D2.3 – Worker feedback dashboard

Empowering and Participatory Adaptation of Factory Automation to Fit for Workers

Abstract

Smart factories are characterized by increasing automation and increasing customization. In these dynamic environments flexible and adaptive work organization is crucial, both for productivity and work satisfaction. The Factory2Fit project will support this challenge by developing adaptation solutions which can engage and motivate people with different skills, capabilities and preferences to be productive members of the work community in manufacturing industries.

This deliverable describes the implementation of the first version of the Factory2Fit Worker feedback dashboard. The purpose of the Dashboard is to provide personal feedback to factory workers regarding their well-being and work performance outcomes with the aim to improve job satisfaction and create self-awareness about the relations between well-being and work. The feedback is presented visually via various graphs and charts, and is mostly based on data collected automatically by commercial wearables with open interfaces and the manufacturing production system.

The Dashboard is implemented as a web application, and its demonstrator can be accessed from https://omaprofiili.fi/?token=Factory2Fit-testuser. The current implementation illustrates well-being measurements tracked by a commercial well-being tracker, and work performance outcomes provided by the machine operation system of Prima Power. The development of the Dashboard functionalities and feedback content will continue up to the month 22 of the project, when the final implementation will be announced.

Keywords:

Quantified employee, self-tracking, feedback dashboard, job satisfaction, work well-being

D2.3	Dissemination Level: PU	Deliverable Type: DEM

The research leading to these results has received funding from Horizon 2020, the European Union's Framework Programme for Research and Innovation (H2020/2014-2020) under grant agreement n° 723277

Authoring and review process information	
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The research leading to these results has received funding from Horizon 2020, the European Union's Framework Programme for Research and Innovation (H2020/2014-2020) under grant agreement n° 723277

Version History			
Date	Version	Author	Description
25.04.2017	0.1	Anita Honka / VTT	Table of contents for review
31.5.2017	0.2	Anita Honka, Juha Leppänen, Timo Kinnunen / VTT Petri Uusitalo / Prima Power	Updated the table of contents. Chapters 1 and 2, and the Appendix written by VTT. Integrated the contribution of Prima Power to section 3.1.3.
13.6.2017	0.3	Anita Honka, Päivi Heikkilä, Miikka Ermes / VTT Cemalettin Ozturk / UTRC-I Thomas Walter / Continental	Chapters 3, 4, and 5 written by VTT. Chapter 6 written by VTT, UTRC-I and Continental.
15.6.2017	0.4	Anita Honka / VTT	Executive summary and Conclusions written. Deliverable ready for review.
21.6.2017	0.5	Cemalettin Ozturk / UTRC-I Eija Kaasinen / VTT Michael Bojko / TUC	Review by project partners.
26.6.2017	0.9	Anita Honka, Miikka Ermes, Juha Leppänen / VTT	Revision based on review comments. Ready for approval.
27.6.2017	1.0	Ralph Riedel / TUC	Deliverable approved.

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Executive Summary

This document describes the purpose and definition of the Factory2Fit Worker feedback dashboard, explains the implementation work completed to date, and the design and specification process behind the current implementation.

The purpose of the Worker feedback dashboard is to provide personal feedback to factory workers regarding their well-being and work performance outcomes with the objectives to improve job satisfaction and create self-awareness about possible relations between well-being and work performance metrics. The Dashboard attempts to influence job satisfaction by providing data-driven feedback that is positive and encouraging – highlighting personal achievements during the work day and demonstrating the development in one's work competence. The personal data collected for and presented in the Dashboard can be accessed only by the workers themselves, which is in accordance with the Quantified Self approach.

The Dashboard is implemented as a web site. Most of the well-being metrics presented in the current implementation of the Dashboard are tracked by the Fitbit Charge 2 wristband and retrieved automatically from the Fitbit cloud service. These metrics include steps and heart rate during work shifts, as well as, the daily sleep and resting heart rate. In addition, workers can follow their attention level during work in the Dashboard via self-assessments. Currently, the work performance outcomes are tailored to be relevant for the workers operating the machinery of Prima Power, and these metrics are provided automatically to the Dashboard by the machine operation system of Prima Power. In the Dashboard, these data are transformed into visual feedback with various graphs and charts. A test user account (https://omaprofiili.fi/?token=Factory2Fit-testuser) with limited data has been created to demonstrate the content of the Dashboard to the interested audience.

The Dashboard was designed as a co-design activity with end-users, in an iterative and user-centric way, by interviewing five workers operating the Prima Power machinery and the managers in two Finnish factories. The idea of the Dashboard seemed promising and the received feedback was mostly positive. Four of the five factory workers were interested to test the Dashboard as part of their daily work. Valuable feedback was also received about the most and least interesting data metrics to be presented in the Dashboard, which was taken into account when implementing the content.

The development of the dashboard will continue up to the month 22 of the project, when the final implementation will be announced and this deliverable will be updated accordingly. The Worker feedback dashboard is tentatively planned to be utilized also in the Continental and UTC use cases, which would require implementing relevant work performance outcomes for the workers of these pilot sites. Discussions have started regarding the technical feasibility of using the Dashboard in these use cases and the relevant content.

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1 Introduction

1.1 Purpose of the Document

This document (D2.3) describes the purpose and definition of the Factory2Fit Worker feedback dashboard and explains the implementation work completed to date, i.e. the functionalities and content of a website presenting the dashboard. In addition, the design and specification process behind the current implementation is described. The development of the dashboard will continue up to the month 22 of the project, when the final implementation of the dashboard will be announced and this deliverable will be updated accordingly.

In the current implementation of the Dashboard, the content is tailored to be relevant for the workers operating the machinery of Prima Power. The Dashboard is intended for the use of factory workers, only. The future development plans for the Dashboard, considering also the Continental and UTRC-I use cases, are described at the end of this document.

1.2 Intended readership

D2.3 is a public document (PU) and is, therefore, intended for the European Commission, the Factory2Fit Project Officer, the members of the Factory2Fit consortium, the members of other national and H2020-funded projects, as well as, the research and industry more widely, and even the general public.

1.3 Relationship with other Factory2Fit deliverables

In *D1.1 Enabling technologies,* delivered in month 6 of the Factory2Fit project, the expert review results of devices for monitoring worker well-being were reported. These results guided the selection of personal devices that are currently integrated to the Worker feedback dashboard.

In *D1.2 Industrial requirements,* delivered in month 6, the nature of factory work and the working context, as well as, workers' initial attitudes towards self-monitoring are described. The literature reviews regarding worker well-being and job satisfaction were presented in *D1.5 Design and evaluation framework and measuring tools* and *D2.1 Dynamic worker model,* also delivered in month 6. These deliverables provided relevant background knowledge for the development of the Worker feedback dashboard.

D1.4 Adaptation architecture, delivered in month 8, described how the Dashboard is connected to the Factory2Fit architecture framework.

D2.2 Set of online and offline measures for users, contexts and tasks is delivered in parallel to this deliverable. D2.2 introduces measures that may be used to complement the content of the Dashboard in the later versions.

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1.4 Acronyms and abbreviations

Abbreviation	Description
D	Deliverable
PU	Public document
Dashboard	Worker feedback dashboard
HTTPS	Hypertext Transfer Protocol Secure
SSL	Secure Sockets Layer
oAuth2	Open Authorization 2.0
GDPR	General Data Protection Regulation
MES	Manufacturing Execution System
CAM	Computer Aided Manufacturing
AHU	Air Handling Units

Table 1: List of Abbreviations

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2 Overview of the Dashboard

2.1 Purpose and background

The purpose of the Worker feedback dashboard is to provide personal feedback to factory workers regarding their well-being and work performance outcomes with the objectives to improve job satisfaction and establish self-awareness about possible relations between the well-being and work performance metrics. The Dashboard attempts to influence job satisfaction by providing data-driven feedback that is positive and encouraging – highlighting personal achievements during the work day and demonstrating the development in one's work competence. The personal data collected for and presented in the Dashboard can be accessed only by the workers themselves.

