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POLYGRAPHIC REPRESENTATION OF ANXIETY DISORDER - A CASE STUDY

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ABSTRACT

The german research project PsychoPort aims at the mobile detection of pathological states of anxiety and a suitable intervention. In this paper an exemplary case of anxiety disorder is examined. Four different biomedical signals were monitored, namely the electrocardiogram (ECG), the sympathetic skin response (SSR), four electromyogram (EMG) leads at regions with high tension potential and three respiration belts. Video stimulations with invasive and positive character were used to distinguish anxious states from relaxed ones. The obtained signals were analyzed statistically, in the time-frequency domain and by extraction of characteristic parameters. The parameters obtained during the two stimulations were compared with respect to the patient's subjective evaluation of the perceived level of fear. The results show higher sympathetic activation for all biosignals during an invasive video stimulation compared to a relaxed state of mind.

Index Terms— biosignal processing, anxiety disorder, ECG, EMG, respiration, sympathetic skin response, video provocation

1. INTRODUCTION

Anxiety disorder is a highly prevalent psychological disorder which affects about 15% of the population in developed countries [1]. The psychological diagnosis and therapy of anxiety disorder are well studied. However, many therapy sessions are required and long waiting periods prevail. The main goal of the PsychoPort project is the development of a mobile device which measures and processes biomedical signals and triggers psychological interventions in everyday life in order to support the psychological therapy. In this contribution we focus on the investigation of differences in biosignal measurements during a phobic reaction and a relaxed emotional state of mind. For such information it is necessary to reliably detect a phobic reaction.

Polygraphic biosignal measurements were already taken in a case study of the panic syndrome [2]. There it was shown that several biosignals show changes before the panic attack is observed by the patient using blood pressure, ECG, EMG, peripheral pulse, respiration and pupillary reflex.

In Section 2 we present the subject, the measuring procedure, the measuring equipment and the choice of biosignal parameters. In Section 3 we display the results of the case study. In Section 4 we sum up the findings and give perspectives on the further work in this project.

2. METHODS

2.1. Subject

The subject was a 45 year old male in moderate health condition. He had few sleep in the night before the measurements and described several factors in his life as stressful. The subject was beforehand tested with the Symptom Checklist-90-R (SCL-90-R) [3], the d2 Test of Attention [4] and the Interaktions-Angst-Fragebogen [5]. Multiple specific phobias (ICD-10 F40.2) were diagnosed, namely aviophobia, ophidiophobia and cynophobia.

2.2. Procedure

The measuring session was divided into three stages. First, the subject was seated comfortably and connected to the measuring device. After a rest of five minutes to adapt himself to the situation he was exposed to an invasive video on a television screen. In the present case the video depicted a flight with a microlight and several cut-scenes of winding snakes and barking dogs. The video has a playtime of about 10 minutes. At last, another video was presented, which depicted a positive ambiance according to the patient's liking. In this case it was a purling mountain brook with birds chirping. After each stage an interview took place to inquire the subject's impressions of the procedure and a subjective rating of his condition and stress level on a scale from 0 to 12 was taken.

2.3. Measurement

All recordings were taken with the Tower of Measurement, a polygraphic measurement device. The device has 16 polygraphic channels, a sampling frequency of 2048 Hz per channel and an amplitude resolution of 24 Bit. All channels are sampled synchronously. For all surface abreactions Ag/AgCl electrodes were used.

The ECG was measured between the subject's forearms with reference to the left foot (Einthoven Lead I). The mean was subtracted from the raw signal and a 50 Hz notch filter was applied to eliminate artifacts from the utility frequency.

Four EMG leads were applied to measure muscle tension during the video exposition. The positions were on the right side of the back (splenius cervicis), the right side of the neck (sternocleidomastoid), the left side of the face (masseter) and on the right forearm (flexor carpi radialis). All leads were measured in reference to a neutral point near by. The mean and the utility frequency 50 Hz were removed from the raw signals. Afterwards a bandpass filter ranging from 10 Hz to 500 Hz was applied [6].

The SSR lead was applied to the medial phalanges of the index and middle finger of the left hand. The reference was placed at the wrist. The raw data was filtered by a 0.3 Hz lowpass filter to restrain high frequency signal components unconnected to the slow skin reactions.

The respiratory activity was obtained by measuring the circumference change of the subject's torso using piezoelectric sensors. Three respiratory belts were applied: the first to the upper torso covering the pectoral muscles, the second in the area of the thoracic diaphragm and the third around the abdomen. Due to the differentiating nature of the piezoelectric sensors the raw signals were centered and integrated to obtain a respiratory curve. The resulting signal was smoothed by a 0.3 Hz lowpass filter for the detection of the respiratory frequency. Hyperventilation at a higher frequency is detected in the unfiltered signal.

