COMPARING ENDOGENOUS AND EXOGENOUS ELECTRODERMAL RESPONSE

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Abstract: Simultaneous measurements of endogenous and exogenous electrodermal response (EDR) have been compared. Results show that there is a remarkable correspondence between measurements in the two hands and the endogenous measurements seem to correspond with the derivative of the exogenous measurements. This will be used in an ongoing study to seek a better understanding of the basis of the endogenous EDR.

Introduction

The sympathetic nervous system innervates a large number of organs in the human body, such as the emotional sweat glands in the palm of the hand and sole of the foot, the blood vessels in the skin and muscles, the adrenal glands, and the heart.

The emotional sweat activity is very sensitive to psychological stimuli or conditions. One will usually not be able to perceive these changes in sweat activity as a feeling of changes in skin hydration, except for example in stressing situations such as speaking to a large audience. The changes are easily detected by means of electrical measurements, however, and since the sweat ducts are predominantly resistive, a low-frequency conductance measurement is appropriate.

Electrodermal response (EDR) measurements have for many years been based upon dc voltage or current, and accordingly the method has also been termed galvanic skin response (GSR).

The so-called "lie-detector" is perhaps the most well-known instrument where the electrical detection of this activity is utilized. There are, however, several other applications for such measurements, mainly within two categories; neurological diseases and psychophysiological measurements. Examples of the first category are neuropathies (from diabetes), nerve lesions, depression and anxiety. The latter category may include emotional disorders and lie-detection.

The neuroanatomical basis of the neurophysiologic arousal that is monitored by means of EDR measurements is not well understood, but it is assumed that it is linked to increased sympathetic activity [1].

The following areas have been found to be involved: The brain-stem reticular substance, the hypothalamus, the premotoric cortex, the amygdala, the hippocampus and the sympathetic preganglions [1].

Two different types of sympathetic efferent nerve fibers in the skin have been described: The fibers with nor-epinephrine in the post-ganglionic synapses lead to the smooth muscles in the vessels, and the fibers with acetylcholine in the post-ganglionic synapses innervate the sweat glands. Sympathetic activation of the palmar and plantar sweat glands result in increased sweat production and sweat duct filling which can be measured in terms of skin conductance or transepidermal water loss (TEWL). Thus, this provides an indication of the emotional state [2-4].

When an outgoing sympathetic nervous burst occurs, a wave of skin conductance or skin potential will follow. During spontaneous skin conductance or potential changes, an increased number and amplitude of the waves is commonly interpreted as increased activity in this part of the sympathetic nervous system [3].

The basal level is associated both with the sympathetic nervous system and the properties of the skin, e.g. factors such as the degree of moisture in the stratum corneum [5,6], membrane permeability, etc. [7,8]. The various methods typically used for measuring skin conductance changes have involved analyzing externally elicited responses by measuring the latency time, amplitude and recovery time for each stimulus [9].

The measured activity can be characterized as endogenous or exogenous. The exogenous measurements are conducted as resistance or conductance measurements at dc or low-frequency ac. These kinds of measurements were first suggested by Féré in 1888 [10].

The endogenous measurements are carried out as dc potential measurements. The mechanisms behind the changes in skin potential during sympathetic activity are still not fully understood, but processes like sodium reabsorption across the duct walls and streaming potentials in the sweat ducts are probably involved. Endogenous measurements were pioneered by Tarchanoff in 1889 [11].

The terminology in this area can be somewhat confusing and the Society for Psychophysiological Research has been working on directives concerning both measuring methods and terminology [7].

The following abbreviations are used:

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EDA	Electrodermal Activity
EDL	Electrodermal Level
EDR	Electrodermal Response
SCL	Skin Conductance Level
SCR	Skin Conductance Response
SRL	Skin Resistance Level
SRR	Skin Resistance Response
SPL	Skin Potential Level
SPR	Skin Potential response

The exogenous responses can be evoked, i.e. they appear as a result of a given stimulus, or they can be spontaneous. Stimuli for evoked responses can be of physical or physiological nature, e.g. visual, auditory, sensational (touching, pain, temperature), or due to cognitive activity.

