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Proficiency Test Analysis of a Simple Electro-dermal Activity Measurement Technique for Measuring an Emotional Task

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Abstract. An electrodermal activity (EDA) measurement device has the ability to measure the electrical properties of the skin. The electrical properties of the skin change based on different kinds of stimuli that produce sweat generated by sweat glands. This study aimed to examine the sensitivity of a simple acquisition technique of EDA to detect conductance changes on the skin as a response to different stimuli that caused by emotional response state. A simple measurement technique and a fabricated instrument device for comparison were used when an emotional task was applied to the participants. Four participants were chosen, consisting of 2 men and 2 women between 20-25 years old. The EDA was measured while the participants watched a short scary movie using both devices. The result signals were analyzed using Convex Optimization Approach to Electrodermal Activity (cvxEDA) algorithm. The results revealed that several participants showed a state of psychological stress during the experiment using both devices, indicating the suitability of this simple device to detect changes of the EDA signal among the participants.

INTRODUCTION

Autonomic Nervous System (ANS) is divided into sympathetic and parasympathetic subdivisions. Sympathetic arousal generates increasing metabolism like higher heartbeat and dilation of pupils. In contrast, parasympathetic activity promotes counterbalance of the sympathetic arousal. Sympathetic arousal is associated with the emotional state of a person and referred as Electrodermal activity (EDA). Sweat on the skin is generated by sweat glands controlled by the sympathetic nervous system [1]. Sweat is related to the physical or emotional condition of humans. When these conditions are changed, the sweat glands generate sweat on the skin. The EDA signal is produced as a response of the skin conductance. An EDA instrument device is normally used to capture this signal. The instrument device is able to detect any conductance changes of the skin surface based on the sweat produced by the sweat glands. EDA signal consists of tonic and phasic components. Tonic component is related to the slower components of the signal including the baseline of signal which also known as Skin Conductance Level (SCL). The phasic component refers to the faster changing response of the signal or the Skin Conductance Response (SCR) [2].

Previous studies have reported the application of EDA signal. Sano et.al. [3] analyzed sleep based on the EDA activity. To analyze long term activities of human, Poh et.al. [4] used the EDA during physical, cognitive and emotional tasks. A study was carried out by Lewith et.al. [5] to test whether the EDA is able to distinguish environmental allergies. In addition, many researchers have conducted studies about emotional tasks using EDA. Nakasone et.al. [6] utilized EDA and Electromyography (EMG) to create real time emotion recognition combined with neural network. Meanwhile Setz et.al. [7] used EDA to discriminate different kinds of stress such mental stress and psychosocial stress. Based on speech signals and EDA, Kurniawan et.al. [8] investigated the stress levels of humans.

Different measurement devices have been used by researchers. Kurniawan et.al. [8] used LEGO Mindstroms NXT to gather signals and detect stress. Nourbakhsh et.al. [9] measured cognitive load using fabricated EDA device. In order to make the device moveable, Strauss et.al. [10] added wireless feature to the sensor. Meanwhile

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Tronstad et.al. [11] used a PC and PCMCIA DAQ card to obtain the EDA signal. Different type of sensor and position place were developed by researchers. Greco et.al. [12] acquired the data where textile electrodes placed on index and middle finger combined with a glove. Ag-AgCl electrode was used by Lim et.al. [13] and Blain et.al [14], while Poh et.al. [4] used Ag-AgCL electrodes as comparison to their proposed measurement device. Ag-AgCl electrode is an electrode that is commonly used as a reference electrode. Ag-AgCl electrode is simple and easy to use [15, 16]. Other electrodes used by Tronstad et.al. [11] were skin surface gel electrode. However, simpler electrode for the EDA instrument is required. Simple electrodes from aluminum foil and copper attached in the Velcro straps were used by Kurniawan et.al. [8]. Nevertheless, these previously published studies have mostly used fabrication devices that have been passed a rigorous scrutiny.

