Working Title

Master Thesis

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Saarland University of Applied Sciences
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Matriculation Number	:	3662306
Course of Study	:	Biomedical Engineering (Master)
Specialisation	:	Neural Engineering
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Saarbrücken, November 4, 2019

Abstract

Physical illness, distress and injury are all well known to be possible consequences of a stressful workplace. Therefore, managing the risk of workplace stress has become a key component in today's industry and has been a common research topic in recent years. Where disciplines such as organizational psychology attempt to address this matter by offering practical guidelines for the assessment and mitigation of workplace stressors, neuroergonomics merges the disciplines of neuroscience and ergonomics to provide for a deeper understanding of the neural bases of perceptual and cognitive functions in relation to technologies and settings in the real world. In this thesis, we take a neuroergonomic approach to optimize stress management in collaborative workplaces by regulating the information flow of a human-robot-interface (HRI) according to changes in the mental state of the user. Using a commercial device, we created a wearable and universally applicable system that is capable of obtaining psycho-physiological information and interpreting it in real-time. We believe that the application of such a system could be a potent tool in risk management and therefore be greatly beneficial for the overall reduction of stress related incidents at collaborative workplaces.

Zusammenfassung

Hello, here is some text without a meaning. This text should show what a printed text will look like at this place. If you read this text, you will get no information. Really? Is there no information? Is there a difference between this text and some nonsense like "Huardest gefburn"? Kjift – not at all! A blind text like this gives you information about the selected font, how the letters are written and an impression of the look. This text should contain all letters of the alphabet and it should be written in of the original language. There is no need for special content, but the length of words should match the language.

Declaration

I hereby declare that I have authored this work independently, that I have not used other than the declared sources and resources, and that I have explicitly marked all material which has been quoted either literally or by content from the used sources. This work has neither been submitted to any audit institution nor been published in its current form.

Saarbrücken, November 4, 2019

Dominik Limbach, B.Sc.

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3.1 Materials

All experiments and measurements were conducted within the facilities of Systems Neuroscience and Neurotechnology Unit, particularly the Green Lab, located at the University Hospital Saarland, and the Mindscan Lab, located at the HTW Saar (Technikum).

3.1.1 System Components

3.1.2 Hardware

Empatica E4 Wristband The Empatica E4 wristband is a wearable wireless device designed for comfortable, continuous, real-time data acquisition. It is a class IIa medical device in the EU, according to CE Cert. No. 1876/MDD (93/42/EEC Directive) and was designed for daily life usage [1].

Figure 3.1 shows an overview of the entire E4 wristband from either side indicating key attributes as wells as a total of four different sensors that will be discussed briefly in the following:

- **Photoplethysmography (PPB)** to provide blood volume pulse (BVP), from which heart rate, heart rate variability and other cardiovascular features may be derived

- **Electrodermal activity (EDA)** is used to measure sympathetic nervous system arousal and to derive features related to stress, engagement and excitement

- **3-Axis accelerometer** to capture motion-based activity

- **Infrared thermopile** for reading skin temperature

As the E4 is intended to be worn on the wrist these sensors are set up in a specific way to provide for optimal use. As can be seen on 3.1 the majority of the sensors are located on the backside of the main unit not including the EDA-sensor, which is located on the wristband itself.

Wearing the E4 wristband is equally intrusive to wearing a watch and therefore providing a high level of convenience compared to other physiologic measures such as electrocardiogram ECG or electroencephalogram EEG.

Sampling Specifications All recordings were performed using only software licensed by Empatica. Using the approved streaming application and the compatible Bluetooth receiver, the recorded data was streamed directly to an operator's personal computer via a Bluetooth connection.

EDA sensor

- Sampling frequency: 4 Hz (Non customizable).
- Resolution: 1 digit 900 pSiemens.
- Range: 0.01 μSiemens – 100 μSiemens.
- Alternating current (8Hz frequency) with a max peak to peak value of 100 μAmps (at 100 μSiemens).
- Electrode(Placement): on the ventral (inner) wrist.
- Electrode(Build): Snap-on, silver (Ag) plated with metallic core.
- Electrode(Longevity): 4–6 months

PPG sensor

- Sampling frequency 64 Hz (Non customizable).
- LEDs: Green (2 LEDs), Red (2 LEDs) Photodiodes: 2 units, total 15.5 mm2 sensitive area.
- Sensor output: Blood Volume Pulse (BVP) (variation of volume of arterial blood under the skin resulting from the heart cycle).
- Sensor output resolution 0.9 nW / Digit.
- Motion artifact removal algorithm: Combines different light wavelengths. Tolerates external lighting conditions.

