenaxa has experience with employee assessment, employee engagement, recruitment, talent management software.	http://www-01.ibm.com/software/smarterworkforce/ http://www.forbes.com/sites/joshbersin/2013/01/31/ibm-launches-its-smarter-workforce-initiative/
IBM HR analytics*	An analytics-driven solution that infers the expertise of employees through the mining of enterprise and social data that is not speci cally generated and collected for expertise inference. This expertise analytics system has been deployed for key employee population segments, yielding large reductions in manual effort and the ability to continually and consistently serve up-to-date and accurate data for several business functions. The goal of the system is to match job functions and employees' and their qualities.	Varshney, K. R., Chenthamarakshan, V., Fancher, S. W., Wang, J., Fang, D., & Mojsilović, A. (2014, August). Predicting employee expertise for talent management in the enterprise. In Proceedings of the 20th ACM SIGKDD international conference on Knowledge discovery and data mining (pp. 1729-1738). ACM.
Sociometric Solutions	Gathering data by badges worn by employees and out of computer systems (team) performance is explained and predicted.	http://www.theatlantic.com/magazine/archive/2013/12/theyre-watching-you-at-work/354681/;
Evolv	Employee workforce management—centered around predicting employee fit with the long-term of the company. Monitoring the entire life cycle of a worker at any given company. Pre-hire assessments are coupled with an array of post-hire data: about not only performance and duration of service but also who trained the employees; who has managed them; whether they were promoted to a supervisory role, and how quickly; how they performed in that role; and why they eventually left.	http://whartonmagazine.com/blogs/count-down-to-the-end-of-old-style-hr/; http://www.theatlantic.com/magazine/archive/2013/12/theyre-watching-you-at-work/354681/
Gild.com	A company that uses people analytics to help other companies find software engineers. It does so by analyzing the code a specific engineer has created	http://www.theatlantic.com/magazine/archive/2013/12/theyre-watching-you-at-work/354681/; www.gild.com

	that is on the world wide web and giving a quality score to it.	
Vita.io	Vita.IO measures social interaction within a company (who is emailing or calling who) combined with employee engagement, employees expertise and employees personality. Based on language analyses from email, documents, chats and telephone calls. Data is aggregated of at l east 15 employees. Employees can see a personal dashboard and can decide to share their data on an individual level with the organization.	http://vita.io/
Colliers Quantified workplace	Employees wear a fitbit wristband which is connected to a smartphone dashboard in order to gain insight into the optimal balance between wellbeing, productivity, stress and health. Part of the data is shared with the organization and used for research.	http://www.vastgoedmarkt.nl/nieuws/2015/06/04/colliers-start-experiment-quantified-workplace http://www.quantifiedworkplace.eu/
LifelogExplorer*	LifelogExplorer combines arousal information, tightly linked to stress, with contextual information in form of artifacts produced by users' activity in the digital world such as calendar activities, e-mails, (logs of) phone calls. The tool allows users to explore correlations between their activities and their emotional responses and reflect on their behavior. By realizing such relations they may identify possible problems, attempt a change in their behavior, and observe its effects.	Kocielnik, R., & Sidorova, N. (2015). Personalized Stress Management: Enabling Stress Monitoring with LifelogExplorer. KI-Künstliche Intelligenz, 1-8.
P4Well*	The P4Well intervention integrates different personal health technologies, including a Web portal, mobile phone applications, personal monitoring devices, and analysis software, with a CBT- and ACT-based intervention program which was specifically designed to utilize personal health technologies. Program consisting of three group meetings held by a psychologist in which skills were taught like clarification of personal values, goal setting, self-monitoring, relaxation, mindfulness and acceptance. In-between the meetings users choose	Lappalainen, P., Kaipainen, K., Lappalainen, R., Hoffrén, H., Myllymäki, T., Kinnunen, M. L., ... & Korhonen, I. (2013). Feasibility of a personal health technology-based psychological intervention for men with stress and mood problems: randomized controlled pilot trial. JMIR Research Protocols, 2(1).

	from a wellness toolkit: web portal, mobile phone with 3 preinstalled applications, pedometer, heart rate monitor. In addition the users wore heart rate belts.	
Brightr app	Brightr helps you become more aware of different aspects of your vitality: physical activity, sleep, and mental resilience. It gives you challenges to further improve your vitality. It also gives advice and provides access to vitality coaches that can answer your questions. Brightr is based on the latest behavioral science and is built with unrivalled sensing technology. It enables real-time behavioral tracking and intelligent personalized coaching for high effectiveness.	https://www.getbrightr.com/
Kelaa app	Kelaa measures and analyses the effects of stress with your smartphone and provides you with a 14 day programme to improve your mental resilience.	http://www.kelaa.me/
Tinké	The only tracker that measures your heart rate, respiratory rate, blood oxygen saturation and heart rate variability to determine your fitness and stress indices.	https://www.zensorium.com/tinke/
BeWell app	In this work, we take a step towards a more comprehensive smartphone based system that can track activities that impact physical, social, and mental wellbeing namely, sleep, physical activity, and social interactions and provides intelligent feedback to promote better health. We present the design, implementation and evaluation of BeWell, an automated wellbeing app for the Android smartphones and demonstrate its feasibility in monitoring multi-dimensional wellbeing. By providing a more complete picture of health, BeWell has the potential to empower individuals to improve their overall wellbeing and identify any early signs of decline.	http://www.cs.dartmouth.edu/~campbell/papers/bewell_pervhealth.pdf
WellMo	Wellmo is a holistic, configurable and ready-to-go cloud-based solution that enables individuals to take charge of	http://www.wellmo.com

	their own health with the support of professionals. With Wellmo, organizations can successfully leverage the opportunities of mobile health by developing agile, innovative, engaging and cost-effective preventive services. Wellmo solution consists of two components: Wellmo app and Wellmo Pro tool for health and wellbeing professionals. Easy-to-use mobile app helps users to track their health and wellbeing and aggregates data from leading wearable devices and apps, e.g. Fitbit, health, Garmin and RunKeeper. Service providers can bring their own services to the app and launch activating campaigns. Wellmo Pro allows professionals to create meaningful conversations with individuals through real-time health data and stay connected through in-app messaging.	