There are many types of EDA device instruments which are sold in the market. In addition, several simple and sensitive EDA measurement techniques have been made and tested. However, most of these techniques have not been investigated to explore the characteristics of the techniques. Therefore, a simple EDA measurement technique was created and analyzed to find alternative measurements because the EDA measurement equipment is still relatively expensive. This study was conducted to investigate the sensitivity of the simple measurement technique and to investigate the result signals produced by a simple EDA measurement technique. Convex Optimization Approach to Electrodermal Activity (cvxEDA) was applied to the result signal to explore the characteristic of the signals. Additionally, a statistic standard calculation and calculation area under tonic component were performed.

METHODOLOGY

Subjects

This study was approved by the local Ethics Committee (Ref. No. 062/SKAP/LAB.BIOLOGI/I/2019) and all participants had been informed about the study. The signals were gathered from 4 healthy participants, consisting of 2 men and 2 women aged between 20 and 25 years old in a room with a temperature of 26-28^{o}C. This age range was chosen because it provides strong emotional strain [17]. Participants who smoked, took medications and had their period were excluded in this study. Since the aim of initial study is to investigate the reaction from the measurement, only small number of participants were involved. A much larger number of participants will be taken in future studies. In order to collect the signal of their skin responses, participants were asked to seat on a chair. The data were recorded while the participants were seated and calm down for five minutes and the electrode was attached to the participant fingers one minute before starting the measurement in order to get the baseline of the measurement. After that a short scary movie (title: WhatsApp status 30 second of horror, share with your friends in night, duration: 30 seconds) was played to be watched by the participants. The movie initially gives a picture of a dimly lit hallway and in the next few seconds a scary ghost character suddenly appears with a screaming voice. After the movie was played, the participants were given some time to calm down again for a minute. Fingers are chosen to measure the skin conductance since it has high sweat gland density [18]. The electrodes were placed on index-middle fingers to avoid a synchronism of sweat glands [19]. The simple device was attached to the left hand and the fabrication device (GROVE) was attached to the right hand.

A simple measurement technique was created, and a fabricated device instrument was used to compare the result from the simple device technique. The electrodes of both devices were made of stainless-steel buttons and a Velcro straps consisting of two strips of thin plastic sheet to wrap the fingers. The Arduino duemilanove board was used for gathering signals from both devices and saved them as a csv file for data processing. The simple measurement technique was built by connecting the electrode to the power source 5 V of Arduino and another electrode was connected to the ground with 300 K resistor as shown in Figure 1. The fabricated device instrument (GROVE) was used for data comparison and it was connected to another ADC port of Arduino. The outputs of both device instruments were connected to a laptop via USB for data acquisition using serial communication with a transfer rate 9600 bps.

Instrumentation

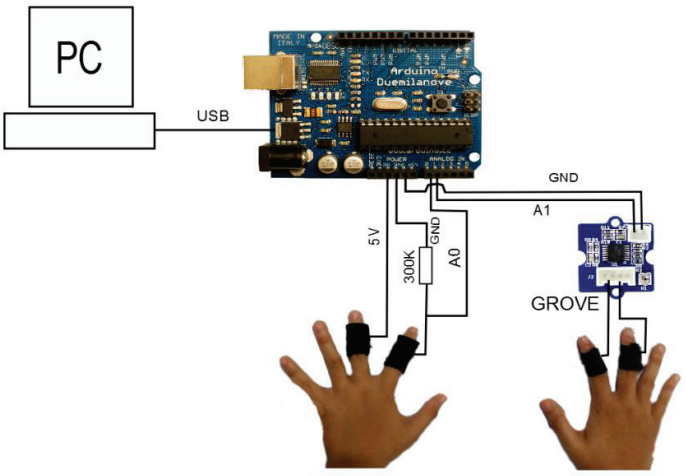


FIGURE 1. Circuit diagram of the system which consisted of Arduino board, a PC and two data acquisition techniques.

