From Stress Awareness to Coping Strategies of Medical Staff: Supporting Reflection on Physiological Data

Lars Müller, Verónica Rivera-Pelayo, Christine Kunzmann, and Andreas Schmidt

FZI Research Center for Information Technologies, Karlsruhe, Germany

Abstract. Nurses and physicians on a stroke unit constantly face pressure and emotional stress. Physiological sensors can create awareness of one's own stress and persuade medical staff to reflect on their own behavior and coping strategies. In this study, eight nurses and physicians of a stroke unit were equipped with a wearable electrocardiography (ECG) and acceleration sensor during their everyday work in order to (a) make them aware of stress and (b) support the re-calling of experiences to identify stressors. In an interview one week later, the participants were asked to recollect stress related events through the examination of the sensor data. Although high activity levels diminished the expressiveness of the data, physicians and nurses could recall stressful events and were interested in their physiological signals. However, existing coping strategies turned out as barriers to the adoption of new tools. Future persuasive applications should focus on integration with existing coping strategies to scaffold the reflection process.

Keywords: Reflective learning, physiological sensor, user study, healthcare

1 Introduction

According to the Health and Safety Executive [17] Stress has consistently been the second most commonly reported type of work-related illness in the UK and is responsible for 55% of workdays lost due to illnesses. Besides, employees in health and social work have the highest rate of illnesses across all occupations and industries. Employees are not aware or deliberately ignore their stress level until they develop depression, anxiety or burnout.

Today, wearable sensors [2, 14] are becoming commercially available that measure stress indicators and can be unobtrusively worn during the whole day. These sensors provide a base for new persuasive computing [9] applications that create awareness of one's own stress level and provide assistance in avoiding stress or appropriating coping strategies.

However, there is no one-fits-all solution to cope with stress, because stressors largely depend on the specific workplace. While there are some techniques like relaxation exercises and breathing techniques, the causes of stress need a careful evaluation. Reflective practice is seen as a particularly promising approach in the healthcare profession[10], improving quality of care and supporting personal and organizational competence development. At its core are reflective learning processes, which can be understood as the re-evaluation of past experiences by attending to its various aspects (including feelings and emotions) and thereby producing outcomes [6]. More precisely, reflective learning at work means returning to and evaluating past work performances and personal experiences in order to promote continuous learning and improve future experiences. Sensors can provide the necessary data and moreover support the selection of relevant time spans for reflection.

In this paper, we analyze the potential of physiological sensors to (a) make the employee aware of stress and (b) support the re-calling of experiences to identify stressors and ultimately change their behavior. Towards that end, we used physiological sensors and conducted an ethnographically informed study based on a method similar to [4] in a German hospital, which will be described in the following section. Section 3 shows a concrete example how stressful events were examined from physiological data. The following section 4 summarizes our results regarding data quality, usability and the subjective potential to recognize stress from the captured data. In section 5, we discuss our results with special focus on existing coping strategies and conclude in Section 6.

2 Study Design

We have combined a sensor-based study with an ethnographically informed study, which has been extended with a contextualized interview that was based on preliminary findings of the observations.

For the first part, we selected the Movisens sensor [2] (as described in detail in Section 2.2). The sensors were worn by the study participants during at least two consecutive shifts of approximately 8 hours. After each shift, the participants were asked to state their experienced stress level on a 5 point scale for each hour of their shift. The sensors captured the daily activity and the physiological reactions of nurses and physicians.

The second part was based on the adapted rapid ethnographic method [12], which has been further developed in the context of the MATURE project [4]. Ethnographically informed methods are becoming increasingly popular in design-based research approaches, and their key characteristic is active participation in social settings to understand why things happen [8, 11]. In contrast to field observation which describes what happens, ethnography focuses also on the why and how things happen. While traditional ethnography is based on long-term studies, the adapted method compensates the much shorter time frames with (a) a more focused observation scheme and (b) an interview at the end of the study that is used to clarify issues that arise from a preliminary analysis of the data. In observation and interviews, special attention was given to existing coping strateies. In this study, we had four days of observation, followed by an

interview one week later.
The next sections describe the used sensor equipment, the tasks of the observer, and the structure of the concluding interviews.

