Telemedical System for Diagnosis and Therapy of Stress Related Disorders

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Abstract. The consequences of stress on the health of a person as well as the impact on the health system attracted more and more the public's attention during the last years. In contrast to this, only a few instruments for an objective assessment of stress for the use in diagnosis and therapy of stress related disorders exist. In this article, a model for the phenomenon "stress" is introduced to understand the complex correlations between psychological, physiological and behavioral level. According to this model, a telemedical system that allows a comprehensive assessment of stress-related parameters is presented. This system consists of a psycho-physiological measurement device based on a chest-strep with dry electrodes in order to measure physiological parameters like ECG, physical activity, breathing and photoplethysmogramm (PPG) and a wirelessly coupled smartphone used as an e-diary and e-questionnaire to assess subjective and behavioral parameters.

Keywords: stress measurement, ambulatory assessment, physical activity, pulse transit time.

1 Introduction

Over the last years, stress and its negative consequences have become one of the most important health problems in the industrialized countries. Stress is one cause for a number of the most serious widespread diseases and responsible for the increase of costs in the health system.

According to the Federal Statistical Office of Germany, in 2004 Germany spent EUR 22.8 billion on therapy of mental diseases where stress is one of the main causes. The high burden of stress is also shown in a survey conducted by a health insurance (Techniker-Krankenkasse) in 2009 (see Fig. 1). After this study, 80 % of Germans are suffering from stress, one third is always stressed.

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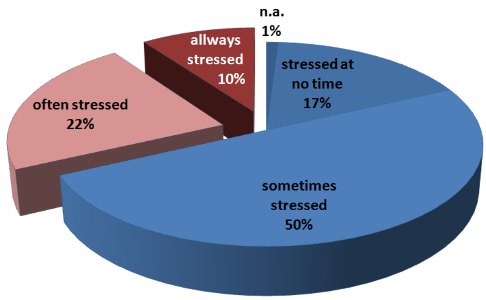

Fig. 1. The incidence of stress in German population (Techniker Krankenkasse, F.A.Z.-Institut, 2009)

Beside this, there has been an increasing interest over the last years in finding new, technology based methods for capturing physiological, subjective and behavioral data in “real time” in the field. Especially in the area of telemonitoring of cardiovascular diseases, a large number of products appeared on the market [1]. The use of these systems in diagnosis and therapy support of stress has some restrictions, because of specific requirements for a stress monitoring system that is able to measure all the relevant aspects of a stress reaction.

A high burden of stress releases reactions on different levels. After a cognitive appraisal of the situation, there could be changes in the emotional state, in the vegetative and hormonal system as well as in the muscular tonus [2]. The reactions of the vegetative and hormonal system could be measured by different methods [3]. It can be differentiated between invasive and non-invasive methods on the one hand and between stationary explorations in a lab environment and mobile explorations in the field on the other hand. There have been a large number of systems that measure some of these aspects, like electrodermal reaction caused by hormonal system or reactions of heart rate or heart rate variability (HRV). Systems for measuring psycho-physiological parameters or stress could be divided in two groups. On one side, you have special devices for stress measurement and biofeedback. Normally these systems are used in relaxation and stress prevention training. They could not be used for mobile and continuous monitoring (e.g. connection to PC). On the other side, you can find mobile monitoring devices. These systems are very small and are normally used for monitoring of one vital signal, but they have disadvantages in establishing long-term electrical contact that do not irritate the skin of the users. For the assessment of subjective data you can find mobile solutions for mood monitoring, which allows the user to fill in basic information on current circumstances and experience.

The goal of a reliable measurement of stress is to assess a holistic view of the whole stress reaction of a person. This has to be done with a simple monitoring system that allows a non-invasive, mobile, continuous and unobtrusive measurement. For this, we need a system with very small size, light weight and electrodes that do not cause discomfort. To understand the complex relationships in the stress process in order to design an appropriate system for the assessment of the different levels of reaction, we use a model based design approach.

1.1 The Stress Model

An integrated stress model that contains aspects from different disciplines was developed by Ice and James [4], see Fig. 2. According to this model stress can be defined as a process that induces emotional, behavioral and physiological reactions. These reactions are dependent on the personal, biological and cultural context of the individual and affect the physical and mental health of that person.