Infrared Thermopile

- Sampling frequency: 4 Hz (Non customizable).
- Range(Ambient temperature): -40...85degC (if available).
- Range(Skin temperature): -40...115degC.
- Resolution: 0.02degC.
- Accuracy ±0.2degC within 36-39degC.

Real-time clock

- Resolution(Recording mode): 5s synchronization resolution. Average of 6 seconds in 6 million seconds drift.
- Resolution(Streaming mode): Temporal resolution up to 0.2 seconds with connected device.

3.2 Methods

3.2.1 Experiment

Participants

Paradigm One of the most important parts to this project was the collection of authentic data that could be used later on to develop a reliable classifier for our system. For that reason a experiment, specifically designed to elicit certain emotional and cognitive states in a subject, was conducted. The following section is focused on the procedure applied in this experiment.

The procedure was comprised of a total of five sessions. Every experiment was initiated with a short briefing session. Containing a short questionnaire, covering personal information of the participant as well as habits that may have a influence on the measurement. Further a series of questions, regarding their handedness, use and frequency of use of watches or other wearables was posed, to estimate the additional influence that may be caused by wearing the Empatica E4 wristband. Concluding the first session, the participants were given a coarse outline of the experiment covering the structure and a basic description of their responsibilities.

The second session consisted of a baseline measurement used to log the participants form of the day and also to be able to account for environmental influences in the following processing steps. Before the start of the measurement the subject was placed on a chair in front of a monitor (24 inches, Resolution: 1080p) with a approximated distance of 1m. The Empatica E4 was then put on the wrist of the non-dominant hand and secured in a position that caused minimal light leakage to the PPG-sensor and provided optimal contact for the EDA electrodes. After the participants were comfortable with the device a one minute test sequence was measured to verify the functionality of the system. Consequently the paradigm was displayed on the monitor and the session was started. After reading the instructions, in which the subjects were asked to relax and remain still, and confirmation with the participant the measurement was initiated with a ten second countdown to give some additional time for preparation. During the measurement the EDA, BVP, and temperature of the subject were measured for a duration of five minutes. Afterwards, to conclude the second session, the participants had to give a subjective rating of their current mental state, regarding their stress level, ranging from 1 (completely relaxed) to 10 (stressed out).

The third session was comprised of three separate measurements, two cognitive tasks and a relaxation segment. As before a rating followed the recording. The ratings consisted of a subjective assessment by the subjects regarding their stress level. Additionally subjects had to rate the test difficulty on a scale from 1 (very easy) to 10 (very difficult) for both tasks. For the first measurement the subjects were instructed to count down aloud from 700 in steps of 7 while maintaining a certain pace. The counting rhythm was indicated by a flashing dot on the instruction screen, for a duration of five minutes. The dot's color and flashing frequency were altered during the experiment to further increase difficulty at the three and four minute mark. If the participants were to slow down or loose track an instructor would intervene to help. The second task consisted of a Stroop-Word-Color test. The test featured 11 different colors, resulting in a total of 220 trials the subjects had to work through. Although the color palette seems rather extensive when compared to the standard 3 color variation of the test, this was a conscious decision to guarantee a test time of at least 5 minutes to mitigate monotony. Each trial presented the subject with a colored word in the center of the screen and one possible answer to either side. The participants then had to choose the right answer based on the color of the word.Each decision was recorded via a key press on the keyboard.

3.3 Signal Analysis

3.3.1 Heart Rate Variability

3.3.2 GSR

3.3.3 Temperature

4 Results

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5 Discussion

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6 Conclusions and Future Work

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Bibliography

[1] *E4 wristband from empatica. User's manual.* Empatica, Via Stendhal 36, 20144 Milano (MI). URL www.empatica.com.