The Society for Psychophysiological Research has also suggested standardized parameters for analyzing evoked SCR. These parameters are shown in figure 1.

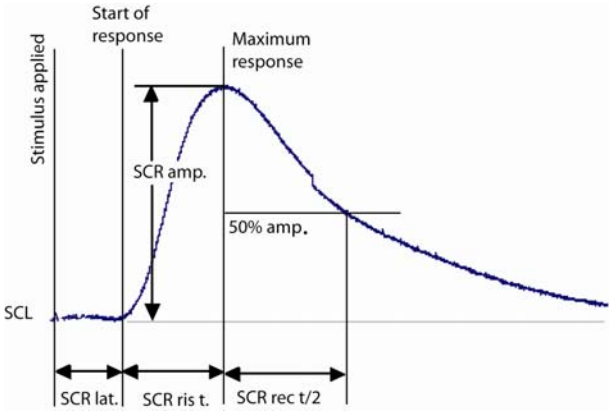

Figure 1: Parameters of the SCR

The time duration from the stimulus is applied until the onset of the response, is called the latency time (SCR lat.). Then the SCR will change from the baseline value to a maximum peak value (SCR amp.) during the so-called rise time (SCR ris t.). The recovery time (rec. t) is then the time until the signal has reached the baseline value again.

Measuring the recovery time can be difficult if the baseline drifts or if spontaneous SCRs occur during the recovery time. Hence using e.g. the time until the SCR is reduced by 50 % of the SCR amp., as indicated in figure 1, could be more practical. To separate the evoked SCR from any spontaneous EDR, investigators use a response window of 1-5 s following the stimulus, during which a signal will be accepted [12].

The main purpose of this study was to compare the endogenous and exogenous responses in order to acquire a greater understanding of the underlying mechanisms responsible for the endogenous EDR.

Materials and methods

A simple circuit for dc potential measurements was constructed using an ac coupled instrumentational amplifier based on Burr-Brown INA128. The circuit is shown in figure 2. The potential difference between an electrode in the palm of the hand and one on the ventral side of the forearm is measured, and a third electrode is used for minimizing the common mode voltage.

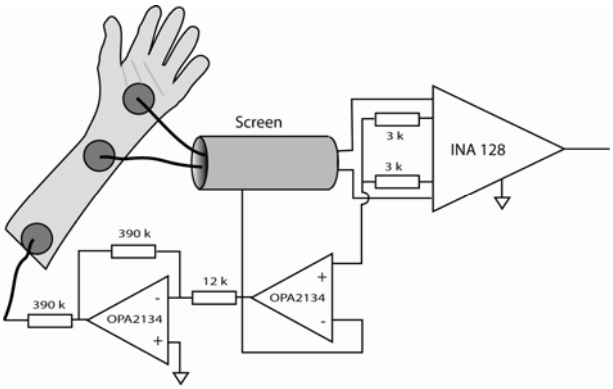

Figure 2: Circuit used for endogenous measurements

The circuit includes a buffer which feeds the common mode voltage as measured by the instrumentational amplifier, to the screen of the shielded cable carrying the wires to the electrodes in the palm and at the wrist. This will reduce any capacitive coupling between the screen and these wires. The common mode voltage is furthermore eliminated by applying a negative feedback of the common mode voltage to a third electrode attached to the underarm, and hence drive the common mode voltage to zero.

The exogenous measurements were done using Stanford Research SR830 digital lock-in amplifiers; measuring the electrical conductance at 22 Hz. Conductance was preferred to resistance because of the parallel nature of the electrical polarization and conduction in the skin [13]. Low-frequency electrical conductance reflects the ionic conduction in the stratum corneum, which is largely determined by sweat duct filling [14,15].

