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Design of a Low Cost Health Status Indication Device using Skin Conductance Technique

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Abstract: The research in this paper highlights the development of a low cost device in the field of affective computing. Effective computing is related to the study and development of system and devices to process, detect, and interpret human affects. Skin conductance technique is one of the widely used parameter for this purpose. The devices to measure skin conductance are either too expensive or not commonly available. This paper focuses on the design, development and testing of a low cost skin conductance measurement device and its validation by comparing the acquired results with laboratory equipment. The results are also discussed with a psychiatrist to check the feasibility of the device to be used as a low cost and long term wearing assessment tool for various applications. The device is light in weight, portable and can wirelessly transmit the data to a remote Medical practitioner/ caregiver's computer or smart phone for further assistance

Keywords: EDA, ANS, GSR, SCL, SCR, Skin Conductance.

1. INTRODUCTION

Health monitoring has always been a hot research topic. With the advancements in technology various new devices and methods are being explored for the development of a better health care system. Emotional stability, stress management and psycho physiological behavior are the key parameters in wellbeing of a healthy person. Various vital signs have been researched for this purpose but the most widely used and accepted measure is the skin conductance. The skin conductance comes under the umbrella term of Electro dermal Activity (EDA). The skin conductance varies when a person becomes emotionally aroused, nervous, excited or physically active (Chaspari *et al.* 2015)

A survey was conducted to check the availability of the device for measuring skin conductance and is summarized in **(Table 1)**. Similarly another survey for checking device availability in hospitals of Pakistan was also conducted and is summarized in **(Table 2)**.

The device is not commercially available in Pakistan neither its shipment in most cases. The price for the sophisticated clinical device is also quite high. The interfacing software is also quite expensive. These are some of the factors that motivated us to develop a low cost skin conductance measuring device. It does not only operate in lab environment but is also capable to be used in hospitals for health monitoring applications.

The paper is organized in 4 sections. Section 2 covers the background and the related work. Section 3 describes the system design and phases for this research. Section 4 describes the results whereas Section 5 concludes the paper.

2. RELATED WORK

Sweating occurs due to heat or environmental temperature, it also occurs due to emotional factors. This kind of sweating is termed as 'emotional' or 'mental sweating'. Some emotional factors like anxiety, fear, pain and concentration causes the sweating to increase while some like relaxation, sleep and happiness causes it to decrease. The emotional sweating is not dependent upon ambient temperature (Storm 2001) and hence can be used as a measure to detect emotional stability. Fingers, palms and feet are most widely used locations for measuring skin conductance however (Payne *et al.* 2016 and van Dooren *et al.* 2012) have suggested and analyzed alternative sites for recording skin conductance. These sites include arch of the foot, toes of the foot, abductor hallucis of the foot, wrist, forehead, armpit, back, thighbone etc. They have compared the responsiveness of various sites and considered feet and fingers to be most responsive. Skin conductance measurement or galvanic skin response has

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Table 1: Survey for the cost and availability of Skin Conductance device

S. No	Device Name	Company	Availability	Price (Rs)	Shipment to Pakistan
1	Neulog GSR sensor	Neulog (N, 1996)	UK	10,572.17	Not Available
2	GSR Sensors+ e-health shield	Cooking hacks(GSR, 2016)	Spain	48,347.42	Available
3	Shimmer3	Shimmer(Shimmer3, 2016)	Malaysia, USA, Ireland	42,505.15	Available
4	Electrodes for EDA+module	Psych lab (Psych,n.d)	UK	130,373.56	Available
5	DL3155BIO8 (Base module+ sensors, GSR kit)	DE Lorenzo(De Lorenzo Group - Laboratori - Elettronica - Biomedicale)	Biomedical Eng. Department MUET Jamshoro	150,400.39	Available
6	Power Lab/4ST ML760/W ECG EMG EEG (GSR amplifier not available)	Power Lab by ADI Instrument(industrial, 1995)	Biomedical Eng. Department MUET Jamshoro	31,4265	Available

