LifelogExplorer: A Tool for Visual Exploration of Ambulatory Skin Conductance Measurements in Context

R.D. Kocielnik[1]

[1]Department of Mathematics & Computer Science, Eindhoven University of Technology, The Netherlands.
[l]r.d.kocielnik@tue.edu.nl

Abstract

We present a user-friendly tool for automated analysis, interpretation and visualization of long-term skin conductance measurements in relation to real life context - LifelogExplorer. The automated processing of raw signal defines personalized stress levels that coupled with powerful interactive visualization offers users a friendly and intuitive way of understanding their physiological reactions in various contexts, such as meetings, hours of the day, etc. Our tool cooperates with the Philips Discrete Tension Indications (DTI-2) measurement wristband, and can easily be extended to use also other measurement equipment. We used the LifelogExplorer in a study with 21 vocational school teachers confirming its usefulness for non-experts.

Introduction

Measuring physiological reactions of the body in real life settings is a big challenge; aside from technical constraints, the challenge lies in discovering and communicating long term physiological patterns to a non-expert user. In this work we focus specifically on measurements related to emotional stress. Stress can lead to diseases such as depression and burnout [1] and indirectly influence development of many other health problems [2]. Use of skin conductance (SC) measurements, as indicator of stress, has been well established in lab settings, where everything is closely monitored and controlled by a researcher. However, the real value of such monitoring lies in performing measurements of stress from regular people and in real-life context when most of the stress is really experienced. Modern wearable sensors begin to offer easy monitoring of various aspects of everyday life continuously and unobtrusively. Usually, however, they don't come with any easy to use software that would offer powerful and understandable interpretations of measurement data for regular users, especially in terms of learning long-term behavioral patterns. External analysis tools such as Matlab and LabView suffer from the same limitation- they are meant for experts. Consequently these devices and the measurements they offer are still mainly used by researchers and "hardcore" enthusiasts from Quantified Self communities.

We offer a tool – LifelogExplorer - that brings the power of real-life SC measurements for estimating the level of stress to the regular user. Our tool automatically processes ambulatory measurements of SC, offers interpretation in form of personalized stress levels and a visual exploration revealing stress patterns in real-life context, all in a user friendly, accessible and simple form. To make the user experience complete we offer easy coupling with an unobtrusive wearable wristband – Discrete Tension Indicator (DTI-2) developed by Philips Research. Our main purpose is to let non-experts understand their stress and reflect on it. Practical usefulness of our tool has been demonstrated in a number of studies in different settings. In this abstract we refer only to the most recent one with 21 vocational school teachers.

The rest of this abstract is structured as follows: (1) we describe our tool – LifelogExplorer - and its main functionalities; (2) we summarize results from our user study, and finally (3) we close with conclusions and future work.

LifelogExplorer

Our goal is to offer integrated systems that automatically obtains physiological measurements from a wearable sensors device, analyzes and presents them to a non-expert using simple and informative interactive visualization. To support the user in learning long-term patterns, our visualization summarizes the measurement data for various

practical contexts, such as meeting subjects, participants, locations and such. To meet this goal, the LifelogExplorer tool extends the work done in [3] .We describe selected functionalities of the system below.

Data analysis

The tool cooperates with the Discrete Tension Indicator (DTI-2) measurement wristband created by Philips Research [4] for continuous unobtrusive monitoring of physiological signals and environmental conditions (skin conductance, skin temperature, ambient temperature and lightings, 3D acceleration), allowing to estimate experienced stress level. SC measurements obtained from the DTI-2 are automatically filtered and processed as depicted in Figure 1. A collection of measurements over long term builds up a personalized histogram of physiological responses. This histogram is further used for defining the personalized stress levels represented using a color scale – from blue meaning "calm" to "red" meaning stressed. More precise description of the procedure used can be found in [5].