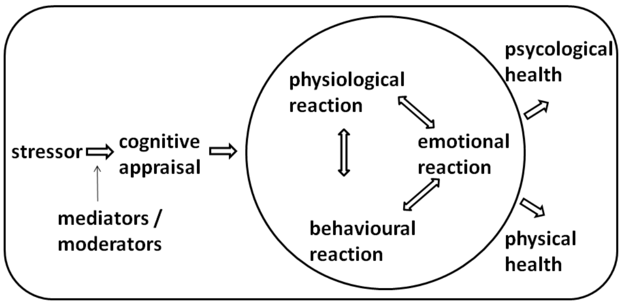

Fig. 2. Stress Model based on Ice and James (2007)

The physiological reactions are caused by an activation of the sympathetic nervous system and by the release of hormones (adrenalin, noradrenalin, testosterone and cortisol). These hormones are released as a consequence of the activation of the hypothalamic-pituitary-adrenal axis (HPA or HTPA axis), the neuroendocrine system that controls reactions to stress and regulates many body processes, i.e. mood and emotions, the immune system, as well as many others. Beside this we can observe behavioral and emotional reactions (like changes in physical activity or time spent for sleeping) which lead to negative affects in physical and psychological health (e.g. heart attack, depression).

2 System for Stress Measurement

The different parts of this stress process need different measurement methods. To get a broad and valid assessment of the whole process, you have to acquire as much parameters as possible and take them into account for the analysis of someone's stress level. During the last years, many hardware and software solutions for multiparametric assessment of physiological signals and experience sampling have been developed [6]. But none of them is able to provide an integrated platform for the assessment of all the parameters defined above.

For the measurement of stressors and the assessment of the cognitive appraisal some approved questionnaires like SAM (Stress Appraisal Measure) [9] and PSS (Perceived Stress Scale) [10] could be used as mobile application on a smartphone. On the smartphone we use the open source software MyExperience as an e-Diary and e-Questionnaire system with the possibility of special extension needed for stress measurement. Therefore we developed some own assessment formats for special parameters like time budget analysis, vigilance or localization of a person (see Fig. 3).

Fig. 3. Special assessment formats for time budget analysis (left), vigilance (middle) and localization (right)

The measurement of physiological reactions in stress process could be done by mobile and unobtrusive physiological sensors. To achieve this goal, we developed a sensor platform for data logging, data processing and wireless data transmission, see Fig. 4. The platform consists of an ultra-low-power microcontroller (MSP430F1611) with 12 bit AD/DA converter, 2 UART interfaces and 48 kB flash and 10 kB RAM. For the storage of the data we use a 2 GB microSD card. The physical activity frontend is built by an ultra low power MEMS 3D acceleration sensor (adxl345) with a range of ± 8 g and a resolution of 4 mg. The acceleration signal is sampled with 64 Hz. The ECG module is a single channel ECG with 12 bit and a sampling rate up to 1024 Hz. With this system we are able to store raw data of the physiological signals up to 12 days. Besides the physiological signals we measure temperature and air pressure to calculate changes in the altitude (BMP085, Bosch GmBH with resolution 15 cm and sampling frequency 1 Hz). These signals are used as context information (e.g. weather) and combined with the acceleration signal for the classification of different types of physical activity and the estimation of energy expenditure. The transmission of raw data after a complete measurement and the power supply is realized by a USB 2.0 interface. The user interface should be very simple, provide an easy to use system and avoid interaction of the subject to the measurement. This is built by a LED with three colors and a vibration motor to give a feedback to the user. User input could be done by tapping on the sensor. This could be detected by the acceleration sensor. Based on this platform we achieved a wearable sensor strap with dry electrodes that is light, small and comfortable for long-term ambulatory measurement of the electrocardiogram and the physical activity.

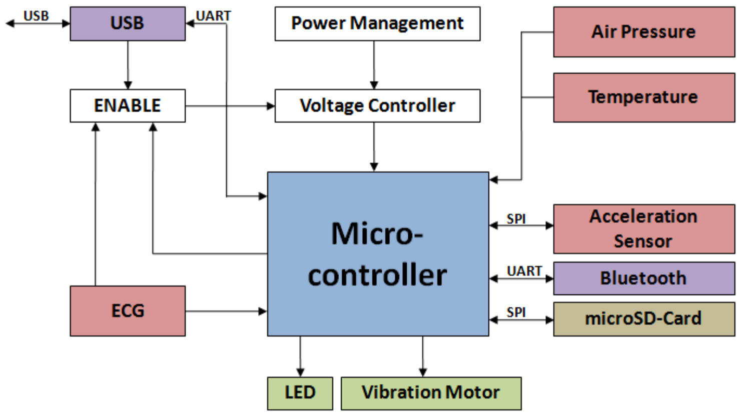

Fig. 4. Hardware Architecture of the Sensor Platform

From the sensor signals physiological features and contextual information is extracted in real-time and can be transmitted to a smartphone via Bluetooth connection, see Fig. 5. For online communication between the sensor and the smartphone we use Bluetooth connection (WML46, Bluetooth-Version 2.0+EDR). Online communication is necessary for interactive assessments where subjective data are collected according to changes or events in physiological signals. The mobile data collecting software is designed to run on smartphones. Smartphones are not only a very good platform for mobile data acquisition but they also provide multimedia features such as digital photo or video capture.

