Simultaneous measurement of skin potential and conductance in electrodermal response monitoring

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Abstract. Measurement of electrodermal activity (EDA) has been an important tool in psychophysiological research. The emotional sweat activity is very sensitive to psychological stimuli or conditions. The changes are easily detected by means of electrical measurements and since the sweat ducts are predominantly resistive, a low-frequency conductance measurement is appropriate for measurement of skin conductance in electrodermal response. The main purpose of this study was to develop a measuring system where DC current was replaced by a small AC current in a system so the DC potential and AC conductance could be measured simultaneously at the same skin site. A small, battery operated, PDA based instrument has been developed. The preliminary results of this ongoing study show that there is additional information in the DC potential channel and that different stimuli seem to produce slightly different response patterns.

1. Introduction

Electrodermal activity (EDA) is a set of physiological parameters of autonomous activity. It has been used for measurement of psychological and sensory activity. However, the mechanism of its appearance and the phenomenon itself, are not sufficiently clarified yet [1]. Two important parameters in the Electrodermal Activity (EDA) tradition are skin conductance and skin potential, even if the conductance parameter has been much more commonly used than the potential parameter [2-3]. It has already been shown that gender, age and race are important for EDA. Women are more emotionally reactive than men. They demonstrated greater electrodermal activity [4].

In this study we focus on the two parameters: DC potential and AC conductance. We have looked more closely at the possibilities offered by modern electronic and computer technology to see whether it is possible to measure more than one parameter simultaneously at one skin site. Measuring with the same electrode is important because of the often large skin site dependence of levels and response waveforms.
2. New measuring method

The measuring instrument has an analog and a digital part. The analog part consists of two circuit boards to measure the AC conductance, susceptance and potential in the skin. The digital part is a PDA (Personal Digital Assistant – HP iPAQ 214) with a data acquisition card card. A LabVIEW program is used to process the signals in the PDA. The results are shown on the PDA display and saved in the memory card. Three electrodes are connected to the skin when using this instrument. Two of the electrodes are used as measuring electrodes, while the third one is a reference electrode (see figure 1) [modified from ref. 5]. The electrodes used here were Kendall Kittycat 1050NPSM small Ag/AgCl electrodes with a diameter of 25 mm from Tyco Healthcare.

![Figure 1: Placement of electrodes](image)

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![Figure 2: Block Diagram for measurement system and measuring system](image)

Figure 2: Block Diagram for measurement system and measuring system

Figure 2 shows a block diagram of the instrument [6]. The oscillator produces a voltage of 2.5 V rms and thus sends a 125 nA rms constant current into the skin because of the 20 MΩ series resistor. A preamplifier then picks up the differential voltage between two of the electrodes and these signals are amplified up one hundred times in the preamplifier. Skin impedance is a complex quantity because a biomaterial, in addition to opposing current flow, phase-shifts the voltage with respect to the current in the time-domain [7]. When sweat ducts are filled, conductance is increased. We hence use dc or low frequency ac to measure EDA [8]. The skin conductance is measured by a constant amplitude AC current, 125nA and 24 Hz. The impedance of the skin is measured only underneath the electrode on the hypothenar area, while the measure potential is the voltage difference between the hypothenar area and the upper part of the volar underarm. The latter skin site will in most cases have no EDA. The impedance measured in the skin is decomposed to resistance and reactance by two synchronous rectifiers. AC conductance G and susceptance B can be calculated from these impedance parameters [8]:

\[
G = \frac{2 \pi f R}{X}
\]

\[
B = \frac{2 \pi f R}{X}
\]
\[ G = \frac{R}{R^2 + X^2} \] Conductance [S] \[ B = \frac{-X}{R^2 + X^2} \] Susceptance [S]

These calculations were performed by LabVIEW program in the PDA. The measured potential goes through a lowpass filter in the analog part to remove the AC signal, and is then saved in the PDA’s memory card.

Since both resistance and reactance are needed to calculate the conductance, the susceptance can be calculated without any extra hardware. The low frequency skin susceptance reflects the stratum corneum hydration, and is hence an interesting parameter to include in this instrument [9].

3. Results

The instrument has been tested on nine healthy male volunteers, age 25-29. Measurements were done in a quiet room with about 21 °C for 10 minutes, with six different stimulations; deep breath, fright (strong sound), joy (hearing a joke), cognitive (mathematical calculations), discomfort (touching the person’s forehead for three seconds) and pain (pinching the skin). It is important to note that these provocations are just for testing purposes, and are hence not standardized in any way. Each provocation may therefore actually involve several different types of stimuli.

Figure 3: Delay time for responses after a deep breath

Figure 4: The average value of fright responses

Figure 5: AC conductance and potential for joy

Figure 6: AC conductance and potential for discomfort
Figure 3 shows the results from one test subject taking a deep breath. There is a delay between the AC conductance and potential responses and there is also a delay between the conductance and susceptance responses. Figure 4 shows the average value of fright responses for all nine test subjects. The potential response rose faster than the AC conductance and had a shorter total reaction time.

Figure 5 shows the joy response from one of the test subjects. The potential response decreases and then rises, then quickly decreases again. AC conductance response is rising for about 50 seconds before it decreases. Figure 6 shows the results for discomfort. The operator keeps his hand on the subject’s forehead for 3 seconds. The potential shows a significant negative response and the AC conductance has almost no response.

4. Discussion
Our results show that it is possible to measure skin potential and skin AC conductance separately but simultaneously in a low noise system. We can see differences in DC potential and AC conductance responses with different stimulation [10]. Typically, DC potential responses are slightly faster than AC conductance response [11], and there seems to be different response patterns for different types of stimuli. However, more measurements are needed before any conclusions can be drawn.

5. References
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