Table 2: Skin Conductance Device availability survey in various hospitals of Pakistan

Hospitals	Availability of GSR device
Civil Hospital Thatta.	NO
Agha Khan Hospital Hyderabad	NO
Agha Khan Hospital Karachi	NO
Red Crescent Institute Of Cardiology ,Unit #2 Latifabad, Hyderabad	NO
Isra University Hospital Hyderabad	NO
Civil Hospital Hyderabad	NO
PIMS (Pakistan Institute of Medical Science) Hospital Islamabad	NO
John D. Dingell VA Medical Center. Detroit, USA	NO
University of Michigan Hospital Ann Arbor, USA	Available (only for prescribed patients)

been used in many applications along with other physiological parameters like emotion recognition (Balters and Steinert 2015). (Quazi *et al.* 2012) have utilized clustering techniques for the visualization of sad, angry, excited (happy), neutral and relaxed states using various vital signs including skin conductance. (Takahashi *et al.* 2012) have developed an emotion recognition system with positive, negative and neutral emotions using four vital signs and machine learning approach for this.(Sun *et al.* 2012) have investigated mental stress with the help of Galvanic Skin Response (GSR), electrocardiogram (ECG) and accelerometer during standing, walking and sitting activities. They have used sensors from SHIMMER for this purpose hence rendering the system to be expensive.

(Kikhia *et al.* 2015)have used Philips DTI-2 to examine problems in sleeping and stress for the patients of Dementia. (Nogueira *et al.* 2016)have investigated the effect of a horror game on player's emotions by analyzing Skin Conductance (SC),Heart Rate (HR) and Electromyogram (EMG) data. They have used NeXus10 along with BioTrace+ software for physiological data acquisition. Besides numerous applications covered by the measurement of skin conductance, research has also been done for the design of the sensors and the researchers are trying to develop a low cost system that can improve accuracy as well as be used for long term wearing. (Huang *et al.* 2011) have presented a low cost design for the skin conductance sensor. The acquired data is then transported wirelessly through RF module. They have not validated it with any other

