A NEW METHOD FOR INDUCING HUMAN STRESS AND RELAXATION STATES

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This paper focuses on designing a new method that can induce a state of stress or relaxation to a subject. The stress part of the method is based on the Trier social stress test and the relaxation part is based on the current research on the effects of classical music on the human stress and on older research performed in the laboratory. The acquired data will be used in electrodermal activity analysis of signals for stress detection.

Keywords: electrodermal activity, stress-inducing techniques, relaxation techniques, Trier test, feature extraction

1. Introduction

Stress detection is an important part in conducted research nowadays and being able to detect various levels of stress by using as little interaction between the subject and sensors is also important.

The purpose of this paper is to develop a new method that will be used to highlight physiological parameters needed in human emotion detection. Current methods used for inducing and detecting stress lack a very important part in signal processing: a baseline needed to establish a difference between a relaxed state and a stressed state. The current method used in laboratory experiments for obtaining a relaxation baseline returned physiological signals that indicated a high activation state. This relaxation method uses a sequence of pleasant images from the International Affective Picture System (IAPS) [1]. In addition, a stress-inducing technique currently used in subject testing that returned good results was improved to integrate a baseline generating method for relaxation and a few corrections needed to keep the subject focused on the task given.

According to [2], a very good stress indicator is the subject's electrodermal activity (EDA). The human body sweat glands will react when the subject enters an activation state that can be associated with stress. This reaction can be observed through the variation of skin conductivity. In [3] it is described a

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very good site to acquire electrodermal activity data by using two small electrodes attached to the subject's hand.

The electrodermal activity data can be influenced by the user's state of mind, image and sound interpretation and environment conditions (air quality, room temperature), in other words, different subjects will react differently when presented with the same image. This means that we need a new test that can relax and stress the subject in such a way that a visible difference can be established between the stressed and relaxed periods.

In current research, there are multiple methods used for stressing and relaxing subjects, but very few of them are actually well documented and can be used in laboratory conditions where we expect to obtain almost the same results every time we apply the method on the same subject. Some of these methods do not report a number of test subjects [4] or the stimulation method is not detailed enough to replicate the results [4][5]. Another problem is that all these relaxing and stress-inducing methods are validated for other human physiological parameters (electrocardiogram, electroencephalogram, skin temperature, heart rate, etc.) [4][5][6][7].

From previously developed methods for inducing emotions [8][9] and literature [10], the following strategies were chosen:

a) For stress, the Trier social stress test [11] was used, consisting of a series of mathematical equations with a variable time available to answer for each equation that depends on the number of correct/incorrect answers. Different methods were used for estimating the time in which the subject was allowed to solve each equation. The aim of this method was to lower this period of time to the point that the subject barely managed to give an answer. The rate at which this period of time increased or decreased was also important, because as far as the subject is concerned this period of time is constant and large variations will be noticed. The old method used in laboratory experiments which is based on the Trier test, computed the period of time based on the average time of the last three equations and the answer given by the subject. This means that in some cases, the period of time decreased significantly after the subject gave three correct consecutive answers to trivial equations in a short period of time.

b) For the relaxation part, the effects of music were considered. According to [10], classical music will reduce stress, but from previous tests, simply playing a sequence of classical music is not enough to induce a relaxation state. Therefore, the new relaxation method has to combine visual and auditory stimuli than cannot let the subject's mind to wander at other disturbing factors

These methods provide a visible difference in the electrodermal activity data variation that allow us to detect the subject's current activation state.

Research was made using electrodermal activity signals and other physiological signals regarding stress while driving [6] where the relaxed state was obtained while driving on a highway and the stressed state while driving during rush hours. Even though the research returned valuable results, these conditions cannot be reproduced in a laboratory environment where the subject can be isolated from external factors.

2. The stress/relaxation inducing method

Various problems encountered when testing previous methods were taken into consideration.

One of these problems is that the subject can enter in an activation state just by simply watching an image, a blank screen or just by thinking of something or someone. This proved to be a problem in the relaxation part of the program, where just playing a classical music sequence was not enough to obtain a completely relaxed state.