The ideology of the Dashboard originates from the Quantified Self movement, which promotes self-knowledge and self-improvements through numbers acquired with the help of technology, such as wearables and mobile devices.[1,2] The Quantified Self movement is largely about collecting personal data for private purposes, only, and finding personal meaning in the data by monitoring personal aspects of interest in order to raise self-awareness and facilitate self-improvement. These principles are supported also by the Factory2Fit Worker feedback dashboard. More recently, the notion of Quantified Employee has been introduced as a "framework for using data produced and shared by the employees to design work that supports learning, interaction, creativity, well-being and sustainable productivity".[3]

2.2 Platform

The Dashboard is implemented as a web site. Most of the well-being metrics presented in the current implementation of the Dashboard are tracked by the Fitbit Charge 2 wristband and retrieved automatically from the Fitbit cloud service. The work performance outcomes are provided automatically to the Dashboard by the machine operation system of Prima Power. The details regarding these feedback metrics are provided in Sections 3.1.2 and 3.1.3. In the Dashboard, these data are transformed into visual feedback with various graphs and charts presented at the web site. The data is acquired to the Dashboard throughout the day once in every 20 minutes, and the graphs are updated as new data comes in. Technical details of the implemented architecture are provided in the Appendix.

The Dashboard will be under development up to month 22, when the Dashboard is to be finalized. The development of the Dashboard is performed iteratively. Hence, several small-scale updates are foreseen to be conducted to the web site regarding the Dashboard functionalities and content.

[1] https://qsinstitute.com/about/what-is-quantified-self/
[2] http://quantifiedself.fi/
[3] http://quantifiedemployee.org/

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2.2.1 Demonstrator account

A test user account has been created to demonstrate the content of the Dashboard to the interested audience, which can be directly accessed from https://omaprofiili.fi/?token=Factory2Fit-testuser. The data shown in the test account is off-line and predefined, expanding over a two week period from 1st to 14th of June 2017. The well-being and work performance metrics presented in the test account are real-life data, but collected in separate contexts. Hence, looking for associations between these metrics will not make sense with the example data.

The available Dashboard functionalities can be freely explored in the test account (including "add" and "remove" functionalities), since user actions will not be saved to the Dashboard database. Thus, by refreshing the web site, any changes made by the user will vanish.

2.3 Expected usage patterns

As a benefit of the web implementation, the Dashboard can be accessed from a variety of devices with an internet connection such as a PC, tablet or smart phone. The workers are expected to view the feedback graphs at least once in a work day towards the end of their work shifts, after work at home or even while commuting from work (assuming one uses public transportation which allows glancing the smart phone while on the move). However, a more frequent daily usage is welcomed, for instance, during work breaks.

The Dashboard is intended for short usage sessions, since using it should not pose additional burden on the workers by taking their working time. It is anticipated that the time required to grasp the feedback from the graphs relevant to one work shift would take 1-2 minutes. However, interested users can spend more time with the Dashboard e.g. by exploring trends in data or comparing the outcomes for different work shifts.

As the work performance outcomes currently implemented to the Dashboard are related to the operation of Prima Power machinery, the current implementation is designed to be used by the operators working with these machines.

2.4 Data security and privacy

Whenever the Dashboard web application is used with client software (i.e. a web browser on a mobile device or a computer), its information and data are retrieved from a web cloud server. The server is operated by Microsoft Azure and is located geographically within EU. Thus, it complies with the current and forthcoming legislation in EU. The communication between any client application and the web server is encrypted (HTTPS – Hypertext Transfer Protocol Secure / SSL – Secure Sockets Layer) and the Dashboard domain has a security certificate issued by a trusted certificate provider (Terena SSL). In addition, all interfaces with other service providers interacting with the Dashboard are SSL encrypted.

The Dashboard users authorize the Dashboard to access their well-being related data from the Fitbit server by using OAuth2 (Open Authentication 2.0 - industry-standard protocol for authorization) process, which produces access tokens for accessing the data. At the moment, the tokens are stored

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in a clear text format at the Microsoft Azure server, but encrypting them may be considered later. The admin access to the cloud server is limited by a firewall, allowing only a limited group of people at VTT to access it with a username and a password. Remote access to the Dashboard database is not allowed. In addition to the Fitbit tokens, the database stores users' login identification data in a hash format, i.e. the identification data are not directly readable - instead they can be checked only at logins. Other user data in the database are currently stored in a clear text format, but encrypting some parts of them may be considered later.

General Data Protection Regulation (GDPR, EU Regulation 2016/679) has been taken into account in the development of the Dashboard. For example, the right of data erasure and portability are supported by the application. In the future, as the requirements set by the GDPR further concretize, appropriate steps will be taken also in the implementation of the Dashboard.

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3 Dashboard Functionalities and Content

3.1 Day view

The main view in the Dashboard is the so called “Day view”, which presents data relevant for one day or work shift (Figures 1 and 2). The day view includes 1) the *Work shift selector/editor*, 2) *Well-being metrics*, 3) *Production metrics* and 4) the *Time series graph* for well-being and production metrics. In the following, each of these components will be described in more detail.

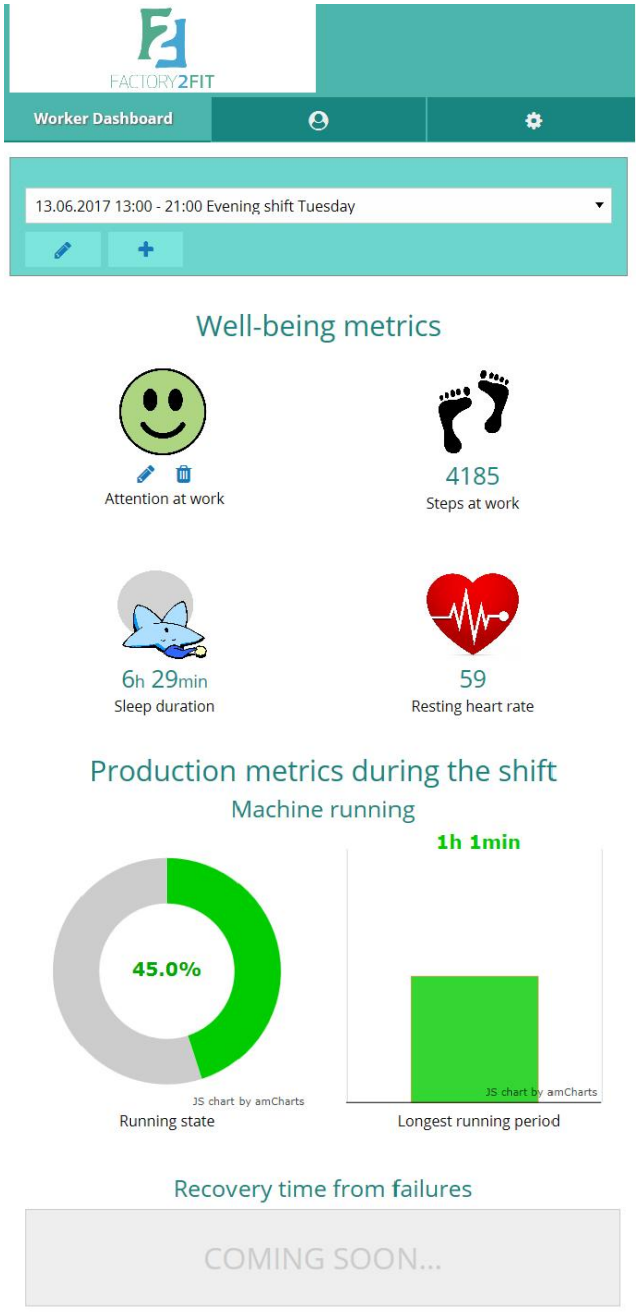

Figure 1: Screenshots of the Dashboard Day view: part 1.