B Platform Inventory

B.1 Platform inventory

In this section, we consider several platforms and discuss them along the lines of the requirements in the previous section. These findings are summarized in Table B.1.

B.1.1 Validic

Validic provides a service for storing health data, intended to facilitate the integration of data from healthcare providers and app developers alike. In functional terms, with that service Validic is in the same category as Apple's native HealthKit, except that they are platform-agnostic. Offering a REST/JSON interface over HTTPS, their integration possibilities are rather standard.

B.1.2 Vitadock

Vitadock offers a platform for storing health data, and also several devices with accompanying mobile applications, and a web-based dashboard for inspecting your data. This is a complete product, and with devices for measuring for example sugar level and body temperature, Vitadock is aiming for an audience with specific or specialized needs.

B.1.3 Apple HealthKit

The HealthKit is an infrastructure for data, a native service and libraries for interfacing with this platform on Apple devices. On the user side, Apple provides the Health app, but the main value will be obtained through applications developed by other parties that collect or analyse data. HealthKit should not be confused with the ResearchKit, although the difference is hard to tell. The ResearchKit libraries allow for swift development of applications that deal with medical data, including standardised consent forms, questionnaires and opt-out procedures. To some acclaim "Can Apple's ResearchKit change the face of medical research?" (Apple, 2015, see also Lomas, N. 2015), the latter library will focus on leveraging and combining 'big' data from many users as an easier, and possibly better way to obtain data for research in health. The HealthKit in contrast is less specific in it's data model (tracking calories and steps for example) and does not include any possibilities for gaining access to other people's data.

B.1.4 Samsung Digital Health

This kit is an equivalent of the Health Kit for Samsung branded OSs. It also integrates with the so-called Samsung Gear devices.

B.1.5 Google Fit

Again, this is a copy of Apple's HealthKit ("Google Fit is Google's answer to Apple's Health app.", CNET, 2015). It focusses on fitness, sports and weight data and integrates with the other productivity tools by Google, such as Calendar. Interestingly, Google's previous attempt at a Health platform (which would also have rendered Apple Health the copy) was discontinued in 2013.

B.1.6 Philips HealthSuite

Philips is a market leader in the production of specialized health equipment for hospitals. With their HealthSuite they will be integrating data from these devices with other input from the Internet of Things. While still focussing on hospitals and patients, a public API is also available that allows other equipment or applications to integrate with these services.

B.1.7 CommonSense

CommonSense is a platform, developed by the relatively small Dutch company Sense, for storing and retrieving health related data. The platform also comes with an app that out-of-the-box reads and stores data from common smartphone possibilities, such as location and measurements from the accelerometers.

B.1.8 FatSecret

As an example of a service that does something completely different, FatSecret is a small website with advice related to health, dieting and food, with an active forum community. There are - at the moment - no easy options for integration.

B.1.9 Open M Health

Open M Health is an interesting non-profit initiative that aims to standardise health data, in order to kickstart the development of apps and research in this domain. Their schema's are open source, and so is their datastore that implements this standard.

Table B.1 A summary of the platform inventory described in this chapter. For each considered platform, the vendor's description, market and our description is included.

Name	Payoff – (their words)	Description - our words	Market
Validic (Vladic, 2015)	Validic solves the accessibility and integration challenges for healthcare organizations by providing a one-to-many connection to digital health technologies.	Platform agnostic data store for integration of health-data.	Healthcare providers, app developers.
Vitadock (VitaDock, 2015)	Now is the best time to start living a healthier life.	Complete stack of specialized devices, apps and a datastore, that also offers possibilities for integration.	Consumers.
Apple Health Kit (HealthKit - Apple Developer, (2015)	HealthKit allows apps that provide health and fitness services to share their data with the new Health app and with each other.	Their description is already accurate.	App developers, consumers through the Health app.
Samsung Digital Health (SAMSUNG Developers,	Samsung Digital Health helps application developers and healthcare providers thrive in an open	Native libraries and a data store for Samsung branded Oss.	App developers.

2015)	environment that connects sensors, devices and partner services.		
Google Fit (Google Fit Help, 2015)	With Google Fit, you can measure, track, and store your fitness information.	A Health Kit, this time for all Google branded OSs, focussing on fitness	App developers, consumers.
Philips Health Suite (Philips Healthcare, 2015)	The HealthSuite digital platform represents a new era in connected care for both patients and providers, as healthcare continues to move outside the hospital walls, and into our homes and everyday lives.	Infrastructure for integration of healthdata, build with IoT and specifically hospitals in mind.	Hospitals, Healthcare providers, app developers.
CommonSense (CommonSense, 2015)	CommonSense greatly simplifies the storage and analysis of large quantities of sensor data.	Dutch HealthKit.	App developers, research teams.
fatsecret (FatSecret, 2015)	Alle hulpmiddelen om uw dieet doelstellingen te realiseren.	Forum and community for sharing recipes and tips for diets	Consumers.
Open M Health (Open mHealth, (2015)	Free, open-source code that makes it easy for developers to standardise, share and process digital health data.	Schema's and an open-source implementation of a datastore.	App developers, platform developers.

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