2.1 Target Context

For the study, we have selected a stroke unit in a German hospital, the Neurological Clinic Bad Neustadt. A stroke unit is a specialized entity in hospitals that deals with acute cases of strokes. The slogan: "time is brain" shows the time pressure at the stroke unit. There are two main types of strokes. If these two types are confused the wrong treatment will aggravate the situation of the patient.
The time pressure and the daily work with emergencies and their results are a burden for all employees on a stroke unit. Some patients die, other will have to cope with disabilities for the rest of their lives. Currently the number of younger patients is increasing, which are in the same age group as the employees. Therefore, it is easier for nurses and physicians to relate to the individual patient and the emotional stress increases. Reflection about current practices and the knowledge of one's own physiological reaction might support the employees in their daily work.
Four physicians and four nurses took part in the study. The participants included all age groups at the stroke unit (22-44), men and women (3:5) and different levels of experience (1.5-25 years). The first part of the study, wearing sensors and observing employees, took place during four consecutive days. The interview was scheduled on two days one week after the study.

2.2 Sensor Equipement

Stress and cognitive load can be measured by monitoring the activity of the heart (electrocardiography - ECG) or the electrodermal activity (EDA) of the skin [7]. While EDA is more closely linked to the sympathetic activity of the autonomous nervous system [16], there are only a few appropriate positions to measure EDA, including fingers, palms and under the feet. In hospitals hands have to remain free and even wrist watches are forbidden. Hence, commercially available EDA sensors cannot be used in a critical environment like a hospital. The activity of the heart, especially the heart rate, is easier to capture by wearable sensors at the chest.
The ambulatory measurement system from Movisens [2] was selected to capture the activity level and physiological reactions, because of its simplicity for the user and the quality of the data. Commercial heart rate monitors for sports [3] do not provide the necessary data quality and use wet electrodes that depend on the sweat of the user. Standard electrodes for ECG measurements use gel electrodes. They provide accurate measurement results, but are inconvenient. The ambulatory measurement system from Movisens uses dry electrodes that do not need special preparation before usage. Thus, test persons can use the system after a short introduction.

The ambulatory measurement system from Movisens, a shown in Figure 1, consists of a breast belt and a small sensor that captures a single channel ECG, the acceleration of the sensor in 3 dimensions, temperature and air pressure. The ECG monitors the physiological reaction of the user's heart. The acceleration sensors at the breast capture the main movements of the upper body and can be used to measure the physical activity of the user.

Fig. 1. The Movisens sensor and the sensor belt: On the inside of the sensor belt one of the two dry electrodes is visible.

2.3 Ethnographically Informed Study

A subset of the participants (3 nurses and 2 physicians, 1 male/ 4 female) was followed by one observer who took the role of an ethnographer during their shift who collects additional data about the work practices and environment for later qualitative analysis as well as benchmarking of the sensor data.
The ethnographers (in total 3) had mixed professional background and experience healthcare to avoid bias in this respect. Each of them was in charge of following a participant during a whole shift.
The tasks of the ethnographers included being close to the participant and annotating (a) time, (b) place, (c) activity of the participant (d) and people that interact with the participant or influence his/her behavior and activities. The ethnographers followed their assigned participants during the whole shift, including work time and breaks. The annotations were made in a traditional notebook, which facilitates the skill to take notes anywhere and anytime, and have a level of detail of about 1 min.

2.4 Reflection Interview

One week later, there were interviews of about one hour with each participant of the study, where the interviewer corresponded to the ethnographer. This seems to be a plausible scenario for reflection because time is limited and prevents daily reflection. The interview was structured into two parts.
In the first part, the sensor data of the participant was shown and chronologically analyzed with the UnisensViewer software [1], inviting the participant to remember what could have happened in specific timestamps where the curves

indicated a special event. The UnisensViewer allows the visualization of different sensor data as line charts in a single window with flexible zooming. Where the data pool allowed it, the selected sensor data was taken from a quiet and a stressful day, in order to have the possibility to compare them. The participants were also given a printed report with the aggregation of the sensor data (heart rate histogram, Poincar plot of heart rate variability, heart rate per hour and activity in steps per hour).
In the second part, the participant was asked about the support that the data offers him/her to remember stress related experiences and which representation of the data is more suitable for her.