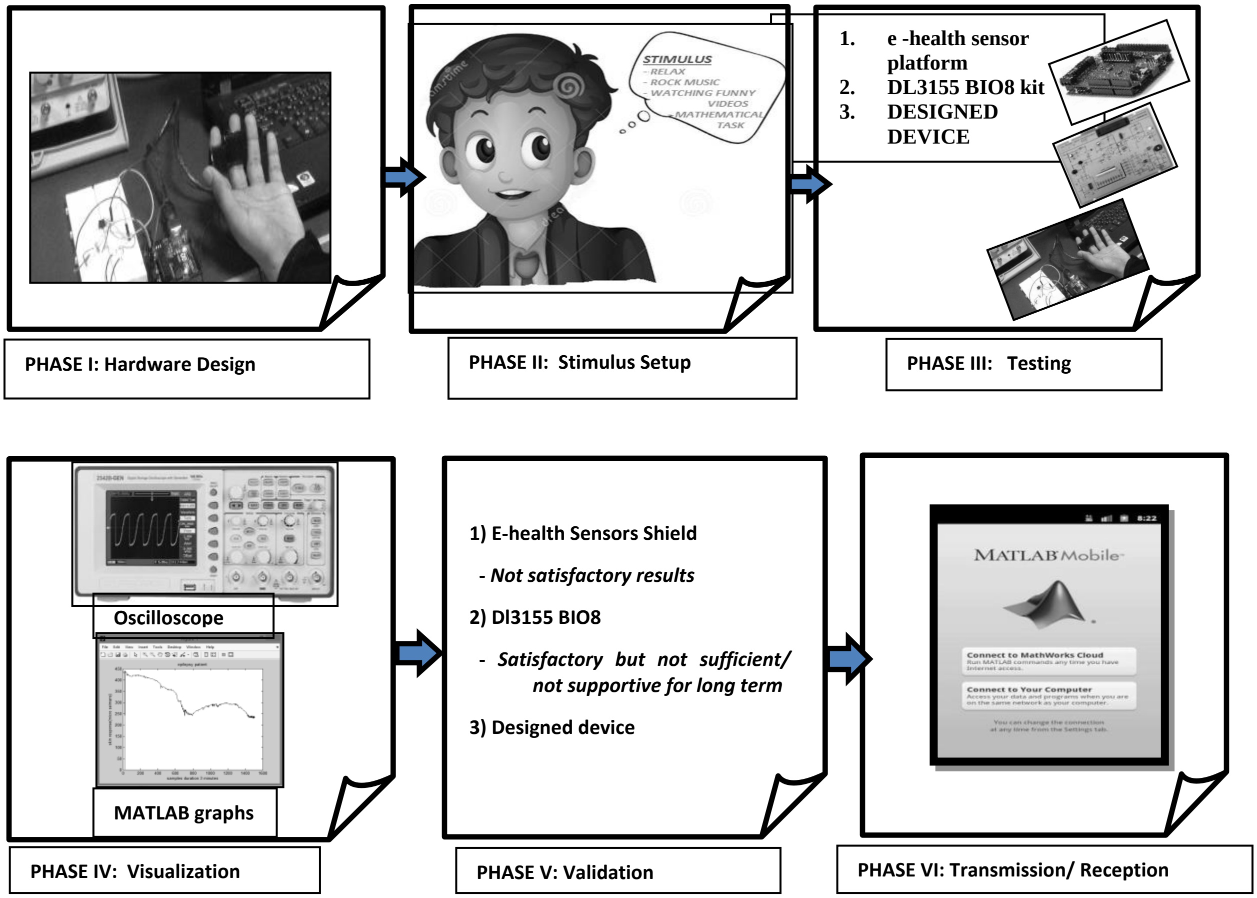


Fig.1: System flow chart

device. The device is not made for long term use. The details about the sensor materials as well as selected locations for SC data acquisition are not provided. (Quazi and Mukhopadhyay 2011) have designed their own smart sensing system by developing simple sensors for HR, SC and temperature for emotion recognition. They have compared the acquired data from their developed temperature and heart rate sensors with commercial devices but not skin conductance data. (Broek *et al.* 2011) have reviewed various commercially available devices for Emotion Sensing. They describe in detail the design of Phillips platform for this using skin conductance wrist band, ECG and pulse sensor. The finger and wrist skin conductance are also compared in this research.(Lee *et al.* 2007) have designed an EDA sensor glove using conducting fabric for detecting drowsiness while driving; the software interface is in MATLAB. (Jeehoon Kim *et al.* 2014) have designed GSR sensor using conductive polymer foam to measure skin conductance from the back.(Ming-Zher Poh *et al.* 2010) have designed their own wrist worn integrated sensor for long term, daily activity outside lab, with palmer and distal forearm sites. They tested conductive and Ag/AgCl electrodes. They have also discussed applications of EDA, where EDA can help in diagnosis. Various expensive and bulky sensors of market are also discussed. (Yoon *et al.* 2014) proposedon chip sensor design for stress monitoring using three sensors fabrication, the SCR sensor is fabricated with layers of polyimide film, silver and aluminum. (Zubair *et al.* 2015) designed a simple SC circuit to detect stress and discusses benefits of SC and flaws of heart rate for the purpose, they also discussed physical activity role in SC.