Convex Optimization Approach to Electrodermal Activity (cvxEDA)

cvxEDA is an algorithm that is based on a model to describe EDA which consists of phasic component (r), tonic component (t) and an additive Gausian noise (ε).

$$y = r + t + e \tag{1}$$

the final observation model can be written as:

$$y = M_q + B\ell + \mathrm{Cd} + \varepsilon \tag{2}$$

where M and A are tridiagonal matrices

$$H = M^{-1}A \tag{3}$$

$$q = A^{-1}, r = M_q \tag{4}$$

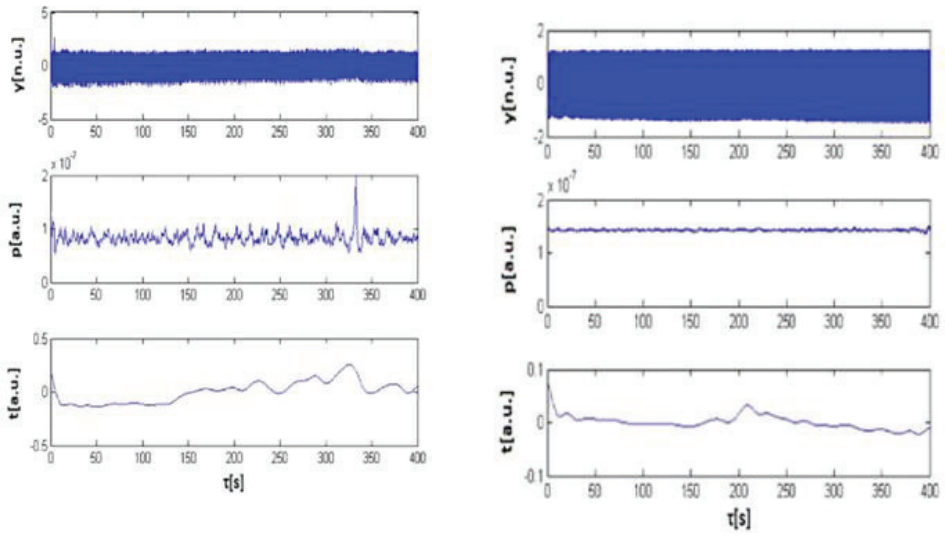
The detail explanation about this algorithm can be seen in Greco et.al., (2016).

RESULTS

Figure 2 shows the decomposed EDA signal of the first male participant. The graphs showed that there were no significant changes of signal for both phasic and tonic components and for both devices. A small peak was shown in the phasic component using the simple device. However, all components showed normal activities which described that the first participant was not scared.

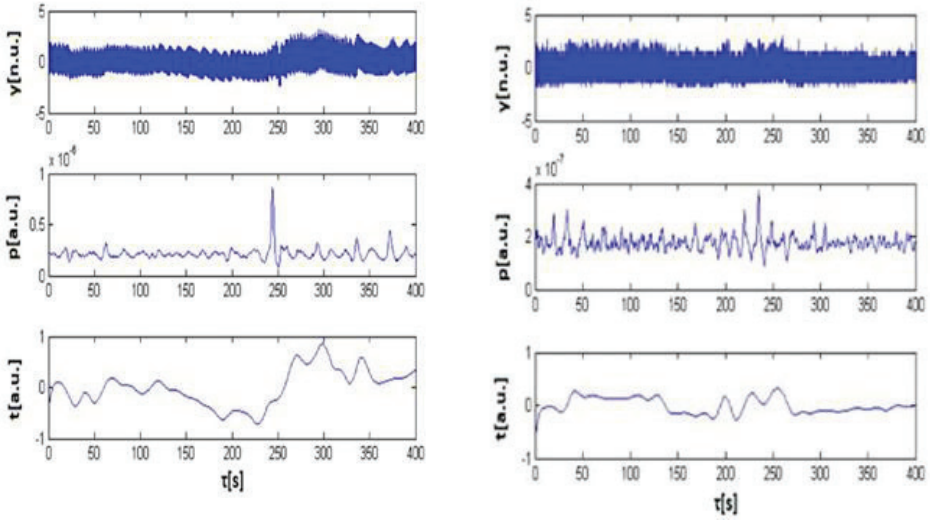
The graph of second male participant shows a slow rise of the tonic component from around 225 to 300 for simple technique as shown in Figure 3. It indicates that the volunteer was a little bit scared as he watched the short movie. However, the participant was reported to not scared at all when using fabricated device.

A significant increase of the tonic component from the third female participant is shown in Figure 4. The signal increased rapidly from around 210 s to 240 s for both devices. The signal slowly fell after getting a peak. This described that the female participant was scared enough for a short time and slowly became calm after the movie was finished.