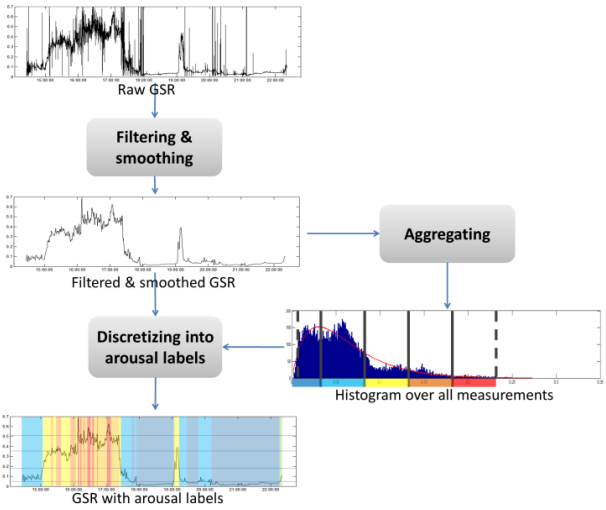

Figure 1 - Steps in processing the raw SC measurements obtained from the DTI-2 measurement wristband.

Calendar views

We use the context of calendar, which most people often work with, as a basis for visualizing short term stress. We offer standard options for defining different time periods being shown: a day, work week, full week. We add a possibility of selecting a set of custom days. This is meant to allow people explore their short term stress in a familiar way. In order to allow people to spot acute stress responses we provide a shape based visualization as shown in Figure 2. The shape visualizes the processed SC measurements in the context of a day. In order to support people in making quick judgments about their day or week we provide a color based visualization as shown in Figure 3. This visualization uses the personalized stress levels for coloring different parts of the day. Through the calendar view we allow the users to explore their short-term stress responses, long-term build-up of stress during the day, and also explore these reactions in different contexts, such as getting stressed during a long, unproductive meeting. We add real-life context to the measurements by importing calendar entries from Outlook, Excel or other source. Aside from these automatically obtained entries we allow users to freely make their own entries if they are interested in tacking or comparing them to the other contexts. Each calendar entry also allows users to indicate their subjective feedback related to the experienced emotions using a questionnaire.

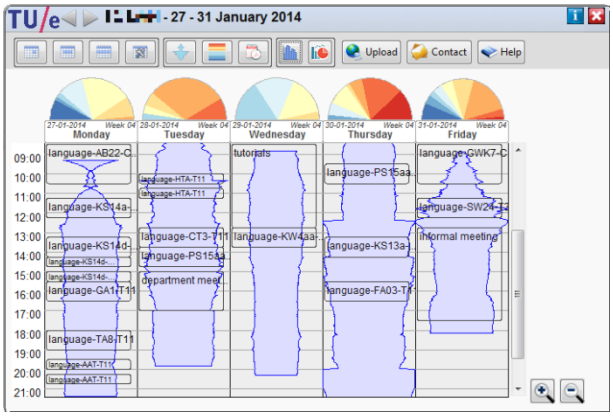

Figure 2 - Calendar view with SC measurements represented as shapes in context.

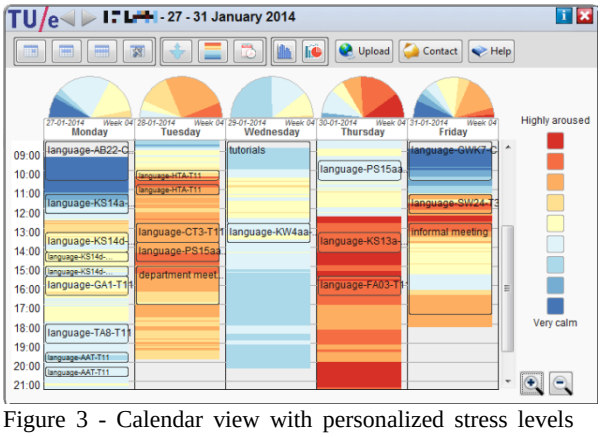

Figure 3 - Calendar view with personalized stress levels represented using a color scale from blue - calm to red - stressed.