2.4. Parameter Analysis

2.4.1. ECG

The ECG was used to obtain the heart rate and related parameters by detecting R peaks in the signal using the Pan-Thompkins QRS detection algorithm [7]. The RR intervals are given in milliseconds (ms) and the corresponding heart rate in beats per minute (bpm). The heart rate variability (HRV) is represented by the root mean square successive difference (RMSSD, see equation (1)) of the RR intervals [8].

$$RMSSD = \sum_{n=1}^{N-1} \frac{(R_{n+1} - R_n)^2}{N-1}, \qquad (1)$$

with R_n being the duration of the n-th RR interval. Especially quick changes in heart rate are reflected in a high RMSSD. A time-variant version of this measure can be obtained by restricting the sum to a constant number of RR intervals and vary its bounds over time. A high HRV indicates a high flexibility of the heart to react on stimuli from the autonomic nervous system and, therefore, a healthy condition. A low HRV indicates several physiological conditions, but also psychological conditions including stress and anxiety.

pNNx is another parameter class describing the intensity of heart rate change. It describes the percentage of successive heart rate changes exceeding a distinct duration x measured in milliseconds. Usually pNN50 is used for psychophysiological research but [9] indicates, that lower measures like pNN20 or pNN10 are better suited for the distinction of different psychophysiological states.

For the analysis in the frequency domain the frequency spectrum of the heart rate is used. The tachogram was interpolated using cosine functions [10, pp. 200]. The low frequency band (LF) ranges from about 0.04 Hz to 0.15 Hz displacement from the mode of the heart frequency and is associated with both vagal and sympathetic influences of the autonomic system. The high frequency band (HF) ranges from 0.15 Hz to 0.4 Hz displacement from the mode of the heart frequency and is of mainly sympathetic origin. The quotient of LF and HF is often used as measure for the sympathovagal balance [11].

2.4.2. EMG

The mean power during the invasive and the positive stimulation was compared taking the quotient of the two for each channel. Since the muscular tension is supposed to increase during the invasive stimulation the progress of the mean power within a small time window was also observed. In two channels (back, neck) periodical artifacts corresponding to the heart rhythm occurred. The pattern of the artifacts was extracted by averaging ten artifacts for each channel and removing the pattern from the signal.

2.4.3. SSR

The SSR is divided into its baseline and fluctuations. The fluctuations are calculated by subtracting the baseline from the SSR. The baseline is approximated by linearly connecting the local minima of the SSR. Using this approach the cumulation of multiple skin reactions within their refraction times is not mirrored in the amplitude of the fluctuations. Therefore, bias errors in these amplitudes can be reduced. Since no specific triggers were given the parameter of interest is the count of fluctuations per minute using only fluctuations with an amplitude of at least 10% of the baseline [8].

2.4.4. Respiration

For each channel the points of deepest inhalation and the points of deepest exhalation were detected by finding all local extremal values of the smoothed time series. The rate of inhalation is obtained by using the points of maximum inhalation. The inhalation time was measured between a minimum and the following maximum of the respiratory curve. The exhalation time was calculated analogous using a maximum and the following minimum. The respiration depth was computed as the difference of amplitudes at the minima and their following maxima.

3. RESULTS

The perceived stress level on a scale from 0 to 12 was stated 6 after all preparations before the measurement were finished. During the invasive provocation the level of stress rose up to 9. As the most unpleasant situation the scene of an approaching snake (about five minutes into the video) was mentioned. After the exposition with the positive video the stress level sank to 1. The subjective rating of the sustained stress indicates that the videos had the intended effect on the subject. Therefore, the influence of the measuring situation as sole source of stress is disregarded.

3.1. ECG

An overview of the main parameters concerning heart activity is given in Table 1. There and in Figure 1 is shown that the median of the heart rates during the invasive stimulation is 4.6 bpm higher than during the positive stimulation. This indicates a higher heart activation during anxiety related stimuli. Though, the standard deviation remains the same for both trials. Therefore, no additional information is gained from this measure for this comparison.