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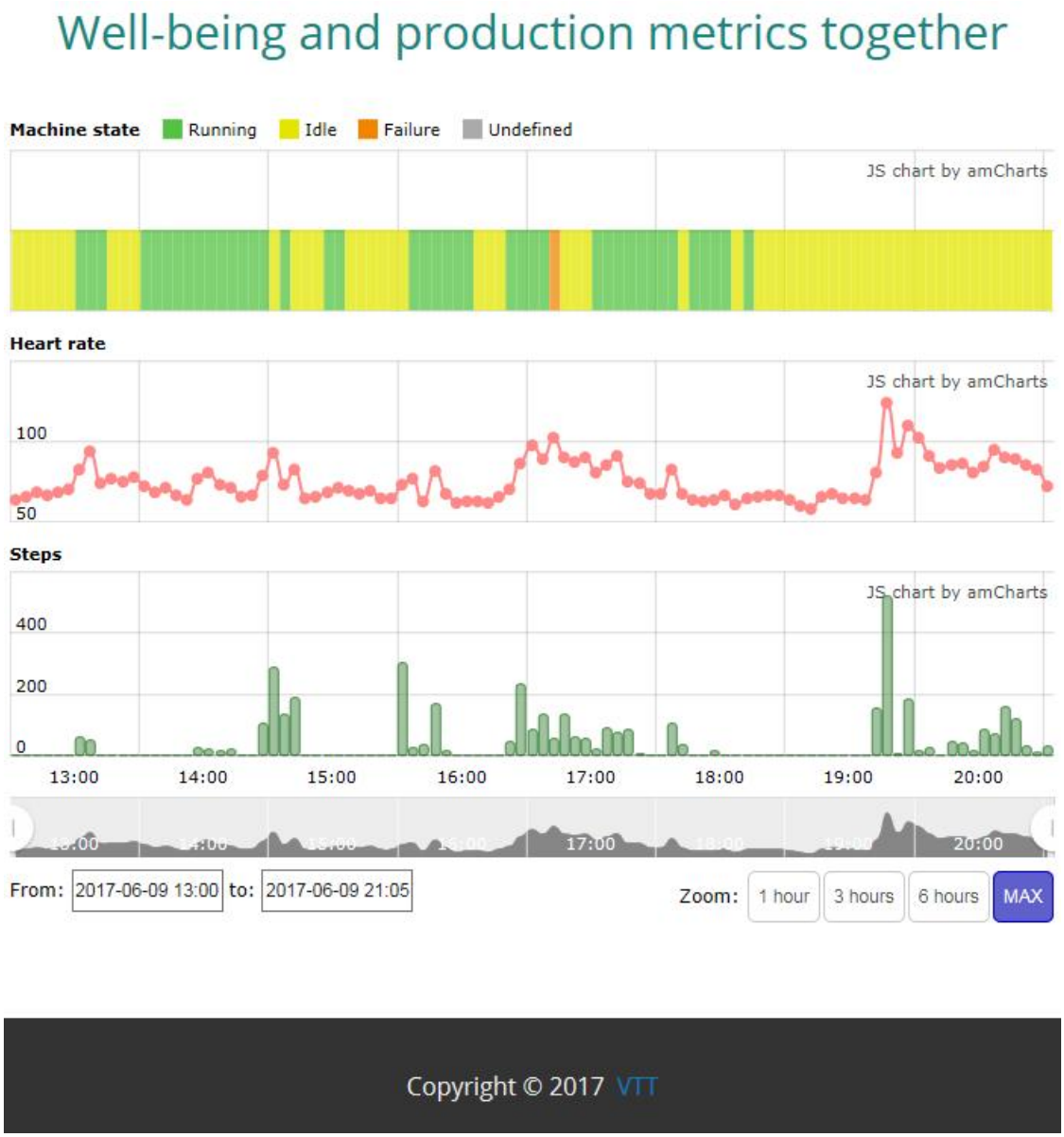

Figure 2: Screenshots of the Dashboard Day view: part 2.

3.1.1 Work shift selector/editor

The Work shift selector/editor is used to select the day and work shift of interest for exploring the well-being and production metrics (Figure 3), add work shifts to the Dashboard and edit the already entered work shifts (Figure 4). It is important to have the work shift information up to date, since the date, and the beginning and ending times of a work shift define the period for which the data will be shown in the Day view. For instance, if the worker needs to stay longer at work than expected and wishes to see his or her data for the whole shift, the ending time of the work shift should be modified accordingly. These types of modifications can be done whenever suitable for the worker: at work, after work or even on the next day. The editor for adding or modifying work shifts supports morning, evening and night work shift types, as well as, having a day-off from work (Figure 4). When

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the user selects the type of the work shift, the beginning and ending times typical for the shift are filled in the editor as defaults, and the user can refine these as needed.

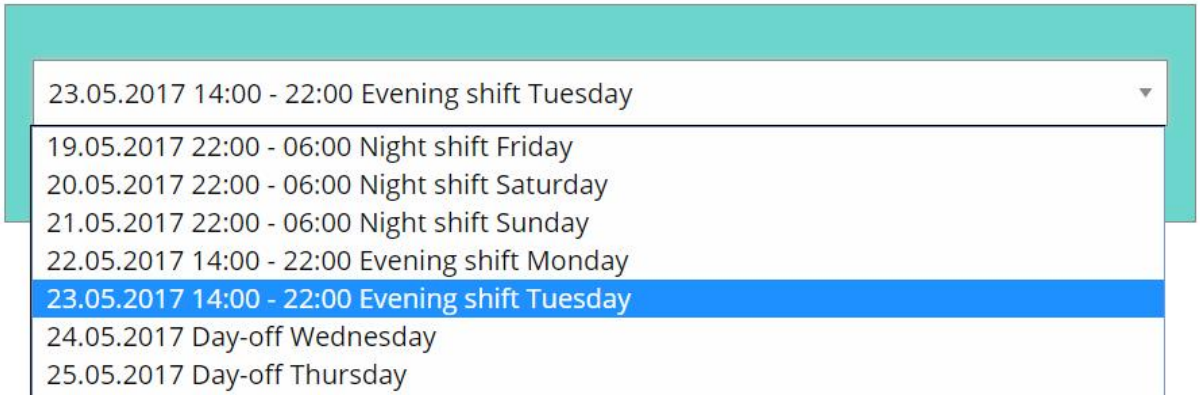

Figure 3: Screenshot of the Work shift selector in the Dashboard Day view

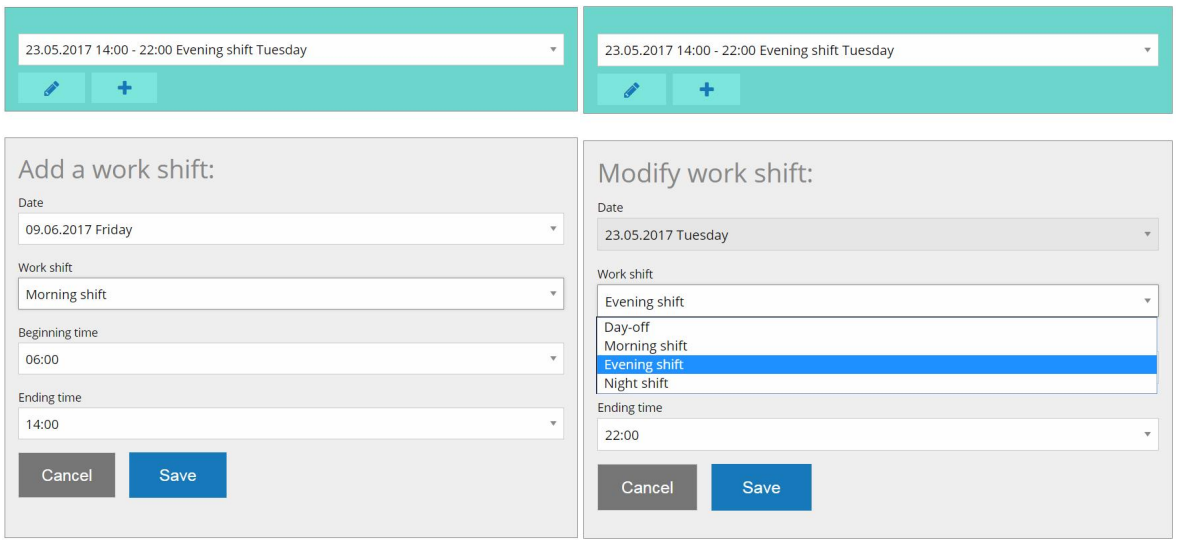

Figure 4: Screenshots of the Work shift editor in the Dashboard Day view

3.1.2 Well-being metrics

The Well-being metrics displayed in the Day view were selected according to the requirements of the *Task 2.3 Development of a worker feedback dashboard* described in the project plan (see Chapter 5 for the list of requirements). The maturity level of the wearable self-tracking technology, in terms of accuracy and user experience, currently available for consumers influenced also the choice of metrics for the Dashboard (see *D1.1 Enabling technologies* for a detailed review of various self-tracking devices). In addition, metrics that may be influenced by the nature of shift work, and by the perceived competence or stress at work were of specific interest.

