The Data Perspective of Sensor-enabled Personal Work Support Systems

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Abstract

In today's working world, work intensification and blurring boundaries between life domains pose major challenges. Stress resulting from high working pressure combined with a lack of opportunities for recreation can cause serious physical and mental health problems. As sensor technology has become ubiquitous and enables new kinds of data collection, it can serve as a foundation for sensor-enabled personal work support systems (SPWSS) assisting users in coping with high work demands while considering individual resources. Such systems could interpret collected data and generate recommendations geared towards maintaining the user's health, productiveness and wellbeing. However, building systems of this type is a complex task due to the large number of sensors, devices, and software components that have to be integrated. Moreover, this kind of work support relies on processing personal and intimate data from users and thus, require the willingness to share these data. As a first step towards building SPWSS, we investigate the data perspective of such systems. In doing so, we present an architecture of connected devices. Since the willingness of users to share their personal data is a crucial prerequisite for such systems, we furthermore present results from an empirical investigation concerning the willingness of users to share selected data for specific purposes.

1 Introduction and Motivation

Mobile devices such as smartphones or tablets are widely used. They help us to work, learn, and manage our social relationships. All this can be done independently of location and time. While there are many benefits, the boundaries between life domains can become vague with a high flexibility. Furthermore, the increasing usage of information and communication technology can cause a high intensity of work. Resulting stress threatens motivation, performance, wellbeing, and health (Leka et al. 2004; Béjean & Sultan-Taïeb, 2005). Also, the complexity

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and information intensity of work constantly increases. Especially for the increasing proportion of knowledge-intense work (Rump et al., 2017), these challenges are amplified greatly since this kind of work goes along with a high self-responsibility. Therefore, it is a major challenge to carefully deal with individual freedoms and resources to avoid overload. In order to improve the management of personal resources, advanced work support systems are required. Such systems should not only consider formal aspects of the work such as routines that have to be followed (e.g. process models) or organisational structures, but also individual data (e.g. heart rate, activity level, tasks, appointments) to support the user in promoting productivity, motivation, wellbeing, and balance in life over the long term. As sensor technology and smart devices are increasingly integrated in everyday life, these technologies can serve as a valuable instrument to collect data that can be leveraged by sensor-enabled personal work support systems (SPWSS). Such systems may include the monitoring of one's everyday behaviour and the identification of necessary development steps. Thus, they can consequently drive the development through recommendations and perform progress checks. Implementing such systems is a highly complex and challenging task. Therefore, as a first step, we investigate how various sensors and smart devices can work together to collect data that can be used to support individuals in their working environment.

The remainder of this article is structured as follows. In Section 2, we present an architecture of connected devices for SPWSS and in Section 3, we show results of an empirical analysis focusing on the willingness of users to share their data for such systems. In Section 4, we discuss our results and provide a conclusion.

2 Architecture of Connected Devices

To elicit potential components of SPWSS, literature was analysed to find features that are relevant for personal work support. As a result, potential components for the steps data collection, data analysis, and feedback generation have been identified. These components are described in more detail in (Lambusch, 2018). In the following, we present a complementary IT-architecture of the data collection for SPWSS that contains relevant devices and illustrates their connections (cf. Figure 1). The architecture follows the key notion that data needs to be collected mainly without user intervention and in an unobtrusive way in order to assist users effectively in everyday work.