As described in [2], a low variability electrodermal activity signal is associated with a relaxed state. To analyze this reaction, a subject was asked to watch different images while listening to music. The subject reacted with a high activation state (high variability of the electrodermal signal) while watching a sequence of pleasant images. The same subject reacted with a lower activation state while watching a slow motion movie with a classical music background. In “Fig. 1” and “Fig. 2”, these two reactions are displayed. Even if the subject reacts better in the second case, there are still a few high amplitude responses in the electrodermal activity data, showing that the subject did not reach a completely relaxed state.

Another problem is that subjects with a fear of water or heights reacted with a high activation state when viewing an image with a lake or a view from a tall building. Other subjects responded similarly to images that contained animals, which evoked fear or happiness. Therefore, the image used for the relaxation method was a simple image with a generic landscape.

Because multiple subjects responded better in the second case, the next step was to analyze the movie and see where the subjects reacted with low amplitude responses. The conclusion was that the movie’s quick transitions, certain images or moving characters produced the high amplitude signals, therefore a new method was designed based on these conclusions.

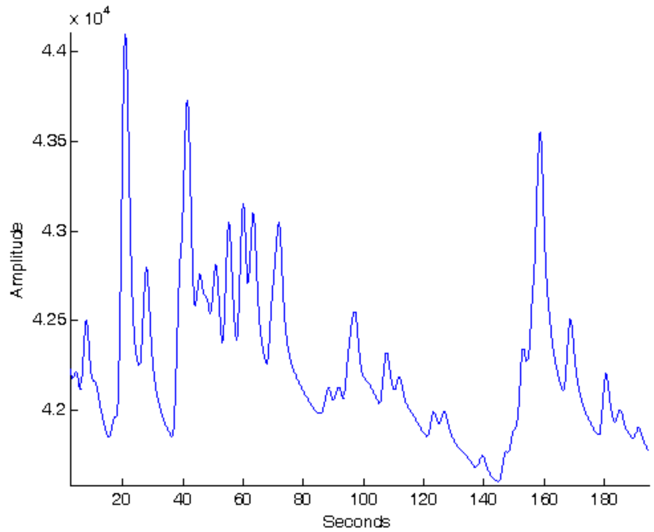

Fig. 1. Subject reaction to a sequence of pleasant images

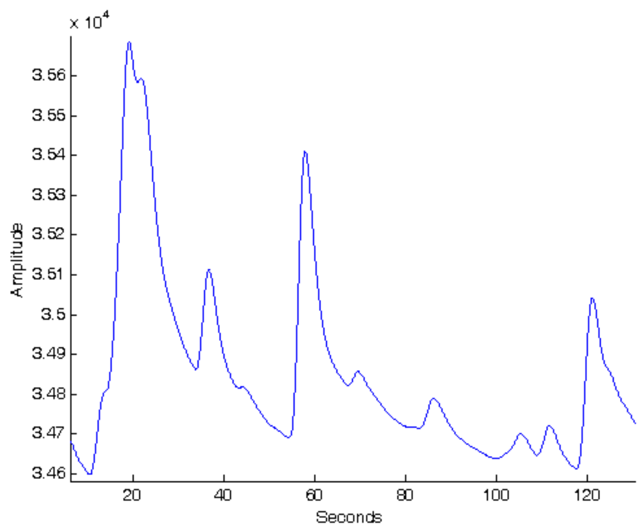

Fig. 2. Subject reaction to a slow motion movie with a classical music background

After analyzing multiple options, only one proved to comply with these restrictions:

- classical music background
- only one image displayed while the music plays
- no quick transitions

- no characters
- the image used must not be static, and it must act as a distraction that prevents the subject's mind to wander

The new method contained a single panoramic image of a landscape that was panned slowly form left to right and right to left with a classical music background. This method was applied to 20 subjects and at the end, each one was asked to offer a subjective opinion about their psychological state during the test. Subjects reported a relaxed state which was correlated with a decreasing trend signal (signals were visually inspected) meaning that the subjects entered a deeper state of relaxation. The results of this method can be seen on one recording in "Fig. 3" that shows a signal with a decreasing trend and low variability, which is a good indicator for relaxation. The sudden amplitude increase (at second 75 in "Fig. 3") was expected because it marks the moment when the subject is presented with audio/visual stimuli used for relaxation.