The well-being metrics currently presented include “attention at work” based on a subjective assessment, as well as, “steps at work”, “sleep duration” and “resting heart rate” based on the data collected automatically by the Fitbit Charge 2 wristband. If the active work shift in the Day view is a

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"day-off", the work shift specific parameters "attention at work" and "steps at work" will not be displayed (Figure 5). However, the "sleep duration" and "resting heart rate" parameters are shown always, since they are independent of the work shift type and the data is collected outside the work context. Workers may also choose to not to wear the self-tracking wristband during their free-time or sleep, and thus data regarding sleep and resting heart rate will not be collected. In this case, the parameters will appear empty in the Day view.

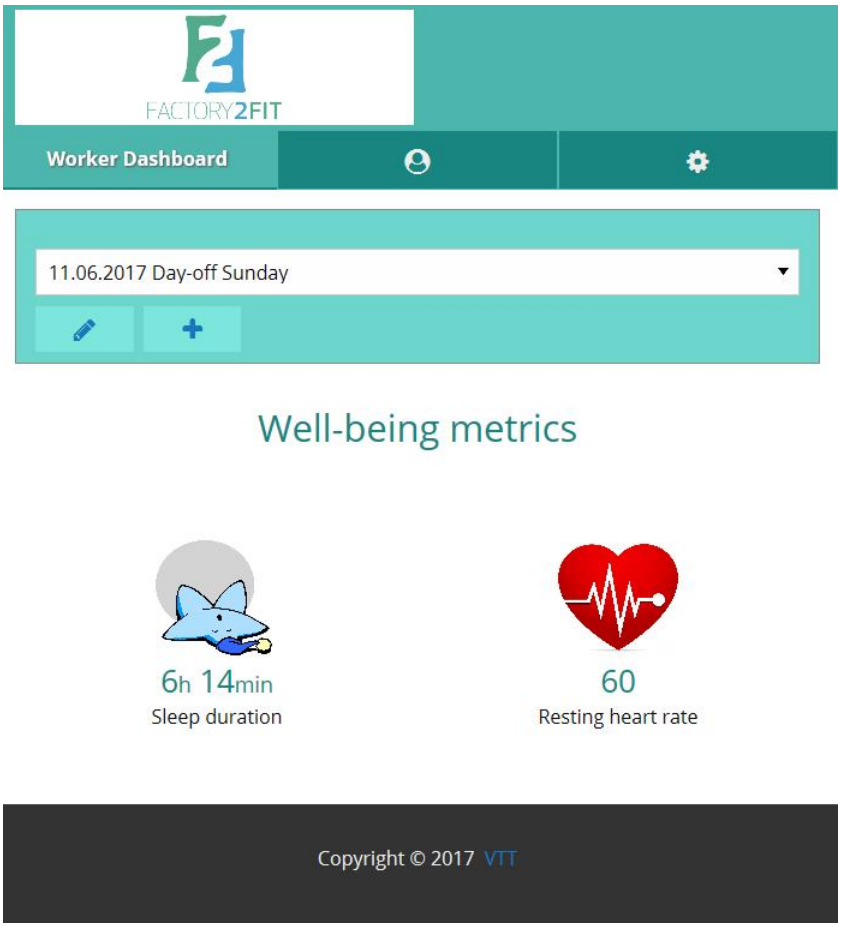

Figure 5: Screenshot of the Dashboard Day view with "Day-off" as the active work shift.

Fitbit provides minute-by-minute steps count data, and the "Steps at work" –metric is computed in the Dashboard by summing the steps over the duration of the active work shift. "Sleep duration" and "resting heart rate" are retrieved directly from Fitbit for each day. The "sleep duration" –metric refers actually to the duration of restful sleep computed by Fitbit by subtracting the wakeful periods from the total time spent in bed[4]. Fitbit utilizes movement and heart rate measurements for conducting the sleep analysis[5].

[4] https://help.fitbit.com/articles/en_US/Help_article/2163#AwakePeriods
[5] https://help.fitbit.com/articles/en_US/Help_article/2163#AutomaticDetection

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The workers are expected to evaluate their attention level for the whole work shift at the end of work or shortly after work by answering the question "How easy it was to concentrate on your work tasks today?" By default, the question will be displayed in the Day view under the Well-being metrics for each work shift (Figure 6). The question is answered simply by clicking a suitable emoji reflecting the worker's evaluation, after which the chosen emoji appears under the Well-being metrics instead of the question (Figure 1). The workers can also edit or delete their attention evaluations for the work shifts (Figures 1 and 6). Only the most recent entry is stored to the Dashboard database per work shift.

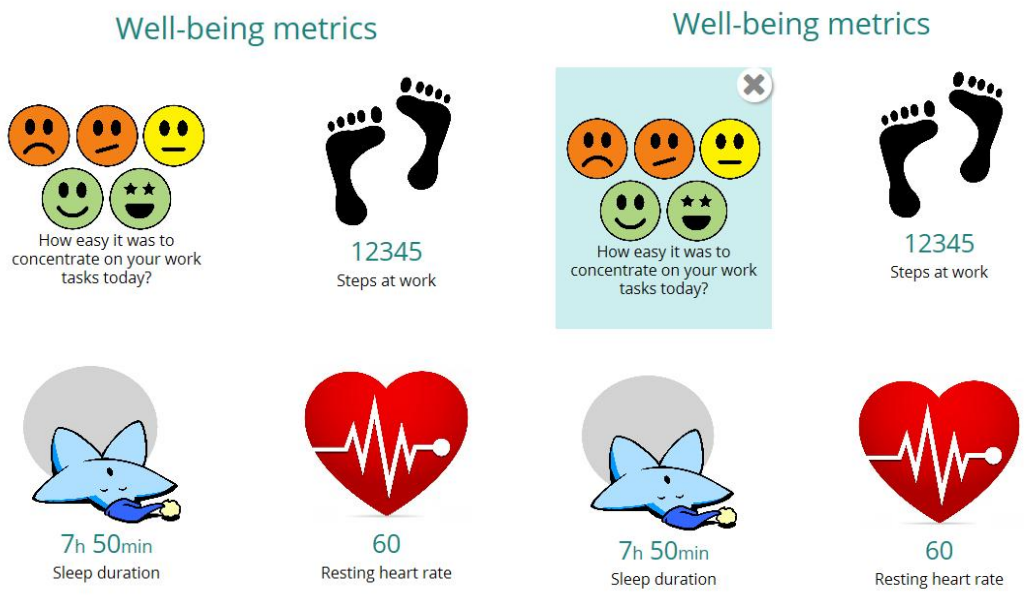

Figure 6: Screenshots of the Well-being metrics presented in the Dashboard Day view. When the user-entry for the "attention at work" parameter is missing, the question to be answered by the worker is directly visible (left picture). When the user wants to update an existing attention entry, the attention editor is opened (right picture).

3.1.3 Production metrics

The following criteria were applied when choosing the work performance outcomes to be presented under the Production metrics: a) the outcomes should be positive in nature, i.e. instead of focusing on errors or waiting times, periods of fluent work should be highlighted; b) the outcomes should foster the feeling of achievement during the work day; c) workers can directly influence the outcomes with their behaviour; d) the outcomes reflect how well workers perform their work; e) and improvements in the outcomes may demonstrate the progress in workers' skills.

Background of the Prima Power metrics

The current work performance outcomes presented in the Day view are provided by the machine operation system of Prima Power, which is a manufacturer of sheet metal machines (see *D1.2 Industrial requirements* for further details). The product catalogue of Prima Power includes cutting, shearing and bending machines, as well as, automation solutions for a large variety of different

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industrial domains. Prima Power provides large manufacturing systems from automated manufacturing lines to automated storage systems.