An important point, which is often confused in the literature, is that electrical resistance is the inverse of conductance only in the case of direct current (DC) [6]. Alternating current (AC) resistance is a function of both conductance and susceptance. The choice of conductance instead of resistance is therefore crucial.

One ECG electrode was used in the palm of the hand and a reference electrode was made by connecting 10 identical ECG electrodes in parallel and attaching them on the stomach. A simple two electrode system could of course have been used with both electrodes in the palm of the hand. However, in order to achieve simultaneous measurements of exogenous EDR in both hands, a system with only one 22 Hz oscillator was desirable in order to avoid interference, and hence a common reference electrode was used.

All measurements were controlled via a PCI-6111 data acquisition card on a computer running a LabVIEW application (both National Instruments Corporation). All electrodes used were Ambu Blue

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Sensor M-type ECG electrodes with a wetted electrode area of 154 mm^2.

Measurements of exogenous EDR were conducted simultaneously in the palms of left and right hand of a healthy volunteer. Endogenous EDR was also measured simultaneously in both hands, and finally exogenous and endogenous EDR were measured simultaneously in the same hand.

A band pass filter was used in some of the endogenous measurements in order to reduce noise and remove the baseline voltage. The filter was a combination of a first order high pass filter (f_c = 0.1 Hz) and a second order low pass filter (f_c = 5 Hz). Fourier analysis of series of endogenous EDR showed no significant frequency components above 1 Hz. The band pass filter was particularly necessary when doing combined measurements of endogenous and exogenous EDR in the same hand.

Results

The results of simultaneous measurements in both hands of exogenous EDR are shown in figure 3. There is a remarkable correspondence between the two hands, although some minor differences can be seen.

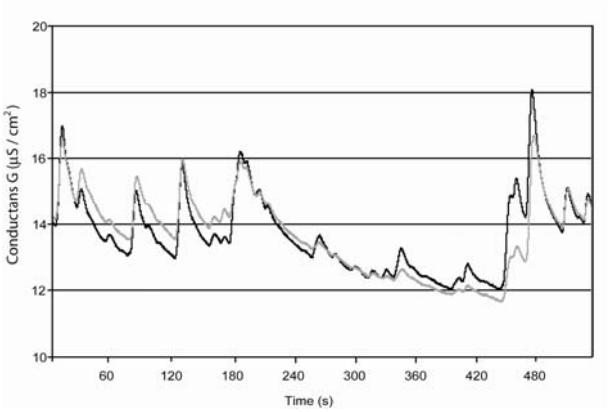

Figure 3: Exogenous EDR measured simultaneously in right (grey curve) and left (black curve) hand

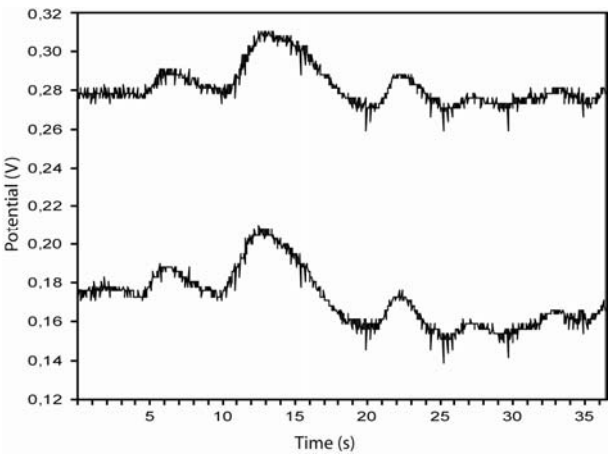

Figure 4: Endogenous EDR measured in right (lower curve) and left (upper curve) hand – amplified 9.3 times

Figure 4 shows the results from endogenous measurements in the two hands. Also here there is a notable correspondence between the curves.