Aggregated views

To support users in gaining insight into the contexts in which they experience stress repeatedly and consistently, and therefore spot possible stress patterns, we provide a set of aggregated views on the data. Aggregated views summarize the long-term physiological responses in different contexts, such as meeting subject, location, attendees, as well as, days of week, weeks, months and such. Each view is composed of a number of aggregations of stress, each representing different value for a particular dimension. An example in Figure 4 presents an aggregated view on "hours of the day". Each half-pie chart with colored stress levels represents a different hour of the day. It is important to notice, that this is not an hour of one day, but a summary across multiple days. The size of each hour represents the amount of SC measurements collected in this hours and each slice of the pie, represents a different stress level. It can be seen in the view, that the usual day for this user starts with low stress, between 7:00 and 8:00 and then the stress level increases till the maximum between 13:00 and 15:00. Another example of an aggregated view on "subjects" is presented in Figure 5, where each single half-pie chart represents an aggregation of stress levels during meetings with the same subject. It can be spotted there, that the "management" meeting takes a lot of time for a person and is more stressful than "lecture classes". Furthermore, since people are better at reasoning based on instances rather than generalizations, we provide an interactive link between the aggregated views and the calendar such that when user click an aggregation "management", the calendar view will display all the individual meetings with subject "management". By providing such link, we enable people to better understand, trust and act on long term conclusions based on understanding of their physiological reactions in specific contexts.

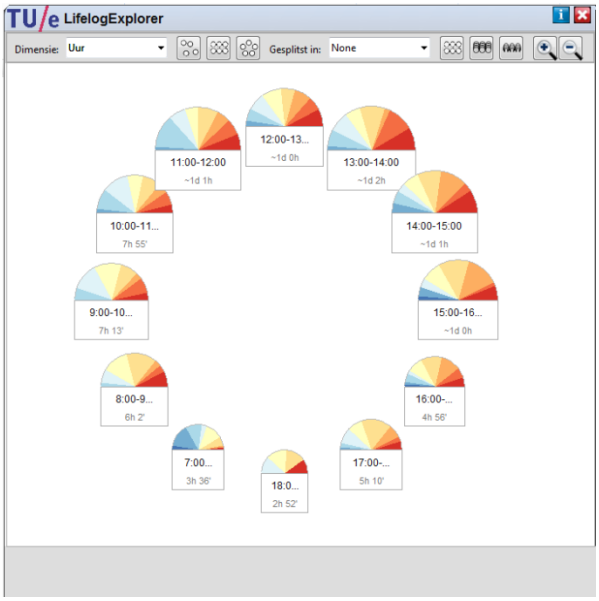

Figure 4 - Aggregated view on "hours of the day", each individual half-pie chart represents a summary of a particular hour across all the measurement days

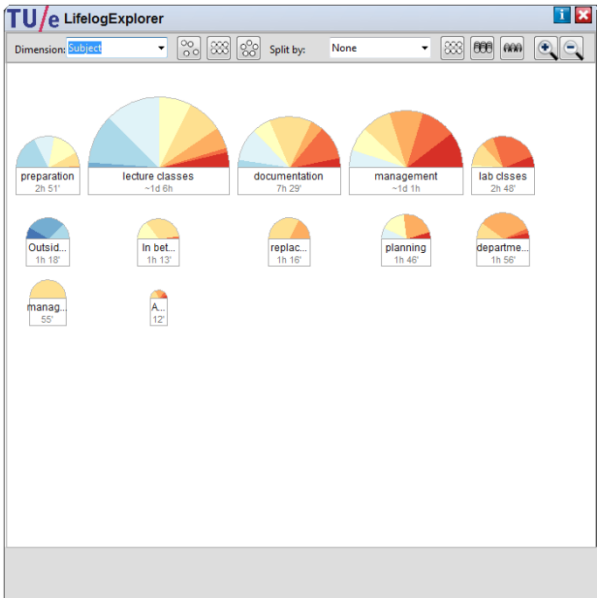

Figure 5 - Aggregated view on "subject of meetings", each individual half-pie chart represents a summary of all the meetings with a particular subject.