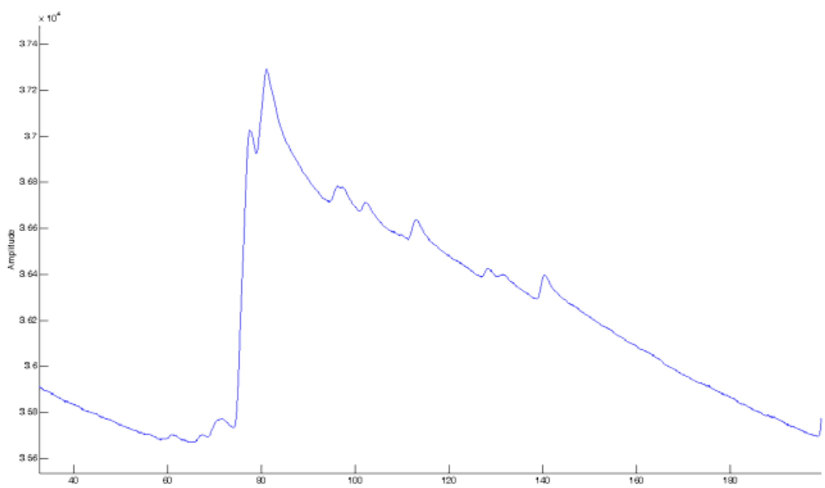

Fig. 3. Subject reaction while using the new relaxation method

Another problem encountered was that during the Trier based stress test the acquired signal presented local relaxed state patterns characterised by a low variability. After each recording that contained such relaxation periods, the subject was asked to describe what happened during those periods. Analyzing the subject's answers, two major flaws in the program were discovered:

- the variable time computed based on the last 3 answers, reached very low values, under two seconds, and the subject did not have time to read the equation and simply relaxed because there was no mental stress associated with equation solving.

- a flaw in the program generated trivial equations like “0 + 0” where the user simply answered from instinct

The first flaw was solved by limiting the minimum value of the variable time, to a reasonable constant of 4 seconds, which allowed the subject to read the question and at least try to solve it. The second flaw was solved by monitoring and conditioning the random numbers generated for the equation, instead of just accepting them as they were generated.

In the end, the final testing method was composed of three parts: a relaxation part (2 minutes of music and a panning panoramic image), a mental stressing part (100 equations to solve with a slowly decreasing time for each equation to further stress the subject) and another relaxation part (2 minutes of music and a panning panoramic image). After database analysis, only ten subjects remained valid for evaluation, the rest of them did not pass the previous cumulative level of stress test (being too stressed before the experiment because of other stimuli) or their recordings quality was not acceptable.

For the stressing part of the test, the period allowed for each equation is computed based on the type of answer from the last three equations. For three consecutive correct answers, the period decreases by 10% and for three consecutive incorrect answers, the period increases by 20%.

For the old method [9][11] that used the same Trier test, the following algorithm computed the period (P):

- the average response time (AT) of the last three questions is computed
- for three consecutive correct answers: (1)

$$P = AT * (1 - 0.1) \tag{1}$$

- for three consecutive incorrect answers: (2)

$$P = AT * (1 + 0.2) \tag{2}$$

3. Results obtained with the new method

To test the performance of the new method, a parameter extracted easily from the electrodermal activity data that could give a broad interpretation to the signal content was needed. By visually analyzing signals that contained both relaxed and stressed states and comparing these signals with the log files created with each subject, a conclusion was reached. Stressed subjects will have a high activation state represented by a high variability in the signal. Relaxed subjects will have a lower activation state represented by a low variability signal with almost no variation. Therefore, a method is needed to obtain the high frequency parts of the signal that are associated with the stimuli responses. In current research [2], this signal is associated with the rapid phasic components of the signal and it is called the skin conductance response (SCR)

In [7], a simple method is described for extracting the skin conductance response by using differentiation and subsequent convolution with a 20-point Bartlett window. The differentiation acts as a high-pass filter while the Bartlett window acts as an amplifier, which keeps the signal noise low while amplifying the rest of the signal.

The next step is to compute the power of the signal by using the Parseval formula, the sum of the squared amplitudes on a 10 second length window from the skin conductance response signal. In “Fig. 4” a SCR signal was computed from an EDA signal sequence and two features can be observed easily: a high activation state (stress) characterised by a high power SCR signal and a low activation state (relaxation) characterised by a low power SCR signal.