A typical production flow starts from a part order, containing information of the sheet metal parts which are to be manufactured by the machines. Prima Power offers its own Manufacturing Execution System (MES) for controlling the production flow of the Prima Power machines. Before manufacturing, the ordered parts need to be nested into sheets by using Computer Aided Manufacturing (CAM) system. During nesting, all the necessary parts are tooled and fitted to the metal sheet by optimizing the tooling procedures and the sheet utilization rate. As a result, a production order is created, which is to be executed by the machine. During production, raw metal sheets are automatically loaded to the cutting or shearing machine. Depending on the type of production and machines being used, produced parts will proceed further to the automated bending machine, storage system or they will be removed manually from the machines.

The cell machine operation software (Tulus) controls and monitors different types of production related parameters during production. It collects data of the estimated and realized run times of the programs, number of produced parts, sheet utilization rate, machine states, information of machine alarms, etc.

Prima Power metrics in the Day view

In the Dashboard, metrics related to machine states are presented for each work shift. A machine can be in one of the following states: running – the production is on-going and parts are produced, idle – the machine is waiting for orders, or failure – the production is interrupted due to machine or user errors. Based on these states and their timings, the utilization rate of the machine, the time to resolve errors that led to failure states and the number of resolved failure incidents can be computed. These measures are used to monitor the efficiency of the production/machine. The higher the machine utilization rate, the better.

Currently, two production metrics are computed by the Dashboard and presented in the Day view: the utilization rate of the machine (“Running state”) is computed as the proportion of the running state duration compared to the duration of the work shift, and the “Longest running period” identified from the machine state data stream for the work shift. If the active work shift in the Day view is a “day-off”, these metrics will be disabled.

3.1.4 Time series graph

The purpose of the Time series graph is to present some of the well-being metrics together with certain work performance outcomes that are part of the production metrics in the same graph to enable workers to spot possible personally interesting relations between these parameters. Currently, the graph shows the steps and heart rate tracked by Fitbit Charge 2 accompanied with the machine state data provided by Prima Power. The graph displays the data at the accuracy of 5 minutes. The minute-by-minute steps data provided by Fitbit is summed by the Dashboard for each 5 minute intervals. The heart rate measurements are provided by Fitbit approximately once in every 10 seconds, which are averaged in the Dashboard over 5 minute intervals. Workers can zoom the

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time axis in the graph, and view the specific values for each metric by touching or moving the mouse on the graph (Figure 7).

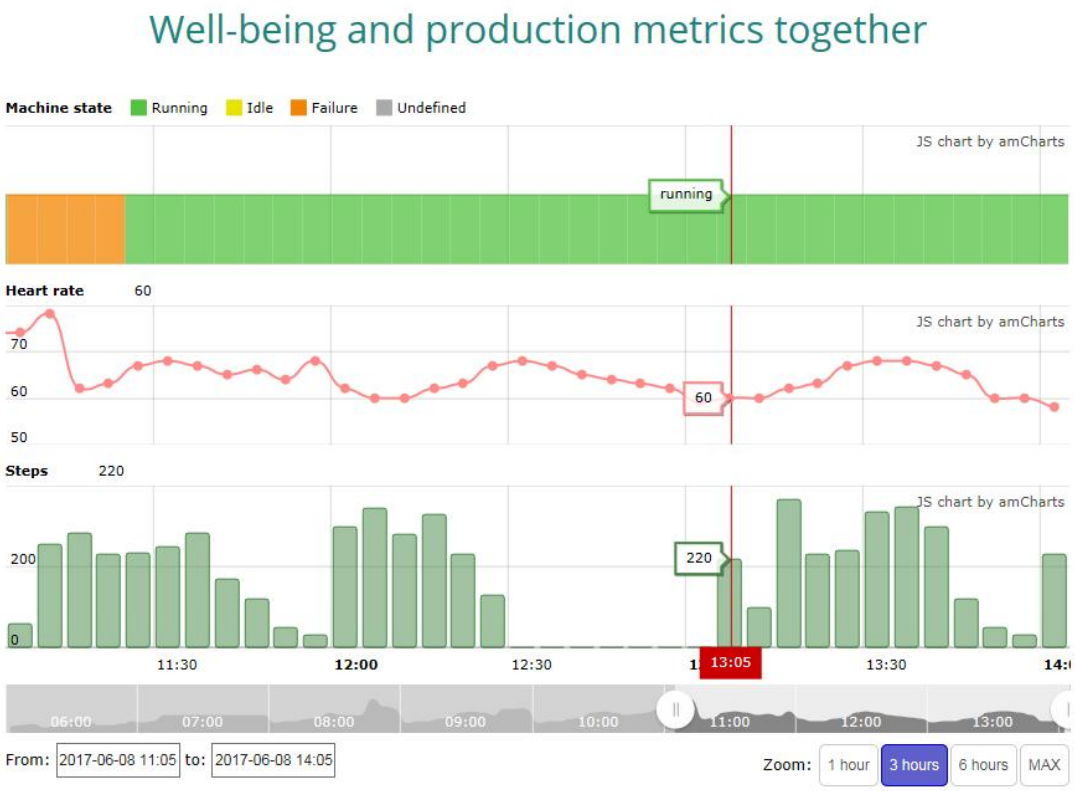

Figure 7: Screenshot of the Time series graph in the Dashboard Day view. The time axis is zoomed out and the values for each parameter are shown.

3.2 Trend views

Through the Day view, well-being and production metric specific Trend views can be accessed, which present the historical evolvement of the metrics. The functionality enabling Trend views is under development, but the graphical user interface for viewing the trend of the resting heart rate has been implemented. By clicking the "resting heart rate" element in the Well-being metric in the Day view, the Trend view for the resting heart rate is opened (Figure 8). The type of the work shift is presented in the background of the trend graph. The time axis in the graph can be zoomed, and the specific heart rate values can be viewed by touching or moving the mouse on the graph.

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Figure 8: Screenshot of the resting heart rate Trend view.

3.3 User-authorization of the Fitbit data

Before the workers' personal Fitbit data can be accessed by the Dashboard, the workers need to authorize the data transfer. An authorization dialog screen is presented during the registration process of Dashboard users (Figure 9). Through the dialog screen, workers can also choose what kind of well-being data they wish to follow in their Dashboards, and thus personalize their Day views.

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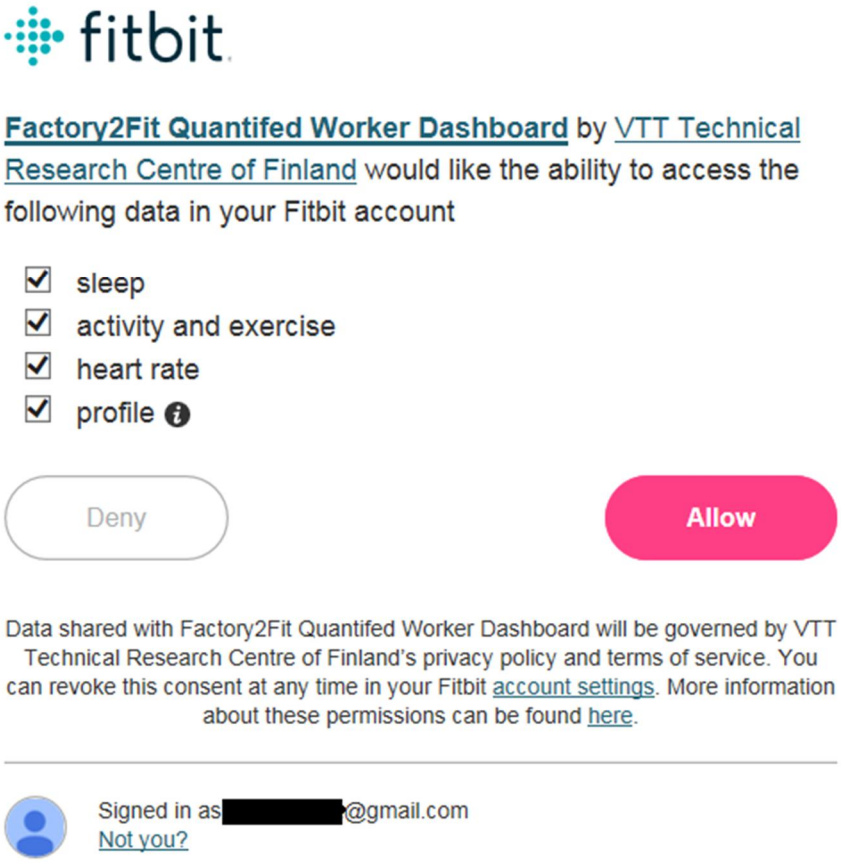

Figure 9: Screenshot of the user authorization for the Fitbit data.