Table 1: *Summary of ECG related parameters*

	invasive		positive	
HR median	82.9	bpm	78.3	bpm
HR standard deviation	2.4	bpm	2.3	bpm
RMSSD	5.8	ms	8.6	ms
pNN50	0.0	%	0.0	%
pNN20	0.4	%	3.3	%
pNN10	7.9	%	20.4	%
LF/HF	102		140	

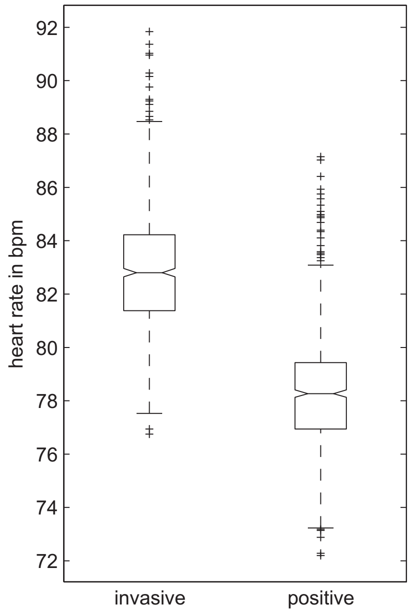

Figure 1: *Heart rate statistics during invasive and positive trials depicted in boxplots*

The RMSSD shows a distinct difference between the invasive and the positive stimulation. The heart rate is more flexible during the relaxed state. Though, the RMSSD is small compared to other healthy subjects of his age, which have a mean RMSSD of about 26 ms [12].

The time variant $RMSSD_{40}$ was calculated within a time window containing 40 RR intervals. At a heart rate of approximately 80 bpm about 30 seconds of heart rate changes are included in this measure. Therefore a balance between reducing the influence of statistical outliers and reacting on recent changes in the signal is kept. The result is shown in Figure 2.

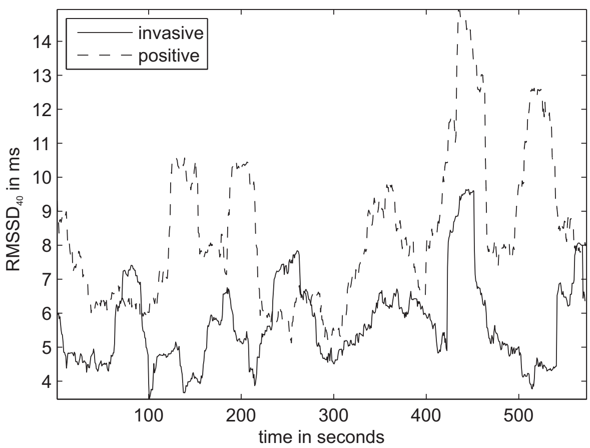

Figure 2: *Comparison of $RMSSD_{40}$ for the last 40 RR intervals during invasive and positve stimulation*

The reactions within the video expositions show no direct relation to the images within the videos. Though, two scenes depicting snakes coincide with two minima at about 150 s and 210 s, the most invasive stimulus perceived, has no representation in the data. The positive video was monotonous and not intended to evoke sudden changes in the biosignals. The slopes in the $RMSSD_{40}$ must be related to other sources which provoked an emotional response.

Due to the low RMSSD pNN50 has no informative value (see Table 1). pNN20 and pNN10 show an increased number of longer heart rate changes during the positive stimulation. As for the RMSSD this shows a higher adaptability of the heart, which is considered healthier.

The analysis in the frequency domain shows an increased LF/HF ratio during the positive stimulation (see Table 1). Therefore, a higher activity within the high frequency band is observed during the invasive stimulation. That indicates a higher sympathetic activation which is characteristic for anxiety and stress.

3.2. EMG

The comparison of the mean power of muscular activity during invasive and positive stimulation shows only small differences between the two. For the leads in the neck and the back a 10 percent greater muscular activity was determined. Since no sudden reactions occurred, the increased power is classified as muscular tension. The leads on the face and forearm show many movement artifacts which are, especially in the case of positive stimulation, unrelated to the received stimuli. Therefore, a distinct conclusion cannot be drawn for them.

Since the mean power of channels 1 and 3 shows a higher muscle activation during the invasive stimulation, a closer look at the progress during the invasive exposition was taken. The time window for the calculation of the time variant mean power is chosen analogous to the $RMSSD_{40}$, namely 30 seconds. The progression of both EMG signals is similar (see Figure 3). There is neither a general uptrend nor a general downtrend distinguishable within the signals. Though, there are several temporary rises in the mean power but none of them is directly connected with a specific scene in the invasive video.

3.3. SSR

During the invasive stimulation 5.1 fluctuations that exceeded the amplitude threshold occurred per minute. During the positive stimulation the activity in the SSR sank to 2.3 fluctuations per minute. Also, the amplitudes of the fluctuations were an average 20 percent higher during the invasive stimulation.

So, the results show more frequent and more intense reactions while the subject is exposed to invasive stimuli. That suggests a higher influence of the sympathetic nervous system during this time. Since no specific triggers were set, the single fluctuations remain unspecific and can only be used as a general indicator.