Fig. 5. Integrated measurement system for assessment of stress

Besides the synchronous recording of the physiological data received from the mobile sensors MyExperience also collects self-reports from the participant [7]. These self-reports can be triggered by the user or automatically by physiological or contextual events. With this system a context-aware experience sampling can be achieved [8]. The different levels of stress reactions could also be measured by this system. We use Positive Affect - Negative Affect Schedule (PANAS) [11] and Profile of Mood States (POMS) [12] for assessment of emotional reaction and Ways of

Coping Questionnaire (WCQ) to get information about behavioral stress reaction and the use of coping strategies [13]. An objective measurement of behavior is realized with acceleration sensors, which measure physical activity, energy expenditure and other parameters like step counts [14]. The physiological level of stress reaction can be measured with different sensors based on the platform described before. Besides the measurement of ECG there are mobile sensors for photoplethysmogramm and electrodermal activity that can also be included in the system. With these sensors it is possible to measure the most important stress-related parameters like Heart Rate, Heart Rate Variability (HRV), Additional Heart Rate (AHR), Pulse Transit Time (PTT) [15] [16] and Galvanic Skin Response (GSR).

3 Results

To validate the physiological measurement of stress related vital parameters, we designed a detailed and complex procedure for a study, where we used the „Trier Social Stress Test" (TSST) for induction of moderate psycho-biological stress responses in laboratory environment. To control the evidence of the physiological signals during the different phases of the study, we calculated a Poincare-plot of the R-R-intervals in the baseline phase and the anticipation phase. As we can see in figure 6, there is a significant difference in HRV in phases with stress (anticipation) and phases of relaxation (baseline).

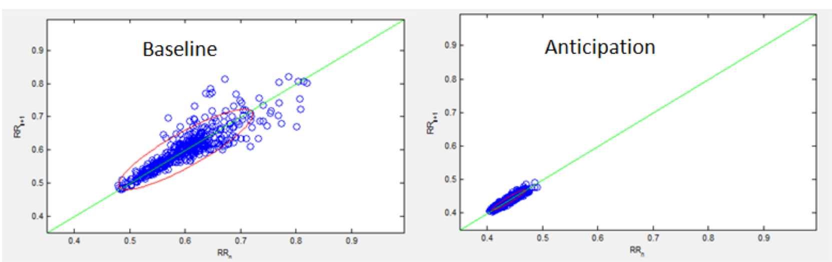

Fig. 6. Poincare Plot for a test person on stress experiment

One of the main aspects in mobile monitoring is the operating time of the system when transmitting data via Bluetooth connection. We measured this time for the sensor chest strap and the smartphone (HTC touch diamond II) for different data transmission rates. The difference between continuous transmission of ECG data and the transmission of some events (if the devices stay connected) is negligible for the sensor, only the life time of the smart phone increases significantly. We also calculated power consumption if the devices are only connected for the transmission of an event. In this case we achieve an operating time for monitoring and online analyzing of ECG data of more than 24 hours.

Bluetooth continuous connection	Chest Strap with logging	Smartphone
High continuous data (256Hz ECG)	3:10 h	6 h
Low continuous data (1Hz HR)	3:15 h	9 h
Connection only (e.g. events)	3:20 h	24 h
Connecting on events only	>24 h, depending on the amount of events	>48 h

Fig. 7. Power Consumption for data transmission for different modi on Sensor and Smartphone

4 Conclusion

The presented telemedical system for diagnosis and therapy of stress related disorders is able to assess synchronously a large number of parameters of the whole process of stress reaction. Besides the measurement of physiological data the system is able to get information about emotional and behavioral reaction. The basis of the system is built by a sensor platform for different physiological parameters which is connected wireless to a smartphone. On this smartphone, subjective data is collected with e-questionnaires and it is also used to get context information. Through the coupling of physiological sensors and mobile device we achieved a system for interactive ambulatory assessment of stress. With this system, questionnaires for emotional and behavioral reactions can be executed as a function of the appearance of specified (physiological) events. With this we get new possibilities in diagnosis and treatment of stress that can lead to an improvement of the present situation.

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