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4 Design and Specification Process of the Dashboard

4.1 Design requirements

We have designed the Worker feedback dashboard as a co-design activity, in an iterative and user-centric way. Workers operating the Prima Power machinery in two Finnish factories and the management of these factories were interviewed about their expectations, potential concerns and practical issues regarding the content and usage of the Dashboard. In addition, the Factory2Fit project members had the opportunity to propose features and functionalities to the Dashboard.

The design process started by gaining understanding of the factory work, working context and workers' initial attitudes towards self-monitoring via individual and focus group interviews (reported in *D1.2 Industrial requirements*); factors related to worker well-being and job satisfaction based on literature reviews (reported in *D1.5 Design and evaluation framework and measuring tools* and *D2.1 Dynamic worker model*); and the opportunities and user experiences of the current off-the-shelf self-monitoring devices based on expert reviews (reported in *D1.1 Enabling technologies*). Based on the gained understanding, the Dashboard Task 2.3 description in the project plan (see Chapter 5 for detailed requirements), and discussions with Prima Power and the other project members, VTT created a prototype sketch of the Dashboard with example content and graphs in the Day (Figure 10) and Trend (Figure 11) views.

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Figure 10: Prototype sketch of the Dashboard regarding the Day view. The "Mood at work" metric was not implemented to the Dashboard due to the lack of interest from end-users.

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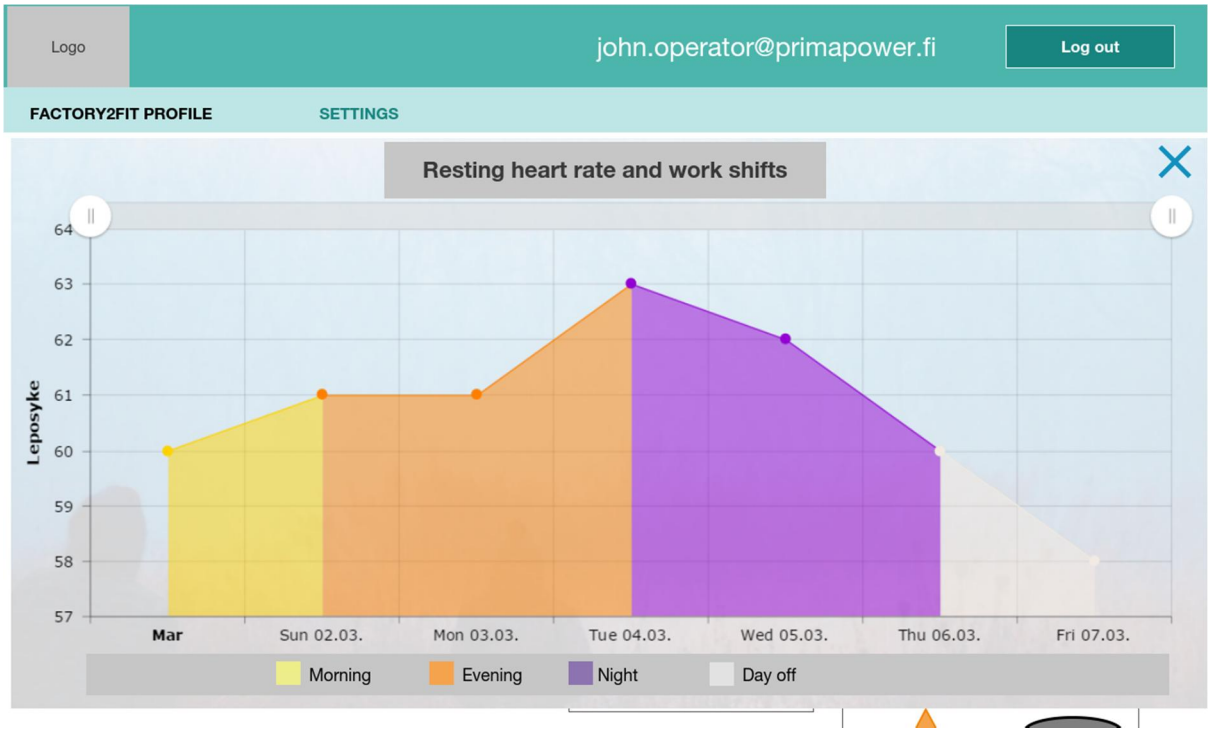

Figure 11: Prototype sketch of the Dashboard regarding the Trend view for resting heart rate.

4.2 Co-design methodology with end-users

We introduced the created sketch of the Dashboard to the operators of Prima Power machinery at two Finnish pilot sites, either as a part of a wider 1.5-hour interview or in more detail in a 1-hour feedback/co-design session dedicated to the Dashboard. Altogether five factory workers gave their feedback to the prototype. The interviews focused on the factory workers' overall feelings towards the Worker feedback dashboard concept, their opinions on the relevant, irrelevant and potentially missing metrics in the Dashboard content and ideas for improvements. In addition, the workers were asked to evaluate the concept and the content of the prototype with a 5-scale numeric feedback: The participants gave an overall evaluation of the concept and assessed it in more detail through five statements measuring whether the content appeared 1) easy to understand and 2) interesting, 3) whether the data metrics seemed personally valuable, 4) whether the appearance of the Dashboard Day and Trend views were pleasant, and 5) whether the use of such an application raised doubts.

4.3 Results of the co-design sessions

Most of the interviewed factory workers perceived the idea of wearing a self-monitoring device and receiving feedback through the Dashboard rather positively. Four of the five interviewed workers perceived the concept and the presented Dashboard content at least somewhat interesting. One of the participants did not like the idea of incorporating well-being metrics to the Dashboard. Especially, when he was introduced to the thought that perhaps group-level statistic could be

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presented to the employer, he emphasised that it is "everyone's own business how he lives, sleeps and eats", not the employer's.

The factory workers did not come up with major suggestions for changes to the content, but highlighted which metrics were the most and least interesting to them. Regarding the well-being metrics, the data related to heart rate and steps were seen interesting. However, the sleep and mood metrics were not considered very interesting. Especially, entering the mood information manually was not seen worth the effort. Regarding production metrics, the participants perceived the machine utilization rate ("running state") and the "longest running period" as the most relevant ones, as these were the most important indicators for good performance in their work. The recovery time from machine failure states was also considered relevant, as the current production reports did not directly provide this feedback. One of the workers highlighted, however, that this would be interesting for him only if he could see also the reasons for the failures. He was prepared to enter this information manually to the Dashboard, if needed. Achievements regarding the number of finished orders and the number of parts manufactured were not found relevant, as the workers felt they could not personally influence these metrics. The workers at the pilot site 1 also discussed the possibility of including the utilization percentage of the metal sheets to the production metrics, since the production manager followed this metric. However, it is not a personally relevant metric for the workers, as often the utilization percentage realized during one's work shift is determined during the previous work shift by a fellow worker. The production manager also highlighted that including this parameter to the Dashboard might encourage the workers to prioritise this issue over the machine running time, which should not take place.

According to the numeric feedback with the scale from 1 = negative to 5 = positive, the factory workers perceived the presented Dashboard concept rather positively. The content was perceived as easy to understand and relatively interesting. Most of the respondents regarded the content as quite valuable for themselves. The question whether the use of this kind of application raises doubts received mixed feedback: Two of the five respondents did not perceive the app doubtful at all, but three of them did not see the use completely doubtless. The appearance of the Day and Trend views were considered mostly as pleasant. The numeric details for the feedback are presented in Table 2.

Feedback item	Evaluation median	Range of evaluations
Dashboard concept in general	4	3-4
Understandability of the content	5	4-5
Interestingness of the content	4	3-4
Perceived value of the content	4	2-5
No doubts towards the content	3	2-5
Pleasantness of the appearance	4	3-5

Table 2: Numeric feedback regarding the Dashboard sketch provided by five factory workers. Evaluation scale: from 1 = negative to 5 = positive.