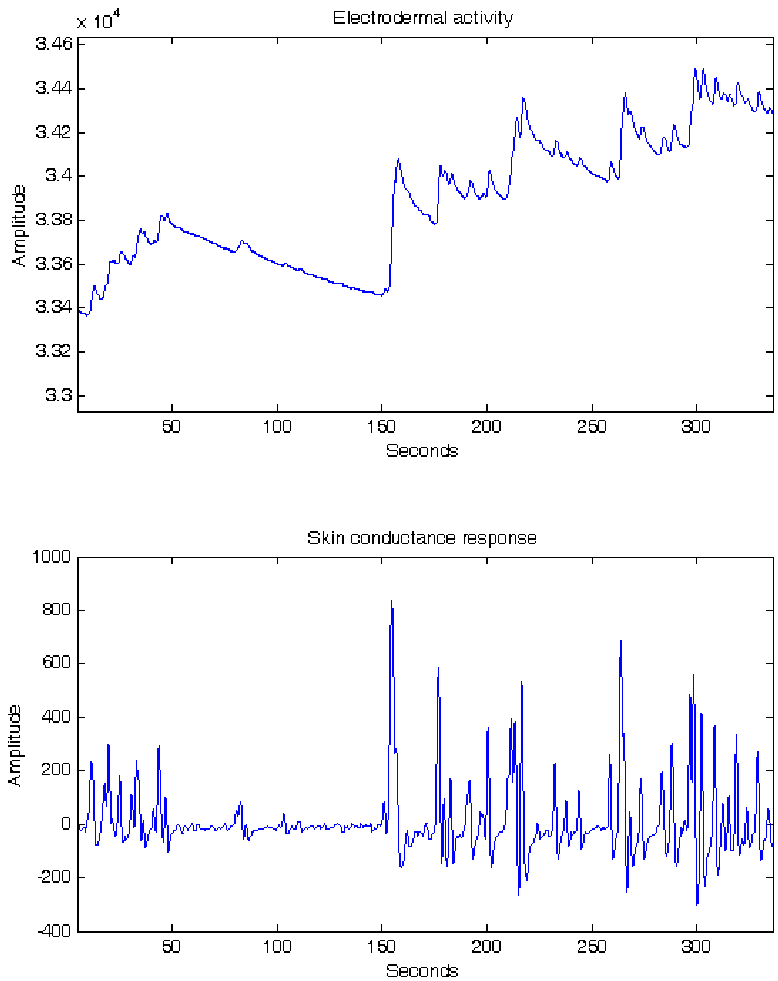

Fig. 4. Sequence from the EDA (up) and its computed SCR signal (down)

For comparison, we will use the mean power of the signal acquired from both the old method [9][11] and new method as follows. For both methods, the stressed state is obtained through mathematical equations solving and the relaxed state is obtained by watching pleasant images [1] for the old method and watching a slowly panning panoramic image with a classical music background for the new method. In both cases, 2 minute windows will be extracted from the main signal and analyzed as described above.

In "Fig. 5" and "Fig. 6", the results of stress/relaxation evaluation, estimated by SCR signal power, for subjects with ages between 25 and 64 years old are displayed.

