Pervasive Monitoring to Support Reflective Learning

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Abstract
Reflection on daily work practices can support informal learning and continuous improvement of work practices. This dissertation aims at supporting reflection by employing sensors and corresponding data visualizations to make employees ask the right questions about their work. Two tools have been developed and initial studies have been conducted to evaluate the impact of psychophysiological sensors and proximity sensing for employees in the healthcare domain. The main contribution of this work is the connection of reflective learning and wearable sensors with the goal to persuade employees to reflect. The resulting tools will be evaluated in real work settings.

Author Keywords
Pervasive; reflection; persuasive technology; wearable sensors

ACM Classification Keywords
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

Context and Motivation
Training on the job is an important part in the professional development of nurses, physicians and carers. Dealing with patients, residents and their relatives requires experience. Reflective practice can

support this learning by analyzing the own behavior. Reflective learning refers to *"those intellectual and affective activities in which individuals engage to explore their experiences in order to lead to new understandings and appreciations" [2]*. In the past, research on supporting reflection was conducted using diaries which provided alternative perspectives on daily activities, but today sensors and mobile applications provide new means to capture alternative perspectives on experiences. This pervasive monitoring enables the development of new computer supported reflective learning approaches.

Statement of the Thesis

This thesis aims at researching how wearable sensors can persuade employees within the health care sector to reflect. Therefore, the following three research questions have to be addressed:

- RQ1: How can computer supported reflective learning benefit from the advances in ubiquitous computing, i.e. persuasive technology?
- RQ2: Which sensors can be introduced into health care work environments and can capture data that acts as a memory cue?
- RQ3: How has the data to be processed to allow employees to learn from their own experiences and improve their work?

The dissertation will start by building the theoretical background to combine reflective learning theory and wearable sensors approaches inspired by persuasive technology. Building on these fundamentals, sensors and corresponding visualizations will be selected and implemented into first app prototypes. Finally, these prototypes will be tested and iteratively adapted in real work environments. In the following section, the current theoretical state is reported.

Reflective Learning and Persuasive Technology

Two main streams of research form the theoretical background of this work. On the one hand, decades of research in reflective learning have highlighted the psychological and pedagogical perspective, but ignored the technological advance. On the other hand, persuasive technology is a relatively new field that aims at influencing behavior by using technology. This discussion was published in detail in [9].

Nearly all research on reflective learning refers to the idea of experiential learning by Dewey [5], i.e. we learn by comparing our expectations to what we experience. However, Dewey's work is mainly focused on the benefits of reflective thinking for formal learning. Hence, the model introduced by Boud et al.[2] was chosen as the theoretical basis of this dissertation, because it considers the complete cognitive process, including affective aspects, but does not define specific activities around this process or a specific domain. This allows for a simplified integration of new tools and varying contexts.

Persuasive technology, a term coined by B.J. Fogg [6], comprises a growing range of mobile applications that visualize sensor data to influence behavior. Consolvo et al. [4] published a set of theory driven guidelines that explicitly require that the provided feedback should be "*abstract & reflective*". However, the feedback in persuasive technology is always geared towards a specific goal and a well-defined change in behavior that can be measured and sustained by technology.

In contrast, reflection support does not define clear goals and rules that should be followed, but encourages the learner to ask the right questions. Until now, only a few researchers follow this notion. Isaacs et al. present an approach to computer supported reflective learning that is based on self-reporting and annotation [7].

Pervasive Monitoring

A wide range of sensors is available to design applications that target computer supported reflective learning. The sensors have to be as unobtrusive as possible to not interfere with daily work. Wearable and mobile sensors are preferred because they accompany the user across different contexts, e.g. rooms and used tools. Furthermore, they put the user into control of the system. If situations should remain private, users can simply remove the sensor or turn it off.

As this work is addressing technological support in health care environments, major non-functional requirements are adherence to organization standards and privacy requirements of employees. Employees are concerned that captured data will be used to assess their work performance. Moreover, the privacy of customers and patients is even more critical for organizations. These special requirements limit the applicability of well-known sensors like the SenseCam [1]. An alternative option are self-reporting approaches, but they are often interfering with daily work or have to be highly customized to integrate with existing tools and applications.

In the following, the available context data at the workplace is categorized into three main categories that could act as memory cues and thus have the potential to support reflection: (a) arousal and other emotional cues, (b) social interaction and (c) tasks and activities.

a) Critical incidents are prone to trigger emotional reactions such as a change in arousal that can be measured by psychophysiological sensors, e.g. Affectiva Q [12].

b) The reflection topics are often related to social interaction, e.g. problems with colleagues or customers. Face to face interaction can be captured by sensors like the Sociometric Badge [11].

c) Tasks are the central element of the daily work and can be captured by augmenting tools with sensing capabilities, e.g. company information systems, or diary like applications.

From the three main categories mentioned above, this dissertation focuses on affective aspects and social interaction. Capturing task context relies mostly on sensors that are specific to a workplace or a tool, because the tools that are augmented with sensors are used only by certain specialists or in a specific setting. Moreover, in the healthcare domain social contacts are basically the central element of work tasks.

Preliminary Results

Two different approaches have been evaluated in initial studies: psychophysiological sensors [10] and proximity sensing [8]. Each study aimed at refining the capturing approach, collecting qualitative feedback on the applicability in a specific workplace, privacy concerns and the potential of the data to act as a memory cue.

Study A: Stress Awareness in a Stroke Unit

Nurses and physicians on a stroke unit constantly face pressure and emotional stress. Physiological sensors can create awareness of one's own stress level and persuade medical staff to reflect on their own behavior and coping strategies. In the study reported in [10], 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 by looking at their and (b) support the recalling of experiences to identify stressors.