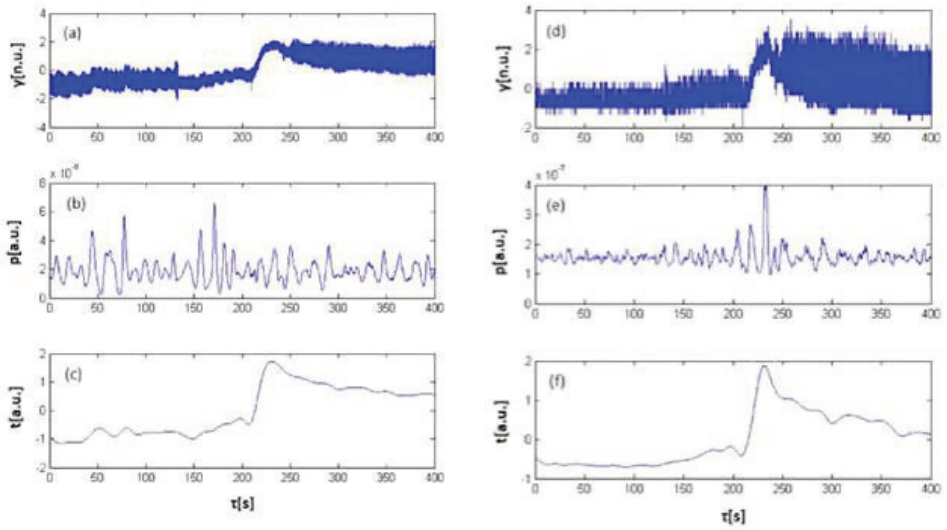
(a) (b)

FIGURE 2. EDA signal (y[n.u.]) of first male participant, estimated sparse phasic driver component (p[a.u.]) and estimated slow tonic component (t[a.u.]) of the first male participant from (a) the simple technique (b) the fabricated device instrument (GROVE)



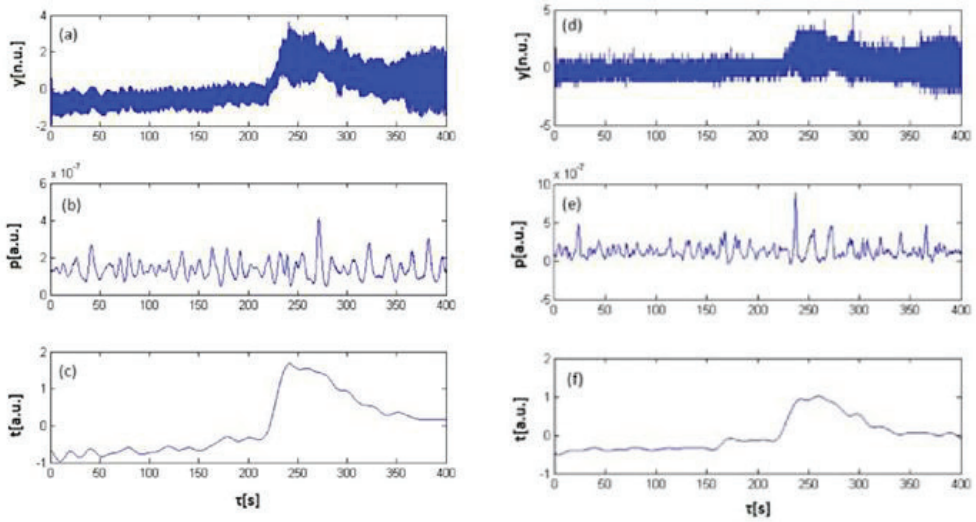
(a) (b)

FIGURE 3. EDA signal (y[n.u.]) of second male participant, estimated sparse phasic driver component (p[a.u.]) and estimated slow tonic component (t [a.u.]) of the second male participant from (a) the simple technique (b) the fabricated device instrument (GROVE).



(a) (b)

FIGURE 4. EDA signal (y[n.u.]) of first female participant, estimated sparse phasic driver component (p[a.u.]) and estimated slow tonic component (t [a.u.]) of the first female participant from (a) the simple technique (b) the fabricated device instrument (GROVE)



(a) (b)

FIGURE 5. EDA signal (y[n.u.]) of second female participant, estimated sparse phasic driver component (p[a.u.]) and estimated slow tonic component (t [a.u.]) of the second female participant from (a) the simple technique (b) the fabricated device instrument (GROVE)

A similar result is shown by the fourth participant who was scared as she watched the movie. This was shown in the graph of tonic component around 210 s and 240 s (Figure 5). The signal rose rapidly and fell slowly after reaching the peak during relax phase.