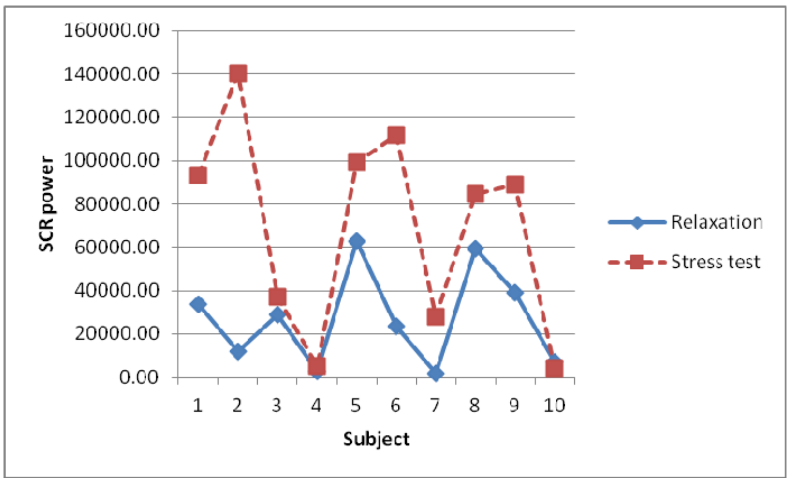

Fig. 5. SCR power obtained for the new method

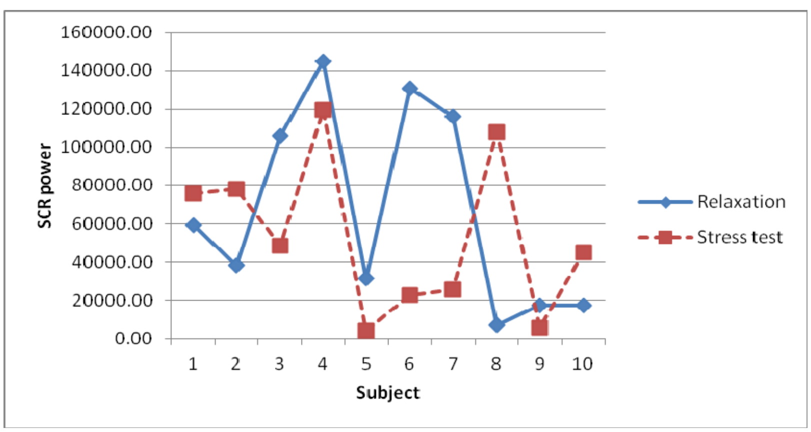

Fig. 6. SCR power obtained for the old method

In “Fig. 5” there is a visible difference between the relaxed state and the stressed state, while in “Fig. 6” there is not a distinct difference between the relaxed state (watching pleasant images) and the stress state (equation solving with limited time), therefore we can assume that watching sequences of images can be related to a mental stress. This conclusion is expected, because the subject’s brain will compare the images with past experiences that can bring both fearful and pleasant reactions. Therefore the old method cannot provide a relaxed baseline to compare with a stress reaction.

Another observation can be made on the signal power for the stress test in both the new and old method. The values for the new method appear to be lower than the values for the old method. The signals obtained while using the old stress method were abnormal. The variable time in the stress test, allowed for each equation, reached sometimes low values that created a situation where the subject was presented with multiple equations to solve in a short amount of time and without enough time to give an answer. This was translated on the electrodermal activity signal with overlapped responses that generated high amplitude waveforms. Also, these overlapped responses result in a phenomena called sweat gland saturation, where these glands cannot secrete anymore sweat to increase the skin conductivity and for a short period of time the skin conductivity signal will decrease without reacting to current stimuli presented to the subject. This is not a desired situation, because the purpose of the stress inducing method is to cause clear responses to the stimuli in the electrodermal activity signal, while avoiding overlapped signals and sweat gland saturation.

Mean values were computed for all 20 subjects, both for relaxed and stressed state, and for both methods. For the old method, the mean value of the relaxed state is significantly larger than the mean value of the stressed state. This proves that the relaxation method is not a good one. For the new method, the mean value is lower than the mean value for the stressed state, which means that the relaxed state is significantly different than the stressed state, and it can be considered a baseline for future research.

The new stress and relaxation method manages to provide an electrodermal activity signal that can be reproduced on multiple test subjects with a visible difference between the relaxed and stressed part.

Furthermore, a recovery time after a stress period can be evaluated on the obtained signal, which can be observed in the second relaxation part of the signal.

In “Fig. 7”, the electrodermal activity signal from a test subject can be observed.