The central hub of the architecture is a smartphone that collects data from various sensors that can in turn be retrieved from various devices. Among these devices is the smartwatch. Current smartwatches such as Samsung Gear, Apple Watch or watches from Huawei have numerous built-in sensors (Kilintzis et al., 2017) and deliver more accurate physiological data (e.g. heart rate, steps) than smartphones (Shoaib et al., 2015). The data can be retrieved from a smartwatch via an Application Programming Interface (API), which can already include some sort of preprocessing of raw sensor values (e.g. deriving heart rate from PPG signals) implemented in the device. In addition, other devices such as stationary beacons can be used to retrieve proximity data that is valuable for indoor location and navigation. From this, it can be detected e.g. if the user works in the office or is in a meeting room. The smartphone retrieves the data from the smartwatch and beacons via Bluetooth and can collect further information on its own, e.g. from GPS or app usage. Furthermore, it is possible to capture software-based work and to monitor contents related to used applications (e.g. appointments, incoming mails) via additional software running on the computing devices such as laptops or tablets. Data from the smartphone and a personal computer are sent via internet to a database. There are dedicated databases for such purposes, called time series databases. As the focus of the figure is on the data collection components of SPWSS, data is only sent to the database, while data analysis and feedback that would be sent back to the devices are not shown here.

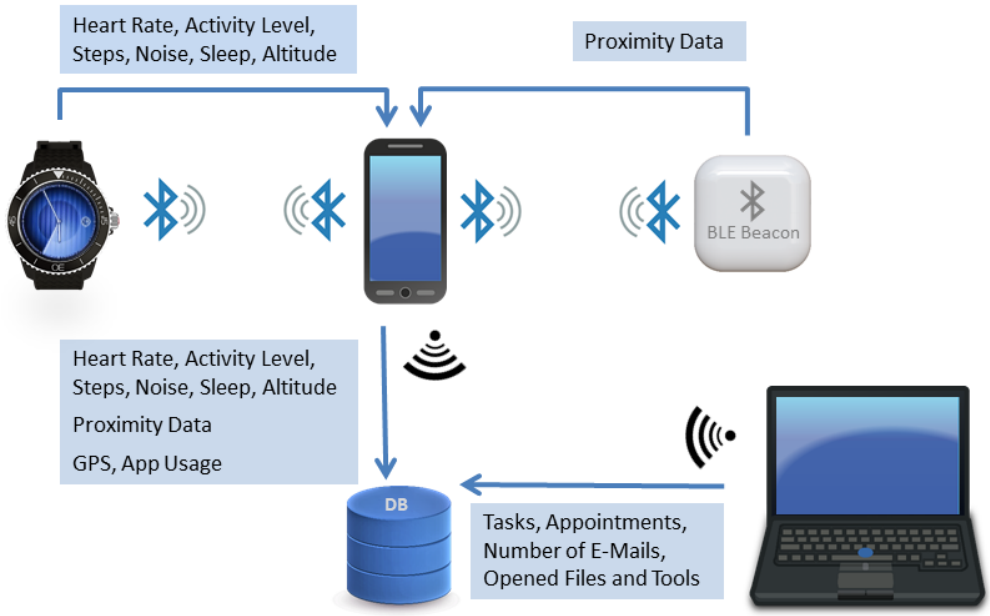

Figure 1: Architecture of Connected Devices for Sensor-enabled Personal Work Support Systems (SPWSS)

3 Willingness to Provide Data

For the implementation and usefulness of SPWSS, it is important, which data may be collected and analyzed. Since some data needs to be aggregated and combined in order to provide users comprehensive feedback, the lack of single components of data collection may lead to a lack of single or even multiple components of the analysis and related feedback. As the presented architecture contains several connected devices that have the potential to collect a wide spectrum of data, considering the willingness of users to share their personal data is a crucial step to check the feasibility of the system. In this section we present results from conducting a survey, where we focus on the willingness of users to share selected data for the purpose of personal assistance.