3 Examining Stressful Events

We used unprocessed data of whole shifts and asked users to recollect stress related events. In this section we present one example from our interviews. Figure 2 shows the overview of the data of an eight hour shift of a nurse. Figure 3 shows the details of a specific event during this shift. This event is clearly visible in

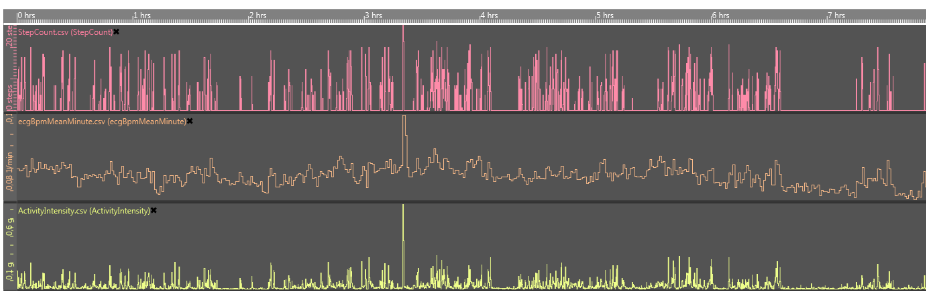

Fig. 2. Screenshot of the captured data as displayed in the UnisensViewer. The first row shows the number of steps, the second row the heart rate, and the bottom row the general activity. Clearly visible is a sudden peak of the heart rate after 3 hours and 20 minutes.

the data shown in Figure 2. At 3 hours and 20 minutes after the start of the recording a peak in heart rate and activity is visible. The participant immediately remembered this event and requested to see more details of this event. The observation protocol notes that heavy muscle spasms of a patient surprised a novice nurse. She sprinted to alarm a physician and returned immediately to the bed. Back at the bed, she was about to inject the required drug without waiting for the physician. Other nurses calmed her down and the incident was resolved after 3 minutes.
The example in Figure 3 shows the stress reaction of the heart rate and the physical activity. Although, both effects overlap in the heart rate, these events can be clearly distinguished from normal activity, if the heart rate jumps to 155bpm.

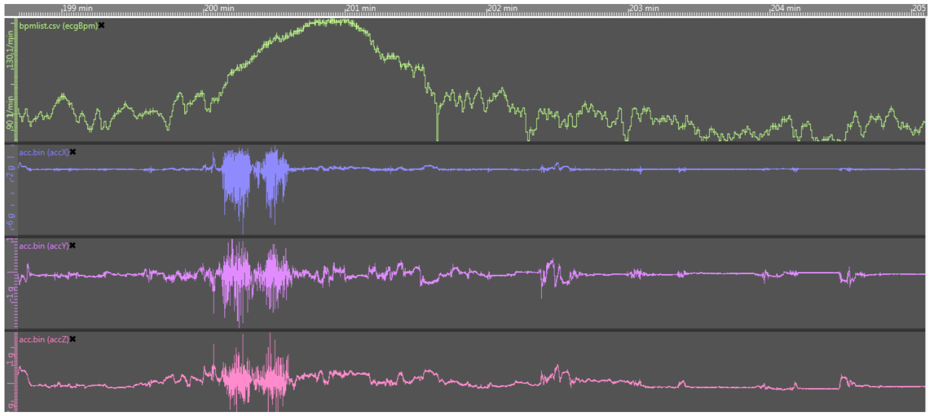

Fig. 3. Details of the reaction to a sudden emergency: the heart rate shown in the first row rises from 90 beats per minute to 155. This is mainly caused by the intense physical activity shown in the lower 3 rows. Close examination of the three activity curves shows the two sprints and a very short stop in between.