Aside from the described views, the LifelogExplorer tool offers a number of additional functionalities that, while not necessarily for a regular user, become useful for an expert. One of such functionalities is the view on the histogram of collected data and the personalized stress level estimations. In this view, an expert can change the automated assignment of colors to SC measurements and define stress levels in a customized way.

Evaluation

We have conducted a field study with 21 vocational school teachers that were asked to use our tool for a period of 4 weeks and wear the DTI-2 measurement wristband during their work hours. They were able to visualize their data in the tool by connecting the device to the USB port of their computer at any convenient moment. After and during the study we collected their feedback about the use of the tool and their overall experience through

questionnaires and interviews. As a result we have collected 20 days of measurements per participant on average ($\sigma = 5.92$) along with an average of 90 calendar entries per participant ($\sigma = 31.30$). We present only the results that directly relate to users' use and experience with the tool. In total 5 of our users voluntarily asked for extending the study by 1 week. 2 of them indicated that they were interested to see if the patterns that they observed will repeat. Others did not provide a specific reason. 7 of the participants used the system on weekends. Those that indicated specific reasons, said that they wanted to see how doing the work related tasks on weekends affects them, or that they wanted to monitor a specific activity. Finally we asked for comments related to their experience with the tool. When asked what they liked about the system most indicated that it is easy and quick to understand and that there is not much you have to do. Also that it is a simple mechanism for learning your day routines quickly, and finally that the visualizations offer a good starting point for conversation. When asked what they did not like about it, most mentioned cumbersome measurement download from the device to the tool and that they kept forgetting to wear the measurement device and to turn it on. These comments suggest that the participants can find their own specific use of the tool and they can see the value it can give them, but still suggests that the measurement procedure could be improved. Voluntary use of the system, outside of requested times, suggests that the participants found the tool useful in practice.

Conclusions & Future work

We presented a tool for effective processing, interpretation and visualization of the long-term SC measurements with real-life context that is suitable for a non-expert user. The proposed visualization supports users in building up self-awareness about their stress responses in various contexts. In our future work we would like to investigate extending our tool with additional signal sources and more information about context.

Ethical statement & Acknowledgements

The studies performed as a part of this research project have been approved by the ethical committee of Philips Research - ICBE (Internal Committee Biomedical Experiments). We would like to thank all the school teachers for participating in our study and providing their comments.

References

1. S. B. Bacharach, P. Bamberger and S. Conley, "Work-home conflict among nurses and engineers: Mediating the impact of role stress on burnout and," *Journal of Organizational Behavior*, vol. 12, p. 39–53, 1991.

2. S. L. Sauter and L. R. Murphy, "Organizational risk factors," American Psychological Association., Washington, DC, 1995.

3. R. Kocielnik, F. Maggi and N. Sidorova, "Enabling self-reflection with LifelogExplorer: Generating simple views from complex data," in *7th International Conference on Pervasive Computing Technologies for Healthcare (PervasiveHealth)*, Venice, 2013.

4. J. Westerink, M. Ouwerkerk, G. de Vries, S. de Waele, J. van den Eerenbeemd and M. van Boven, "Emotion measurement platform for daily life situations," in *In Affective Computing and Intelligent Interaction and Workshops*, 2009.

5. R. Kocielnik, N. Sidorova, F. Maggi, M. Ouwerkerk and J. Westerink, "Smart technologies for long-term stress monitoring at work," in *IEEE 26th International Symposium on Computer-Based Medical Systems (CBMS)*, 2013.

6. E. Singer, "The measured life," *Technology Review*, vol. 114, no. 4, p. 38–45, 2011.