The survey was conducted over one week. The request for participation was sent via a mailing list referring to the information systems research community and thus, in particular, to researchers and practitioners with an IT-focus. The survey resulted in 39 complete datasets. The participants were on average 32 years old. 19 of the 39 participants were between 20 and 29 years old, 17 were between 30 and 39, and 3 participants were between 40 and 49 years old. 41% of the participants were female and 59% male. All participants had a job, which is a prerequisite for answering questions in the context of personal work support. Amongst others, the participants were asked to choose in a table whether statements on their daily work and the structure of their tasks are absolutely, rather, partly, rather not, or not at all true or cannot be assessed. For example, one row of the table contained the statement “My tasks are subject to strict guidelines” together with the options to choose. There are mainly little deviations from the moderate value "partly" in the results. However, the arithmetic mean of the responses indicates that most participants have a large share of knowledge-intensive work. Many participants stated that there are rather no strict guidelines and rare instructions for carrying out tasks. For new tasks, it is only partly clear how to proceed. For many participants, their tasks are rather not similar and often only partly related. The largest deviation from the moderate value can be found in the answers to the statement concerning the time management of everyday working life. The majority of respondents have no or little specifications of what to do when. Also the working hours are fixed only for about 21% of the participants. The rest either has flexible working hours or even no fixed working hours at all.

The questions about the data that participants would give to an assistance system were classified into data collected on the body, software, and location. An overview of the categories is presented in Table 1. For each data collection category, a brief introductory text in the survey exemplified the application and contribution to assistance features.

Category	**Data**
Body	Heart Rate, Activity Level, Steps, Noise, Sleep, Altitude
Software	Tasks, Appointments, Number of E-Mails, Opened Files and Tools
Location	GPS Position, Position in Building

Table 1: Data Collection Categories

The results on the willingness to share data collected directly on the body are shown in Figure 2. Only 13.2% of the participants would not share any of the listed data. Most participants would be fine with the collection of data on their number of steps (71.1%), their heart rate (68.4%), or physical activity (65.8%). More than a half of participants would share data on the noise level (60.5%) or their sleep quality (52.6%). The altitude might be collected for 42.1% of participants.

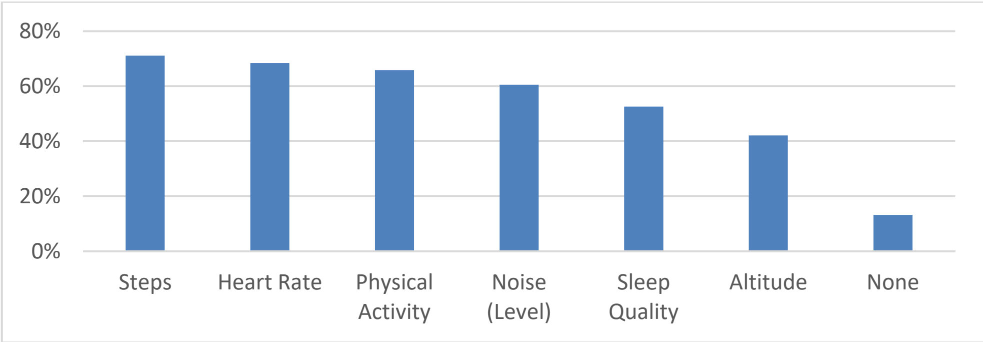

Figure 2: Willingness to Share Data Collected on the Body

The results on the willingness to share data collected on used applications and content retrieved from them is shown in Figure 3. Data on appointments might be collected for the most participants (76.3%). Data on tasks would be shared by 63.2% of participants and the number of emails by 60.5%. Only data about opened files and programs would be provided by proportionally few participants (34.2%). The number of participants who would in principle not share the listed data is with 18.4% slightly higher than at data on the body.

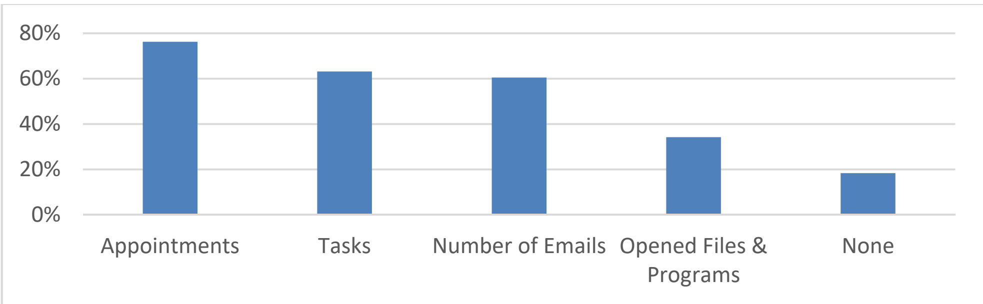

Figure 3: Willingness to Share Data Collected on Software

The results on the willingness to share data collected on the location is shown in Figure 4. Almost half (47.4%) of the participants would not provide any positioning data. While 42.1% of participants would share their GPS position, 31.6% would share their position in a building.