3. MATERIAL AND METHODS

From material selection for the sensor to end results i.e. the overall methodology adopted for this research is illustrated in **(Fig.1)**. The phases or steps taken for the development of the prototype device are discussed as follows

3.1. Hardware design

The hardware designing phase consists of material selection for the sensors, sensitivity adjustment of the

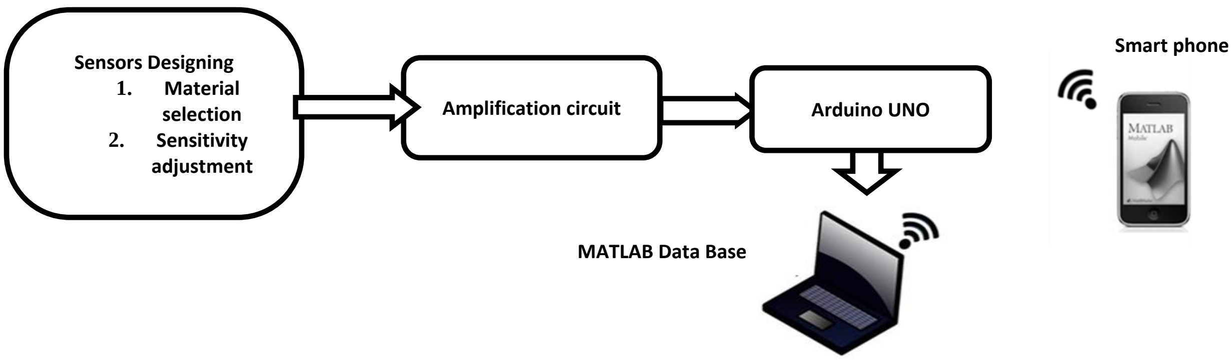


Fig. 2: Conceptual Diagram for Skin Conductance Device Prototype

acquired signal i.e. skin conductance along with amplification stage and finally the signal is fed to a microcontroller for further processing and wireless transmission as illustrated in **(Fig.2)**.

For designing the sensors Aluminum foil, Velcro tape and soft wires are used. The wire is stripped, placed on the sticky side of the Velcro tape and aluminum foil is then placed on top. The construction and making of the sensors is illustrated in **(Fig.3)**.

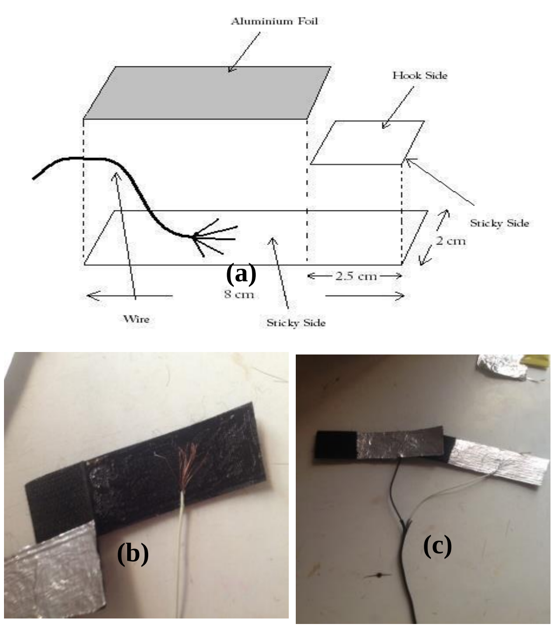


Fig.3: Skin Conductance sensor making (a) conceptual diagram (b) wire and the Velcro tape (c) sensors final design.

The electrodes are then connected with the amplification stage as shown in **(Fig.4)** and the values of the components are tested to adjust the sensitivity of the circuit. These values are given in (**Table 3)** and **(Table 4)**.

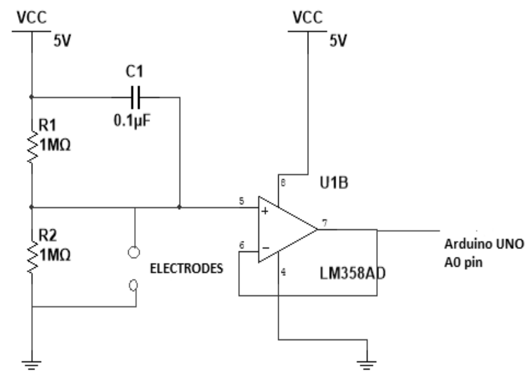


Fig.4: Amplifier circuit for skin conductance measurement

Table 3: Testing of various resistors to mimic the skin conductance and associated output voltages