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Four of the five factory workers were interested to test the Dashboard as part of their daily work, if they were provided the opportunity to use it. At the pilot site 1 also the production management was willing to support the usage of the Dashboard at work. At the pilot site 2, the management was not willing to take the Dashboard into use, as there were urgent challenges in the manufacturing work that the company needed to solve before getting involved into new development projects.

4.4 Implications for the Dashboard design

Based on the interviews, the idea of the Dashboard seemed promising and we did not identify a need for major changes in the design. However, as a result of the interviews, we decided to change the user-defined "mood at work" metric to the subjective assessment of "attention at work". In the factory work context, the workers' perceived attention may be a relevant metric to follow and workers may find reflecting their attention levels on their sleep data interesting, for example. The results of the interviews also questioned the relevancy of the number of finished orders and produced parts as metrics in the Dashboard.

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5 Meeting the Task Requirements in the Project Plan

In the following it is briefly summarized how the current implementation of the Worker feedback dashboard meets the requirements set by the Task 2.3 work plan description in the Factory2Fit Grant Agreement.

Requirement 1: *The Dashboard should "present the workers' personal data back to them in an understandable format that will help them to change their behaviours and habits towards better".*

The data presented to the workers are personal, since they include self-tracking data collected by a personal wearable device and work performance outcomes relevant to the workers' own work (see Chapter 3). By presenting well-being and work performance related parameters together in the same graphs, the workers have the possibility to spot possible associations between these parameters, thus creating self-awareness regarding the personal relations between well-being and performance and encouraging behaviour change. According to the conducted co-design/feedback sessions with end-users (see Chapter 4), the Dashboard data is presented in an understandable and pleasant format.

Requirement 2: *The Dashboard should provide a user interface to the worker that visualises the collected personal data and provides "summarised views on them on a personal device such as phone or tablet".*

The Dashboard presents the data through simple graphs. The continuous time series data available from sensors are summarized into several distinctive aggregated metrics relevant at a daily level. As the Dashboard is implemented as a web application, it can be viewed on any personal device with an internet connection. In addition, the layout of the dashboard is responsive as such that the content fits nicely to different screen sizes (see Appendix).

Requirement 3: *"The dashboard will visualise personal data about physical wellbeing, mental wellbeing (including stress), and work load and attention."*

Physical well-being related data is presented in the dashboard via the "steps at work" and "resting heart rate" summary metrics (see Section 3.1.2), as well as, the time series graph showing the continuous steps and heart rate measurements during each work shift (see Section 3.1.4). The planned Trend views (see Section 3.2) regarding the "resting heart rate" and "sleep duration" metrics address the mental well-being and stress aspects, since changes in the level of mental well-being at a weekly level might be reflected on one's sleep, especially on the sleep quality, and can cause fluctuations in one's resting heart rate over several days. The sleep duration metric presented in the Dashboard provides information about the sleep quality, as it refers to the duration of restful sleep computed by the wearable Fitbit wristband, opposed to only presenting the time in spent in bed (see Section 3.1.2). The workload related data is presented in the dashboard via the work performance parameters (see Section 3.1.3), since these reflect the workload of workers. The

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attention metric is included in the Dashboard as self-reported evaluations of the workers (see Section 3.1.2).
Requirement 4: *"The workers can customise their personal dashboard views so that they are personally relevant and meaningful."*

The personal Dashboard views can be customized when the workers authorize the Dashboard to access their well-being related data from Fitbit. The workers can choose what kind of data they would like to share with and view in their Dashboard (see Section 3.3).

Requirement 5: *"If deemed possible from ethical and legal perspectives, the dashboard may also visualise the worker's data compared to that of the other workers in the same workplace."*

Currently, the feature for allowing social comparison amongst fellow workers is not implemented. The acceptability of this feature from the ethical and legal perspectives will be investigated and considered for the final implementation of the dashboard. However, based on the discussions in the project consortium up to now, having such a feature seems to be challenging, since comparing individual worker's data to the other workers' would require a good number of people from the same workplace using the dashboard (at least > 10 workers per work shift) to assure that individual workers would not be identifiable in the group metrics. It might not be possible to recruit enough workers within the individual industrial use cases. Moreover, the feature should be implemented only, if the factory workers show interest towards it.

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6 Future Development Plans

In the next iterations of the Worker feedback dashboard the Trend view functionality (see Section 3.2) and the missing work performance outcomes ("recovery time from failures)" regarding the Prima Power use case will be implemented.

The Worker feedback dashboard is tentatively planned to be utilized also in the Continental and UTC use cases, which would require implementing relevant work performance outcomes for the workers of these pilot sites. Discussions have started regarding the technical feasibility of using the Dashboard in these use cases and the relevant content.

In the Continental pilot site, the workers conducting measurement tasks with the help of measurement machines are considered to utilize the Dashboard. The first ideas for the interesting work performance metrics for the Continental use case include:

- Quality rate of the measurements conducted by the workers, computed based on the number of tasks which are finished correctly at once without the need to repeat the same measurement e.g. due to insufficient cleaning.
- Team level achievement with a target value which has not been defined yet, e.g. the average duration of the measurement tasks in the lab.

In the UTC pilot site, HVAC-Culoz, the workers conducting manual assembly for producing Air Handling Units (AHU) are considered for using the Dashboard. The assembly of each AHU takes around two to six units that are assigned to different stations and workers based on the skill levels of the workers. Assembly of AHU influences the worker well-being from two main perspectives. The first one is the fatigue of the worker due to (a) the total walking distance between AHU and the tool magazine providing instructions for changing tools for different assembly tasks, and (b) the standing position for assembly operations in different locations of AHU. The second important factor on worker well-being is the stress level due to the complexity of the AHU assembly tasks. As such, each AHU has different configurations for specific customers and the complexity of assembly operations vary considerably. Although this factor can motivate workers by providing variety to work tasks, it could also cause stress at work, especially when tight due dates are required. Therefore, UTC envisages the following well-being and performance metrics to be shown to workers:

- Indicators for the total distance walked during a work shift in terms of the actual distance or step count.
- The level of fatigue with an appropriate measurement method.[6]
- Indicators for stress, e.g. sleep and resting heart rate.
- The number of assembly orders completed during a work shift and the durations for completing the orders.

[6] https://www.icao.int/safety/fatiguemanagement/FRMSBangkok/4.%20Measuring%20Fatigue.pdf

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Tailoring of the Dashboard content to the needs of the Continental and UTC use cases will be considered in the upcoming iterations of the Dashboard, taking into account also any technical limitations that may occur. In addition, the ethical and legal acceptability of the feature allowing social comparison amongst fellow workers, and workers' interests towards it will be considered.

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7 Conclusions

This deliverable described the purpose and definition of the Factory2Fit Worker feedback dashboard, explained the implementation work completed to date, and the design and specification process behind the current implementation.

Most of the Dashboard requirements outlined in the project plan (Task 2.3) are already fulfilled with the current implementation. However, the development of the dashboard will continue up to the month 22 of the project, when the final implementation will be announced and this deliverable will be updated accordingly. During the upcoming months, further functionalities (e.g. Trend views) will be implemented to the Dashboard that are relevant for fulfilling the purpose and objectives of the Dashboard, namely improving job satisfaction and creating self-awareness about the possible relations between well-being and work performance. In addition, as the current implementation is designed to be used by the workers operating Prima Power machinery, and there are tentative plans to utilize the Dashboard also in the Continental and UTC use cases, relevant work performance outcomes for the workers of these use cases need to be considered.

The ultimate goal is to provide the Dashboard into the daily use of factory workers and study whether the introduced concept of providing data-driven, personal feedback to workers regarding their well-being and work performance provides benefits to the workers, and consequently, also to the employers.

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Appendix: Dashboard architecture

Dashboard consists of two main parts: the front-end offers the user interface to the users, and the back-end manages the database and connections to external services and the front-end. Both the front-end and back-end contents reside on the cloud service, Azure Virtual machine. All functionalities are running on the Tomcat server platform.