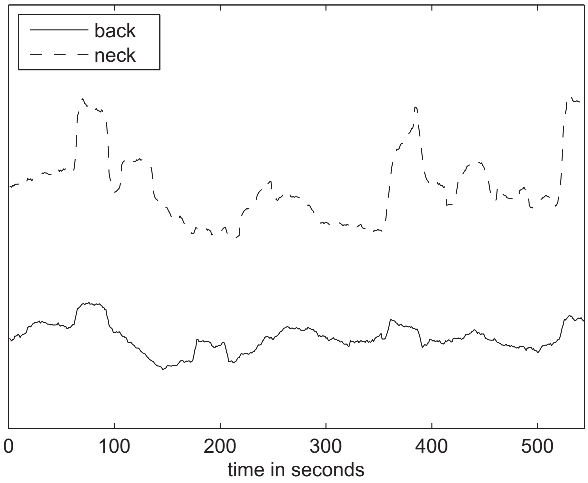

Figure 3: *Qualitative progression of two EMG channels during invasive stimulation*

3.4. Respiration

The result of the rate of inhalation analysis for one respiratory signal is shown in Figure 4. The results for the other two signals were similar to the illustrated one. During the invasive stimulation the median of the rate of inhalation was about 2 inhalations per minute higher than during the positive stimulation. The standard deviation of the rate of inhalation remains nearly the same during both trials, namely 2.4 min^{-1} and 2.5 min^{-1}. These results indicate a higher sympathetic activation

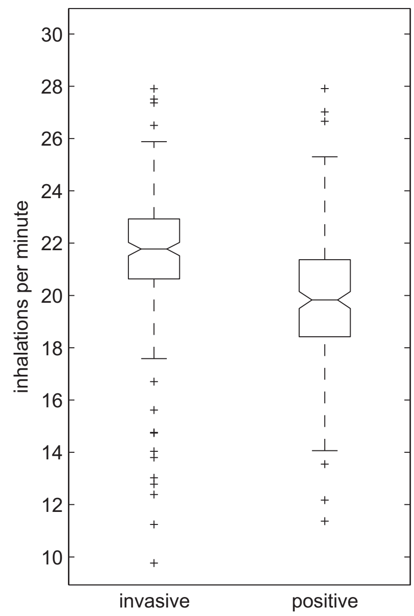

Figure 4: *Comparison of inhalation rates in the second respiration channel statistics using boxplots*

Table 2: *Depth of inhalation in all respiration channels*

		channel 1	2	3
depth of inhalation	invasive	0.74	0.52	1.00
	positive	0.71	0.45	0.97

during the invasive stimulation. Although, no signs of hyperventilation were present, which are a better indicator for anxiety than simply higher rates of inhalation.

The durations of inhalation and exhalation are in each case likewise for all three channels. The average inhalation time was 1.37 seconds during invasive stimulation and 1.48 seconds during positive stimulation. The exhalation time was nearly the same with 1.36 seconds during invasive stimulation and 1.50 seconds during positive stimulation. So there is no imbalance between inhalation and exhalation time. Both measures have a higher value during the positive trial. This is a consequence of the decreased rate of inhalation.

In Table 2 the average depths of inhalation for all channels during both trials are shown. The values of the depth were normalized in reference to the highest value for an easier comparison. In all channels a heightened depth of inhalation can be observed during the invasive stimulation. In combination with the also heightened rate of inspiration an increased oxygen consumption is indicated. Also no shifting of the inhalation depth between torso and abdomen was detected.

4. DISCUSSION

The results have shown that many of the biosignals and related parameters indicate a higher sympathetic activation of the subject during the invasive stimulation. Though, no distinct reactions to specific scenes in the invasive video were noticed. Also no reactions specific for anxiety, e.g., hyperventilation, occurred.

In this case study no comparison to a fear reaction was made. Specific phobias might be too close related to normal fear, which results in a fight-or-flight reaction [13] that also shows a sympathetic activation.

In conclusion, an anxious reaction by using an invasive video was successfully provoked. In comparison to a positive video stimulation psychophysiological differences were shown. Since these differences are of unspecific nature a detection of anxiety with the presented set of parameters will induce many false positive detections. In future research the parameter set will be refined, taking into account information from more than one biosignal.

Regarding the research project PsychoPort the case study imparted some knowledge. It was shown that a subject in an anxious state of mind can be calmed down by positive video stimulation. This will be a starting point for the mobile intervention techniques. Currently similar measurements with nine other subjects are taking place. The increased data pool and a broader variety of different anxiety disorders will provide more insight in this matter.

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