S.No	Resistance Values	Voltage
1	100 Ω	1.4mV
2	220 Ω	2.50mV
3	1KΩ	2.52mV
4	2.2kΩ	2.56mV
5	10kΩ	3.72mV
6	100kΩ	3.77mV
7	1M Ω	3.9mV

Table 4: Designed hardware Parameters and their values

S. No	Parameters	Values
1	Skin conductance	0 - 400 µ Siemens
2	Sampling frequency	8.33 Hertz
3	Resistors values	1 Mega Ohms
4	Capacitor value	0.1 µ Farad

3.2. Stimulus Setup

The Experiments were performed in a well illuminated lab initially as shown in **(Fig.5)**; to test the results and working of the designed prototype device while maintaining the same conditions for temperature, sounds and environment in order to ensure uniformity. The subjects were presented with same set of following stimulus and their response is recorded.

i. Relaxing
ii. Play back of Rock Music
iii. Play back of funny videos
iv. Solving mathematical tasks

Fig. 5: Experimental Setup for testing GSR

3.3. Testing

The skin conductance data is acquired from three different sources after setting the stimulus as described one after another but keeping same settings. The devices used for the testing purpose are as follows.

i. E-health sensor platform from Libelium cooking hacks
ii. DL3155 BIO8 kit
iii. Designed prototype device

3.4. Visualization

Once the physiological data for skin conductance is acquired from any source as mentioned above through Arduino the next step is to visualize the data. This is done in two ways i.e. either on Oscilloscope or the data is exported from Arduino to Matlab. The graphs are saved and visualized in Matlab in form of image files whereas the data values for the skin conductance are saved in CSV file format forming database in Matlab. The results can be accessed or transmitted for the later use as discussed in last step.

3.5. Validation

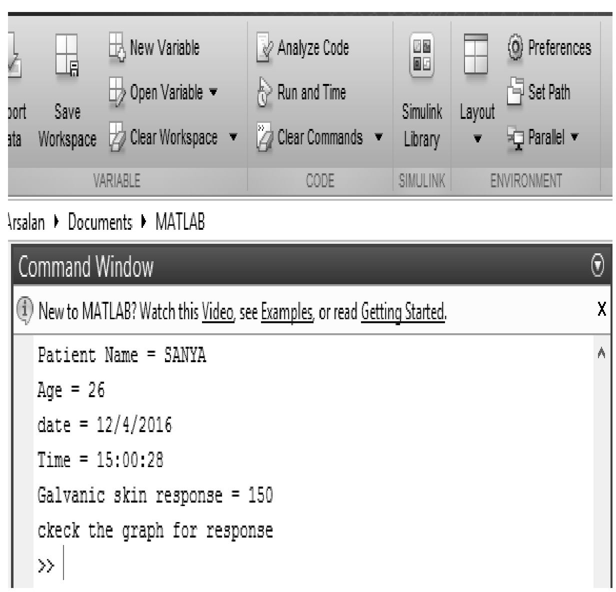
The skin conductance data under same stimulus settings from the three sources is then compared in order to validate the data and verify the results. It is found that the data acquired by the e-health sensor shield was not satisfactory i.e. it lacks in generalization or repeatability. The data from the DL3155BIO8 kit was satisfactory in the sense that it gives same results if the experiment is repeated for same kind of stimulus but it does not support data acquisition for long duration. The results and graphs acquired from the designed prototype device are similar to the graphs taken from DL3155BIO8 and hence validate the data. The designed prototype device has the capability of long term recording.

3.6. Transmission/ Reception

In order to make data accessible to the Medical practitioner or caregiver the skin conductance data and graphs are transported to Smartphone by using Matlab Mobile app. The smart phone having Matlab mobile is connected with the user's computer. A Matlab script is created to load the user's history and graphs in Smartphone which can be easily shared from the Matlab Mobile app if required. **(Fig.6)** shows the output of the script file when executed on Matlab Mobile App.