ANALYSIS

A standard statistical calculation was performed to analyze the tonic component. The result (Table 1) revealed that for simple and fabricated measurements, the values are almost similar. Minimum values are the baseline measurement before emotional task was measured and the values are almost equal. Maximum values should show the maximum number when an emotional task occurs. As shown in Table 1, emotional tasks were detected in the first female (Female 1) and the second female (Female 2) using both techniques. However, an emotional task was not detected with the first male (Male 1) and second male (Male 2) participants using both techniques while a

small peak was detected using simple technique and there was not an emotional task detected by fabricated measurement device. Higher standard deviation values show in simple technique compare with fabricated technique.

TABLE 1. Standard statistic calculation of tonic components from 4 volunteers of two techniques measurement.

Statistical analysis	Min		Max		Std. Dev	
	Simple	GROVE	Simple	GROVE	Simple	GROVE
Male 1	-0.137	-0.021	0.255	0.080	0.100	0.013
Male 2	-0.718	-0.637	0.853	0.321	0.355	0.148
Female 1	-1.151	-0.707	1.718	1.883	0.875	0.679
Female 2	-0.962	-0.514	1.683	1.007	0.783	0.428

In order to calculate the area under the curve of tonic component, three areas were divided based on their phase as shown in Table 2. They are baseline, emotional task and relax. Baseline area was calculated from 0-199 second, emotional task area was calculated from 200-299 second and relax area was calculated from 300-400 second. Areas under the baseline phase were mostly negative because in this phase, the measurement device measured the beginning phase of measurement when the scary movie had not been played yet. During the scary movie was showed, areas under the curve of the first female participant and the second female participant showed significant values for both techniques. Meanwhile values of emotional task of first male (Male 1) and second male (Male 2) show small values which indicate there was no emotional response when the scary movie was played. This indicates that there was an emotional response. During the relax phase, the area under curves were smaller than the area under curve in the emotional task phase. This reveals that the participants were relax after watching the scary movie. It seems that male participants were not scared with the short scary movie and the opposite was happened to the female participants. Value under curve of first female (Female 1) and second female (Female 2) show significant result compared to male participants during emotional task phase. This means that female participants were reacted to the scary movie. However, there was a slight difference in measurement between simple technique measurement compare to using fabricated device due to differences in sensitivity of the two devices.

TABLE 2. The sum of area under curves of tonic component for three phases of 2 techniques measurement

Area under curve	Baseline		Emotional Task		Relax	
	Simple	Grove	Simple	Grove	Simple	Grove
Male1	-14.3081	0.790	6.5722	0.8518	8.4578	-1.3876
Male 2	-27.207	3.655	-3.354	1.121	28.490	-6.800
Female 1	-159.702	-114.465	93.857	78.274	65.686	36.464
Female 2	-128.907	-65.404	91.699	54.044	36.970	10.602

CONCLUSIONS

This study has examined the sensitivity of an EDA instrument device. The measurement was segmented into 3 phases; baseline, emotional and relax. Four participants were asked to watch a short scary movie. A simple device for measuring EDA and a fabric device were used to acquire electrical properties of skins from four participants when they were watching the movie. The signals were recorded as csv files to be analyzed. the cvxEDA algorithm was applied to analyze the signals from both devices. The raw signal was divided into two components, phasic and tonic components. Additionally, a standard statistic and calculation areas under curve of three phases were conducted to confirm the results. The analysis reveals, female participants were scared as it confirmed by an increase of signal rapidly in the tonic component. Opposite results were shown by male participants which the tonic component did not showed any significant change. Both techniques showed almost similar result. This study reveals that simple technique is able to detect an emotional task properly. However, the small number of participants used in this initial study will have some impacts, namely variability and data bias. Therefore, the results can be affected by many variables. For this reason, this study will be continued with a greater number of participants to get better results.

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