Minor stressful events, e.g. a heated discussion while walking, are difficult to capture by using the heart rate of a physical active person.

4 Results

152 hours of sensor data were captured and 49 of them were annotated with observed physical and estimated cognitive activity. 7 clearly and 15 probably stressful events were identified from the observation data. In the interview, participants confirmed that dealing with stress is an important reason to use sensors. Measuring the own physiological data at work was interesting for all of them and the participants expressed their interest about recalling how were their work days and what had happened. Most of them stated that this interest is much higher when they had stressful days and that they would like to compare how the measures look like on different days.

> *'N1: Yes, it would interest me, especially when I had stress or emergencies.'*
> *'D1: How often I would use it I can't tell you... If I had a 24 hours shift with 10 admissions with reanimation'*

In the remainder of this section, we will outline the results from the analysis of the sensor data, the observation and the concluding interviews, regarding the captured data, usability aspects and the subjective potential to recognize stress.

4.1 ECG and Activity Data

The participants expressed that we monitored a set of rather quiet days with only a few emergencies.

'D1: It would have been more interesting for me if it hadn't been so quietly. I was waiting for an emergency to come, but nothing happened.'

The daily questionnaire on the experienced stress level confirms these statements. The average over all participants and days was rated as 2.38 on the 5 point scale where 5 indicates extreme stress and 1 means a very calm day. Only three hours during the four days of the study were rated as stressful (4) by a single participant.
We used the ECG to calculate an accurate heart rate and the variability of the heart rate. Both parameters are well known parameters from psychophysiology and correlate to the stress level of a person [7, 5]. In stressful situations the 'fight-or-flight' system increases the heart rate. However, the activity of the heart is influenced to a larger extent by physical activity. Both effects overlap and make an analysis of stress levels complicated.
This physical activity results in an increased heart rate and hides potential stress related reactions of the heart rate. The observed breaks between activities were mainly used for documentation tasks and small talk. Stressful events during inactivity could not be recorded. However, as shown in section 3 there were stressful events that could be identified from the data even during activity. Nevertheless, these events represent only extremes that do not cover all interesting events for reflection. More information about the individual is necessary to distinguish physical and cognitive activity. This could be accomplished by longer term measurement or the recording of a baseline during several activity levels. Furthermore there are first approaches towards the calculation of the so called additional heart rate from heart rate and activity data [13].
The data shown to the participants during the concluding interview was dominated by high activity levels. This activity mostly comprises walking between patients and offices. Figure 4 shows how many steps the different professions walked during their shifts. Nurses are nearly constantly walking from bed to bed, while physicians spend more time with documentation.

4.2 Recognizing Stress and Identifying Stressors

Watching the curves in detail allowed the participants to compare their expectations to the measured sensor data and thus increase their awareness of their stress. In some cases, the data was surprising for them concerning e.g. the range of their heart rate or their appreciation of a specific moment.

'N2: I thought I was calm but now I see it wasn't like that... '

All participants acknowledged that the sensors had supported them to remember the course of the day. The curves helped them to structure the day and remember the overview of the day. Some of them could think about what happened in a specific moment, where the heart rate curve showed that something could have happened. Some participants could even explicitly say what had happened and why.

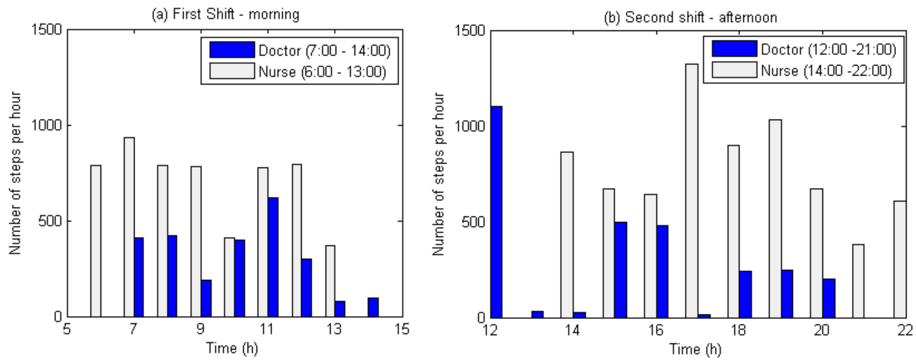

Fig. 4. High activity levels hide the cognitive effort. Nurses are walking more than physicians and have fewer breaks for documentation. The figure shows the number of steps for a physician and a nurse during each hour of (a) first and (b) second shift. While the activity of a nurse never falls below 400 steps, physicians spend more time at their desks.