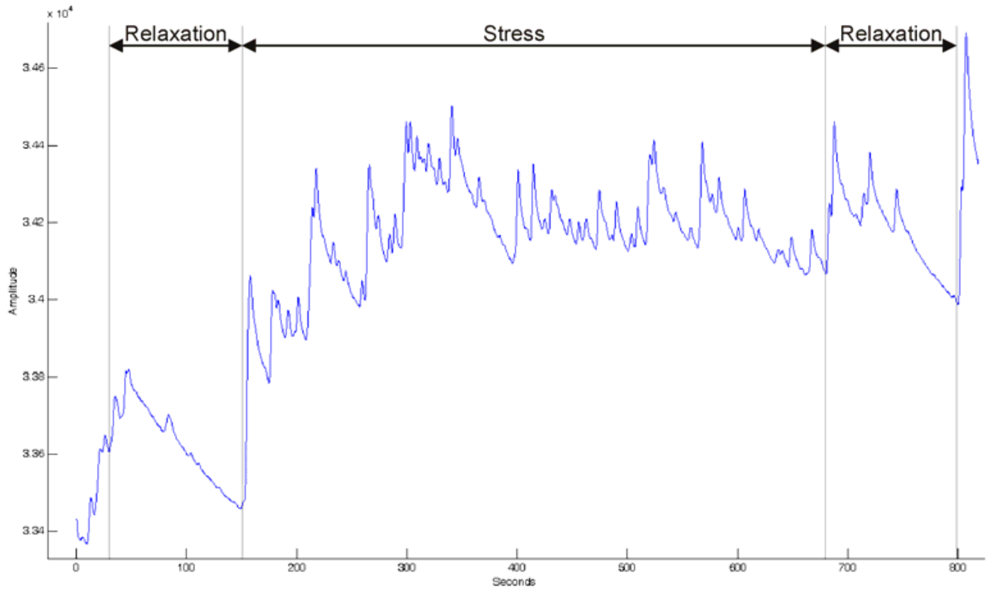

Fig. 7. Electrodermal activity signal acquired from a subject with relaxation and stress periods

The program used for this method generates automatically a log file that contains the following:

- For the relaxation period:
  - Start/end time of the relaxation period
- For the stress period:
  - The timestamp for the moment at which the equation is displayed
  - The timestamp for the moment at which the subject gave the answer for the equation
  - The type of answer given by the subject: correct, incorrect or the time passed without any answer from the subject.

This log file will help in future research to extract a level of stress from the type of answer given by the subject, where it is expected that the incorrect answers will generate a higher level of stress than the correct ones.

4. Conclusions

A new method was designed to aid in future research of stress detection using electrodermal activity signals. Because the program used for this method returns a log file with time stamps and it is independent of the recording device, future research can be carried out on different types of equipment, like heart rate monitors, electrocardiogram recorders and other physiological signal recorders.

Current stress detection research will be carried out only on electrodermal activity recordings, because sensors of this type can be integrated very easily in day-by-day appliances (phone cover, steering wheel).

Signal saturation and overlapped responses to stimuli were avoided by limiting the variable time allowed to solve each equation. By fine tuning this lower threshold we managed to stress the subject even more, because many subjects reported after the tests that they knew the answer for a lot of the questions but there was no time to enter the answer, which further increased the stress level.

To further verify the new method for inducing stress and relaxation, recordings from subjects with ages between 20 and 65 years were used to extract the signal power as described in chapter 3. The results obtained are displayed in "Table 1" where it can be observed that the mean value of the differences in signal power between the stressed and relaxed state is 42205.21, sufficiently high to discriminate the two states for the first method while for the old method the difference is -13615.41 which means that the relaxed state signal power is higher than the stressed state signal power.

Table 1

Mean signal power and standard deviation

		New method	Old method
Relaxation	MEAN POWER	27056.13	66932.98
	STANDARD DEVIATION	22054.78	52412.09
Stress	MEAN POWER	69261.34	53317.57
	STANDARD DEVIATION	47152.33	40924.38
Difference (stress-relax)		42205.21	-13615.41

As described in [2], each individual has a unique physiological response to external stimuli and therefore in the analyzed recordings, each subject reacts to the stress/relaxation stimulation with a different electrodermal activity amplitude variation range and skin conductivity baseline. For implementing a subject-independent emotion detection algorithm, a signal normalization algorithm will be applied in such a way to adjust the signal range to a constant value for all the subjects.

Because the proposed new method provides each time a normalized signal with distinct stressed and relaxed states, without overlapped responses and a log file that can pinpoint each stimuli onset and user reaction in the recording while avoiding signal saturation, a new important feature of this method is outlined: repeatability in laboratory conditions.

These key features prove that the new method can be used as a starting point in emotion detection based on electrodermal activity data.

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