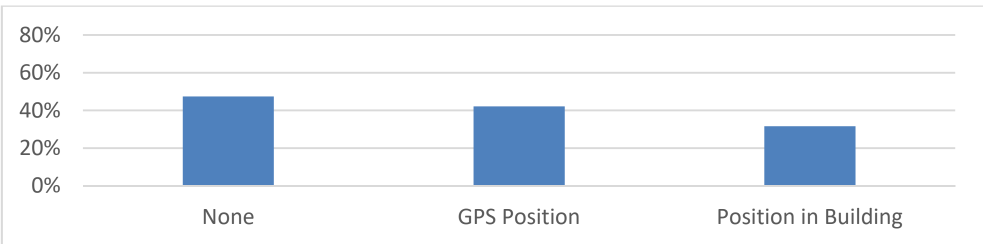

Figure 4: Willingness to Share Data Collected on the Location

In a free-text field, participants could indicate why they would not agree to collect the various described data. It is clear from the entries made by ten of the 39 participants that there are in particular privacy and data protection concerns. It is feared a possible misuse of data and attack on privacy. The protection of data that is being processed by a person using a support system is also mentioned. This comment is presumably based on the information that would be collected on the content of used applications. In one entry it is stated that an assistance would be used, if data were collected only locally and there could be no access by others.

4 Discussion

In this article, we investigate the data perspective of sensor-enabled personal work support systems. Therefore, we presented a technical architecture of data collection components as well as results from an empirical investigation concerning the willingness of users to share data covered by the architecture. The survey results show that the majority of the participants would be willing to provide data collected on the body or on software, while there are much more concerns sharing the location. Maybe there are particularly big security concerns if the collected data is not only personal, but one is even physically traceable by them. These concerns may be amplified for the indoor location that may specify the position in terms of a concrete room in a building. Besides the position in the building, the willingness to provide data about opened files and programs is the lowest. This may be due to the fact that processing external data in files is subject to additional regulations of data protection. Furthermore, information from files may be more detailed than appointment entries or listed tasks. Surprisingly, the willingness to share physiological data such as the heart rate is relatively high. Maybe assistance with respect to wellbeing, where such data are necessary, is particularly desirable. The highest willingness to share data is in appointments, which may indicate a desire for scheduling support, but it is also possible that this data is only perceived as less sensitive.

The study has certain limitations that offer potential for future research. One limitation is due to the number of participants. For future investigations we aim to conduct a survey over a longer period of time and to spread the participation request more widely. Furthermore, the participants may have had a research background as well as an IT-background. This could influence the willingness to collect and share data, so that further investigations with people of a broader spectrum of contexts are required. While the present work is more tailored towards knowledge-intense work, the approach could be extended to other work domains such as industrial production where different types of sensors (e.g. in smart clothes) are available and different questions have to be answered (e.g. number of specific body movements performed).

Responsible handling of confidential information is a crucial factor for establishing SPWSS. Protection against access from outside should be implemented through appropriate security mechanisms. When using a database, privacy could be considered e.g. by aggregating data directly on the device and sending only high-level information to the database that are less sensitive. A completely local solution would be another option that could become more feasible in the future with the rapid development of high-performance mobile devices and the integration of more and more technologies into one device. Currently, however, there are limitations in the features and performance of existing devices. By choosing a modular design for the implementation of SPWSS, the user could choose the desired assistance features according to the data collection components that would be accepted.

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