> *'N4: Yes! I can remember the two patients. They annoyed me'*
> *'N1: Yes [it helps me to remember]. I can say approximately when some things happened.'*
> *'D1: Yes, it was interesting [the support of the sensors to remember]. It was interesting to see it graphically.'*

However, reflection is a matter of time, and one participant explained how the physicians have to act quickly in specific situations, without having time to reflect.

> *'D1: We have to hurry up. On duty you can't do anything against it. What could I do better? You don't think. You are there, and you have to do it.'*

Nevertheless, participants used the data to reflect on their behavior during the interview. They thought aloud about the experienced events and the reasons why they happened.

4.3 Application and Sensor Usability

The general interest of the participants about the use of sensors for tracking their work activities and doing a subsequent analysis was very positive. They were used to see physiological measures and such curves in their patients' monitors, but had not used them on their own before. As one of the participants stated:

> *'D4: I don't like staying in hospitals and going to the doctor. I am not type of person keen on trying new things out but it was actually interesting for me. I would mainly like to know about activity and movement.'*

In general the participants accepted the belt for the study, but all of them saw room for improvement. Hence, they would not like to wear the sensor everyday but accepted it for the purpose of a study. One participant described the belt:

> *'D3: a badly fitting bra that is a little bit inconvenient but still wearable.'*

The participants criticized that the belt was itching, that it was hard to adjust to the right size but the main point of critique was the electrodes. One participant noted that the dry electrodes tend to stick to the dry skin and that this is painful when the electrodes are moving and the electrodes are pulled off. However, a third participant said that the sweating caused the belt to become uncomfortable and proposed that the sensors could be integrated in an ordinary bra.

Concerning the type of visualization, the participants were asked to choose between the UnisensViewer application or a printed summary of the data. This summary showed the captured data aggregated on an hourly basis. All participants except one preferred the UnisensViewer, because it shows the measures in detail and they can discern the impact of specific events.

> *'D4: Amazing, it is easy to understand.'*
> *'N2: I like the UnisensViewer more than the graphics. I can see everything what happened there and make a guess.'*
> *'N1: Maybe UnisensViewer, then I can exactly see when, what time, something happened. .. With the graphics I can't see, when a seizure occurs, for example.'*

However, nurses and physicians are already used to read heart rate diagrams. Users from other contexts might be confused by the amount of data.

5 Replacing Existing Coping Strategies

While our results have shown the potential of combining physiological sensors and reflection, the interviews showed that there are already coping strategies in place. If a persuasive application should replace or support these strategies, it has to provide clear benefits over the existing solutions, which are often non-technical but have proved to be successful for the individual. We gained several insights regarding existing coping strategies from our interviews:

- Developing effective coping strategies is part of gaining experience. Consistently, more experienced individuals had more developed coping strategies. They shared the characteristic of professional distance although they varied in their form. Some tried to suppress emotions and emotional reactions altogether in their work life, while others had more balanced views.
- Some coping strategies (especially for nurses) consisted of a clear separation between work life and private life that was linked to symbols, like changing clothes. It has been explicitly mentioned by one participant of the study that there is resistance to more reflection, as this might lead to rumination after work, which could result in negative emotional effects.

Moreover, we encountered different types of users that reacted completely different. While optimism of participants is important [15] further aspects have to be researched. Some users showed great interest, while others said that they do not want to know about this data to protect themselves. Applications that capture and present this data for reflection have to target a specific type of users, or these anxieties have to be addressed as part of scaffolding reflective processes for inexperienced employees.