4. RESULTS AND DISCUSSION

As mentioned earlier the readings taken from DL3155 BIO8 KIT and the designed prototype showed similarity as compared to the e-health sensor platform. The graphs for the skin conductance taken from the subject under same stimulus conditions are illustrated in **(Fig.7)**



(a)

(b)

Fig. 6:Matlab's script output screenshots (a) MATLAB command window (b) MATLAB mobile app's command prompt

(a)

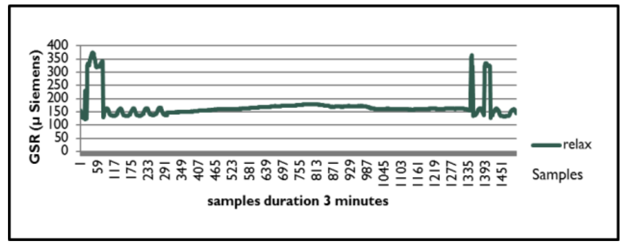
(b)

(c)

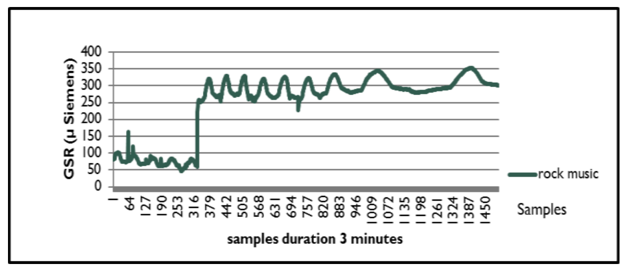
(d)

Fig. 7: Readings taken with DL3155 BIO8 KIT in Biomedical Instrumentation Lab, Bio Medical Department MUET Jamshoro (a) Relax (b) Rock Music (c) Watching Funny Videos (d) Mathematical Task

The similarity can be observed in the readings taken from the designed prototype device as shown in **(Fig.8)**. The readings exhibit introduction of fluctuations if the subject moves his hands or arms or in case of any physical activity so care is taken while taking readings to avoid introduction of such fluctuations. After testing with the predefined stimulus on healthy subjects the device was tested with the epilepsy and anxiety patients with ages 25 to 40 years, one female and three male in Civil Hospital Thatta under the supervision of Psychiatrist Specialist. **(Fig.9)** displays the snippet from the complete recording. The results were discussed with the Medical practitioner and he was able to differentiate between the mentioned diseases with the help of the obtained graphs. The similarity could be observed with the conventionally used EEG signals. The Medical practitioner also appreciated if this system is incorporated in hospitals then it can present a low cost solution and an alternate method to detect behavioral responses through SC instead of EEG.



(a)



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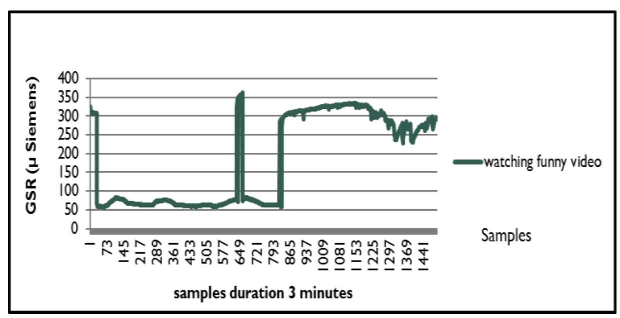
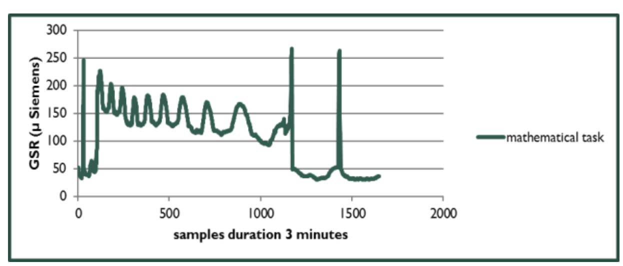