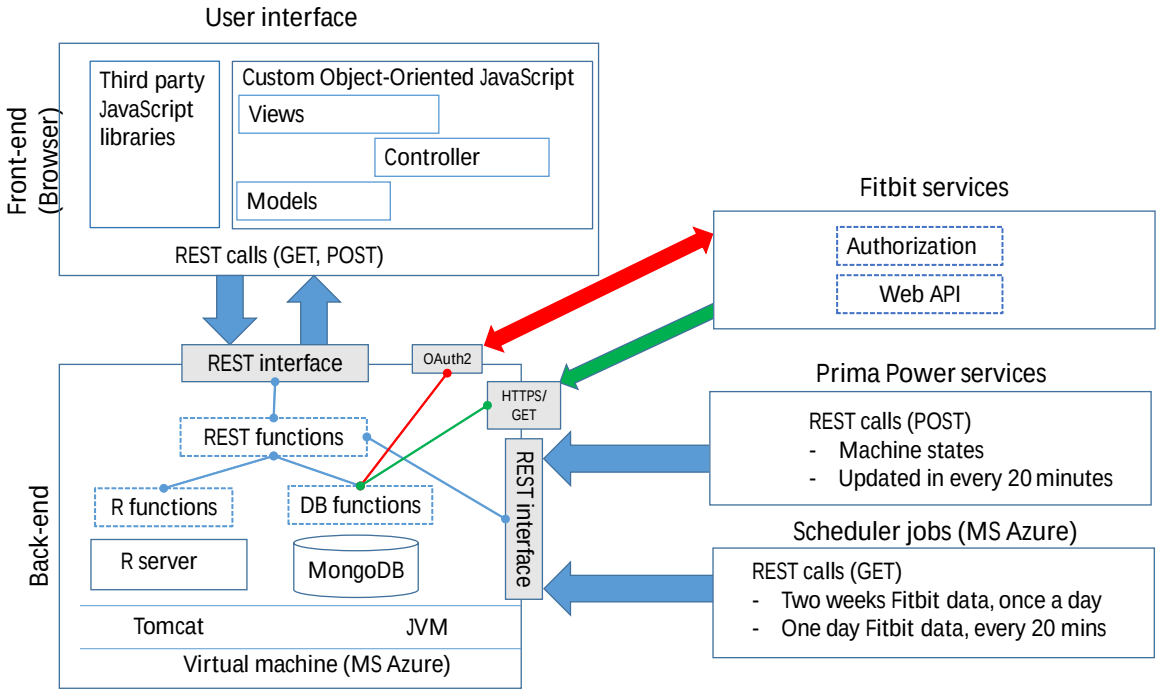

Figure A1: The architecture components of the Dashboard.

Front-end

The front-end is implemented as a single-page application (SPA). The name comes from the fact that HTML-page does not reload at any point in the process, nor does control transfer to another HTML-page. A SPA is a web application where the appropriate resources are dynamically loaded and added to the page as necessary using Ajax (asynchronous JavaScript and XML) techniques. It means that all application logic must be programmed into front-end, which makes it of course very complex. To be able to manage this complex JavaScript code, we implemented the front-end using the Object-Oriented programming paradigm and Model–view–controller (MVC) pattern.

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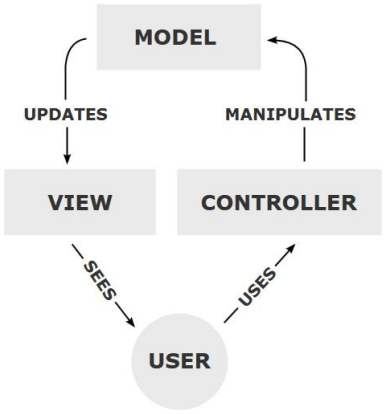

Figure A2: Illustration of the dynamic loading of resources in a single-page application (SPA).

Because Object-Oriented programming strongly emphasizes modularity, object-oriented code is simpler to develop and easier to understand later on.

Representational state transfer (REST) is used to provide interoperability between the front-end and back-end. At the development phase, simulation files (JSON) were used to simulate REST-call responses, so that the front-end development could be done independently from the server implementation.

All modern websites today use responsive web design (RWD) approach, allowing webpages to be viewed in response to the size of the screen, so that all devices from mobile smartphones to tablets to desktops are supported with a single website.

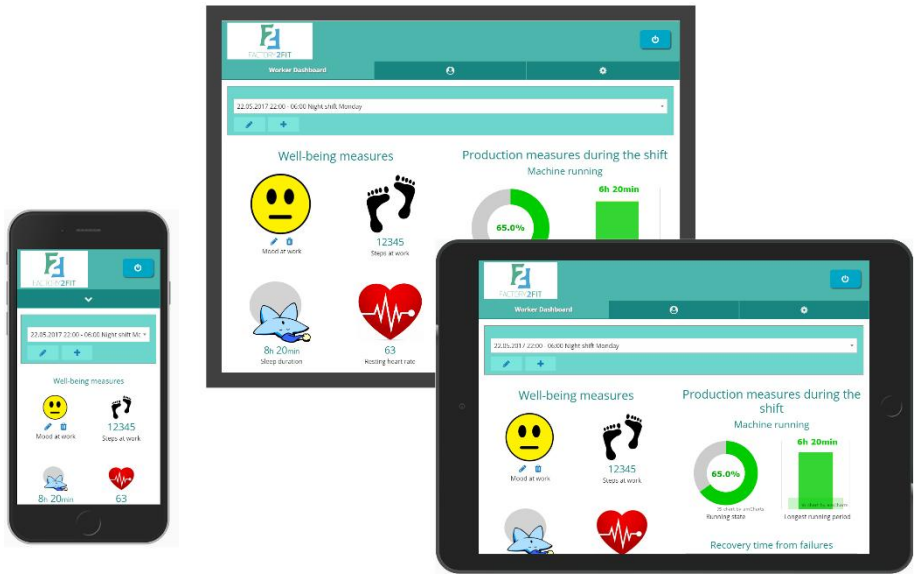

Figure A3: Illustration of the responsive web design.

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The support for different devices and language versions is programmed into the front-end from the beginning of the Dashboard development.

The following JavaScript libraries are used:

- jQuery
  - jQuery is a cross-platform JavaScript library designed to simplify the client-side scripting of HTML.
  - It is free, open-source software using the permissive MIT license.
- Zurb Foundation
  - Foundation is a responsive front-end framework.
  - Foundation provides a responsive grid and HTML and CSS UI components, templates, and code snippets, including typography, forms, buttons, navigation and other interface elements, as well as, optional functionality provided by JavaScript extensions.
  - Foundation is maintained by ZURB and it is an open source project.
- amCharts
  - amCharts provides JavaScript programming libraries and tools for data visualization with charts and maps.

Back-end

The back-end includes the following main components:

- NoSQL- database, MongoDB, including tables for
  - user configuration
  - Prima Power data
  - Fitbit configuration and data
  - work shift data
- REST interface functions for
  - The front-end to manage (read/write) database contents
  - Prima Power services to add new contents into database
  - timer schedulers to start requests to the Fitbit server in order to get Fitbit data updates
- Fitbit management functionalities
  - OAuth2 authorization
  - managing access token and refresh token
- data manipulation algorithms
  - R server environment for running R language tools

Some typical data flows are:

- Prima Power service sends regularly machine states information in JSON format to Dashboard. Optimally this happens in every 20 minutes but occasionally there may be longer

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gaps. Dashboard makes some small modifications in the data and stores it into database, each day as its own JSON document.

- End-users must authorize Dashboard to access their Fitbit data. OAuth2 is in use. After successful authorization, access token and refresh token are stored into database for further use. Accessing the user's data needs access token. Access token must be renewed after some time, and refresh token is then used.
- Scheduler job sends regularly request to Dashboard to start reading the latest data from Fitbit server (Web API) for each user. There are two jobs, one for two weeks readings and one for one day (today) readings. The first one occurs once a day after midnight and the second one occurs in every 20 minutes. The first one is rather heavy process and it could possibly disturb other activities at the server, if running daytime. Some of the Fitbit data is saved (or updated) after small modifications, some data is extracted from it for storing e.g. according to the user's work shift data.
- Front-end makes calls to back-end. Part of the calls directly affect (read from or write to) the database. User specific data needs the user to perform login call first to get the session id for accessing the data. Some parts of the calls e.g. changing the work shift data causes some shift-based data recalculation from Fitbit and Prima Power data. Java functions make Fitbit data calculations, and R language functions make Prima Power data calculations.

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