6 Conclusion

This study has shown how a stress management solution can combine reflection and physiological sensors to analyze stressful events at work. We have used off-the-shelf components to create a basic system, and evaluated its impact in a real work environment.

This is only a first step towards stress management. Sensors are accepted for a limited time but are still not comfortable enough to use them every day. The captured and annotated data provides rich content for additional research. However, a straight forward analysis of the ECG data is complicated by the overlap between physical and cognitive activity. The additional measurement of the activity level provides an approach to distinguish both components.

Existing coping strategies turned out to be a barrier to the introduction of persuasive applications. Employees in hospitals already have their solutions, e.g. ignoring stress and they do not want to give them up. Especially, reflection about stress and stressors collides with their concept of professional distance. They do not want to ruminate about stressful events. Most of our participants have been interested in stress management but accepted stress as part of their job.

In the short time of the study, participants did not change their behavior. However, the study has shown promising results to create awareness about stress and remember stressful situations to identify stressors. The system was positively accepted by the participants and in most cases the sensor data supported the recall of their personal work experiences. Further investigation is needed with respect to the acceptance by different types of personalities and the role of experience.

With these promising results, we are planning to develop tools that facilitate the reviewing of sensor data with more possibilities of aggregation, benchmarking with other people, and highlighting of stressful time spans. These tools will be evaluated on a larger scale and with a longer time frame.

Acknowledgements

This work has been co-funded by the European Commission within the 7th Framework Programme in the MIRROR project (http://www.mirror-project.eu).

References

1. Unisens a universal data format, http://unisens.org/viewer.php

2. Movisens - ECG- and activity sensor (2011), http://www.movisens.com/
3. Polar - listen to your body (2011), http://www.polar.fi
4. Barnes, S., Bimrose, J., Brown, A., Feldkamp, D., Kaschig, A., Kunzmann, C.and Maier, R., Nelkner, T., Sandow, A., Thalmann, S.: Knowledge maturing at workplaces of knowledge workers: Results of an ethnographically informed study. In: Proceedings I-KNOW (2009)
5. Berntson, G.G.e.a.: Psychophysiology, chap. Heart rate variability: Origins methods and interpretive caveats., pp. 623–648. Cambridge University Press (1997)
6. Boud, D., Keogh, R., Walker, D.: Reflection: Turning Experience into Learning, chap. Promoting Reflection in Learning: a Model., pp. 18–40. Routledge Falmer, New York (1985)
7. Cacioppo, J., Tassinary, L., Berntson, G.: Handbook of Psychophysiology. Cambridge University Press (2007)
8. Fetterman, D.M.: Ethnography Step by Step, London. SAGE Publications Ltd (1999)
9. Fogg, B.: Persuasive technology: using computers to change what we think and do. Morgan Kaufmann Publishers, US (2003)
10. Jasper, M.: Beginning Reflective Practice (Foundations in Nursing & Health Care). Nelson Thomas Ltd (2003)
11. Jordan, B.: Ethnographic workplace studies and cscw. Human Factors in Information Technology 12, 17–42 (1996)
12. Millen, D.R.: Rapid ethnography: time deepening strategies for hci field research. In: 3rd conference on Designing interactive systems. New York (2000)
13. Myrtek, M.: Heart and emotion: Ambulatory monitoring studies in everyday life. Hogrefe & Huber Publishers (2004)
14. Poh, M., Swenson, N., Picard, R.: A wearable sensor for unobtrusive, long-term assessment of electrodermal activity. IEEE Transactions on Biomedical Engineering 57(5), 1243–1252 (2010)
15. Scheier, M.F., Weintraub, J.K., Carver, C.S.: Coping with stress: Divergent strategies of optimists and pessimists. Journal of Personality and Social Psychology 51(6) (1986)
16. Setz, C., Arnrich, B., Schumm, J., R., L.M., Trster, G., Ehlert, U.: Discriminating stress from cognitive load using a wearable eda device. IEEE Transactions on Information Technology in Biomedicine pp. 410–417 (2010)
17. The Health and Safety Executive: Statistics 2009/10. A National Statistics publication