The curves in figure 5 show the results from measurements of endogenous EDR after band pass filtering. Although the filtering removes whatever information lies in the baseline level of the endogenous EDR and to some extent distorts the shape of the curves, it also makes the system more practical for general use on a broad range of test subjects.

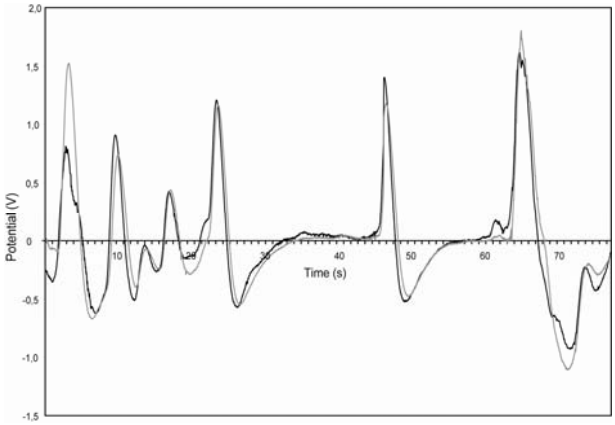

Figure 5: Endogenous EDR measured in right (grey curve) and left (black curve) hand – after filtering – amplified 13600 times

The results of simultaneous measurements of endogenous and exogenous EDR are shown in figure 6. The filtered version of the endogenous measurements has been numerically integrated, and the resemblance with the exogenous EDR is striking. Please note that the Y-axis scale is only applicable to the exogenous measurements, and that the integrated data have been scaled to match these values.

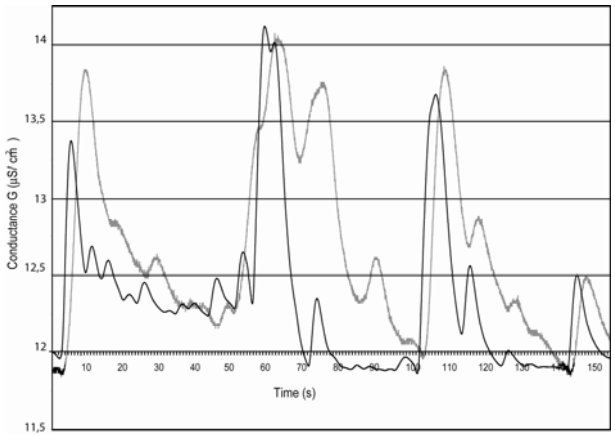

Figure 6: Integrated endogenous EDR (black curve) compared to simultaneously measured exogenous EDR (grey curve)

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Discussion

The preliminary results of this ongoing study show that there is a significant correspondence between the two hands, both in endogenous and exogenous activity. Furthermore, the endogenous activity is rapidly changing with pulses returning to baseline typically within few seconds, while the exogenous EDR gives slower pulses lasting for many seconds.

Visually, plots of the endogenous activity looks like the derivative of the plots of exogenous activity. This was confirmed by numerical integration of the endogenous data sets, which produced curves that corresponded with the plots of the exogenous activity, although with some deviations.

In the further study, problems connected to the simultaneous measurements of endogenous and exogenous measurements in the same hand will be solved, so that unfiltered data can be used for the endogenous measurements. This will make it possible to more correctly compare the data from the two different ways of measuring EDR.

A possible interpretation of the results from the study so far, is that the endogenous EDR activity is largely produced by streaming potentials in the sweat ducts. The counter-ion part of the electric double layer at the duct wall is pushed towards the skin surface when sweat is flowing to the duct orifices. This produces a transient potential difference over the skin. When the flow stops, the ions reorganize to equilibrium and the streaming potential expires.

The exogenous pulse, on the other hand, will be due to the shunting effect of the filled sweat ducts, and the conductance will not completely return to baseline until these ducts are drained.

However, there may also be other sources for the EDR potentials, and the baseline dc potential level may have other causes as well. This ongoing study aims at elucidating some of these questions.

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