A subset of the participants was followed by one observer who collected data about the work practices and environment as a reference of the sensor data as well as preparation for concluding interviews. One week later, the participants were asked to recollect stress related events through the examination of the sensor data. The raw heart rate data was shown to participants who are experienced in analyzing this data.

Physicians and nurses could recall stressful events and were interested in their physiological signals. However, participants did not feel able to act according to their insights. For instance one participant said:

"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."

Hence, participants were very critical regarding the sensors. Furthermore, existing coping strategies turned out as barriers to the reflection about these aspects. Physicians and nurses are trained to rather ignore their stress in order to protect themselves.

The conclusions of this study were twofold. The selected context was not appropriate for the sensors and an iterative approach was necessary to find the right biosensor and algorithm. The needed rapid prototyping was realized by integrating the developed algorithms and sensors into a new sensor middleware – xAffect [13]. Moreover, another more controlled context with less activity is necessary. Telephone conferences were selected as alternative because they are a setting that can cause strong emotional reactions while participants are moving only slightly.

The second major insight was the importance of social contacts in the care domain. Nearly all discussed experiences in the interviews were connected to colleagues, residents or relatives. Participants instantly remembered situations, when interviewers mentioned a meeting with a resident or carer during the shift. Therefore, a second pervasive monitoring application was designed.

Study B: Social Contacts in Dementia Care

The study reported in [10] evaluated new low-power proximity sensors in a care home to track and measure social contacts similar to [11]. Each sensor broadcasts a unique id every 10 seconds within a 2 meter distance. A contact is registered when another sensor is within this range and receives the broadcast.

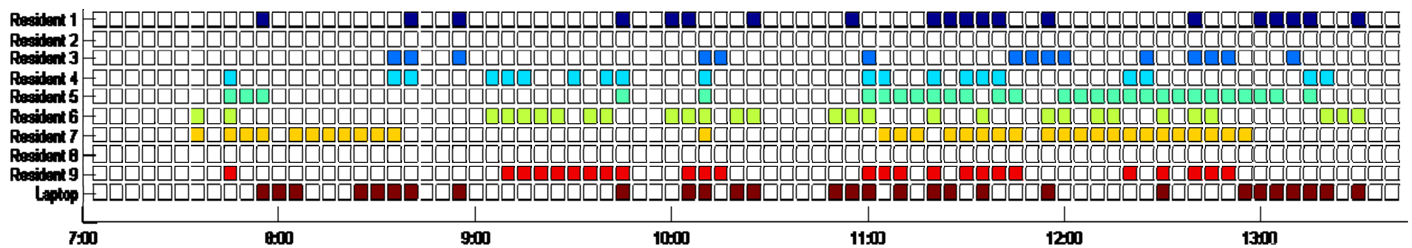

Figure 1 Timeline of a carer's shift showing the time spent in the proximity of a resident within 5 minute intervals.

All carers and residents on a small ward were equipped with proximity sensors. Using the sensors, on average 44% of a carer`s shift could be matched to a specific resident or a documentation task. The remaining 56% of the time carers were walking between residents or caring from a distance. Moreover, the 10 second sampling interval may miss short contacts.

When the results were visualized to carers after the shift, carers could recognize behavior from the raw data and started to discuss care practices. The added value was more important to carers than their privacy concerns. Figure 1 shows an example of the captured data. The break done by the carer between 10:30 and 10:50 is clearly visible and could trigger privacy concerns. Nevertheless, participants had different ideas, such as putting the data on the internet to keep resident's relatives informed.

The insights gained from this study led to the development of a new app that provides feedback to carers in care home – CaReflect which aims at automating the whole process of configuring a study and analysis in order to allow care homes to conduct short (5-7 days) studies on their own. The idea was visualized in a video [3] to reach out to more care homes. The feedback in initial talks is overwhelmingly positive. When speaking to care staff, privacy concerns are rarely voiced and more sharing of data between carers is demanded.

Dissertation Status

Currently the first two steps of this research proposal have been realized. The theoretical basis has been defined and published [9]. Two sensor types, biosensor and proximity sensor, were selected for two work settings, stroke unit and care home, and finally evaluated in 2 studies. Both approaches helped participants to remember their work but only the proximity sensors triggered the desired reflective process. However, this result was achieved in a small setting and was facilitated by the researcher. Additional studies with CaReflect are planned to verify this impact.

In consequence, the first two research challenges have been addressed. The connection between persuasive technology and reflective learning has been established. The selected sensors are promising to monitor relevant behavior in different work context, but have been tested only in one setting. The final verification in other work settings lies beyond this dissertation. The introduction of both technologies has shed light on the specific barriers in the testbeds, e.g. the stroke unit. In the next steps, more studies should evaluate the impact of the proximity sensors in multiple care homes. Biosensors and proximity sensors should be combined in a final concluding study.

Short Biographical Sketch

Lars Müller studied Computer Science and Information Management at the University of Augsburg. Afterwards, he worked as a researcher and project manager at the Fraunhofer Institute for Communication Systems in Munich for 6 years and developed context aware mobile applications. Since 2010, he is working as a research scientist and PhD student at the FZI Research Center for Information Technology (Karlsruhe, Germany) in the team of Prof. Wilhelm Stork. At FZI he is currently leading work package 3 "Capturing learning experiences" of the EU FP7 project MIRROR. His main research interests are context awareness, mobile applications and especially the combination of wearable sensors and mobile applications to create persuasive technology. He aims to complete his PhD in fall 2014.

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