(c)



(d)

Fig. 8 : Readings taken with DL3155 BIO8 KIT in Biomedical Instrumentation Lab, Bio Medical Department MUET Jamshoro (a) Relax (b) Rock Music (c) Watching Funny Videos (d) Mathematical Task

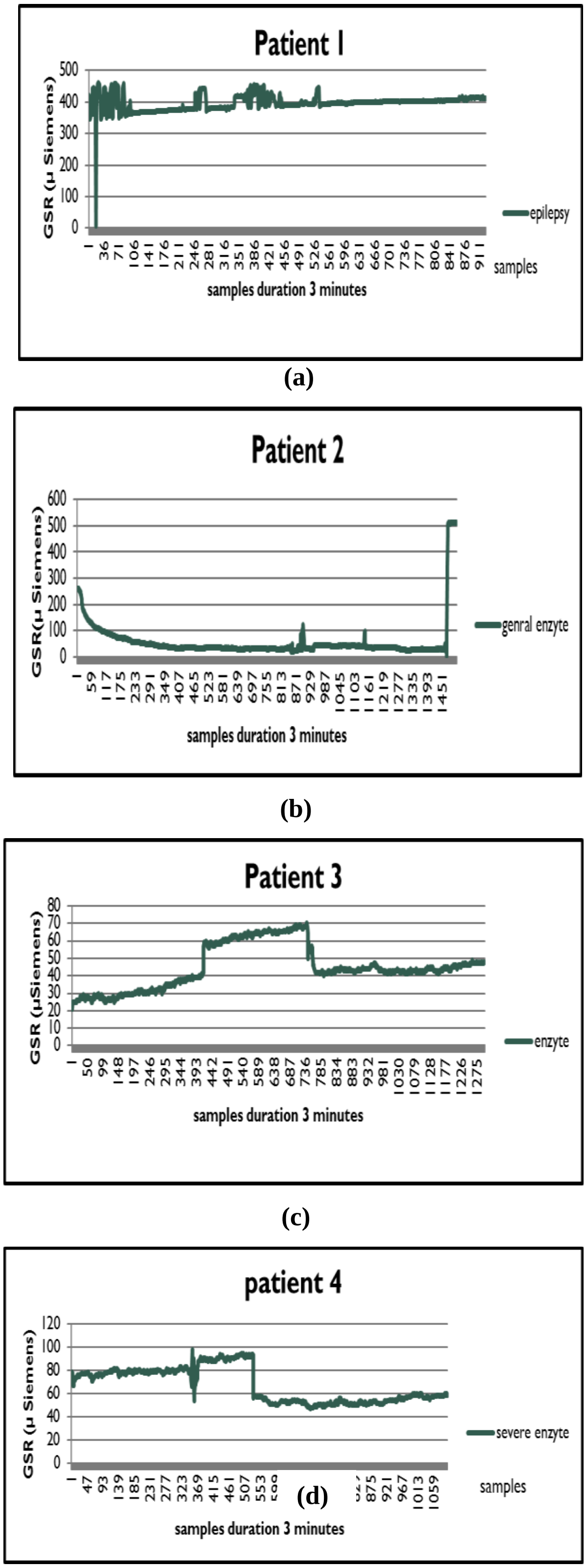


Fig. 9: Patients Readings taken by designed device at Civil hospital Thatta from patients of (a) epilepsy (b) general enzyte (c) enzyte (d) severeenzyte

5. CONCLUSION

A low cost portable prototype is designed in this research for skin conductance measurement which is reliable as well as supports long term wearing. It is cheap in comparison to the devices available in market which are either too expensive or not available in Pakistan. They are only for experimental purpose and cannot be used for Medical purposes. The prime focus of this paper was on the hardware design and testing. This work can be extended to develop algorithms through which automatic detection of various diseases can be done. Also algorithms for feature extraction can also be developed. The work can also be enhanced to apply on various applications like bio feedback games or different health monitoring applications.

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