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Original Research Article

Detection of Sympathetic Activation by Skin Conductance for a Cognitive Load of Mental Subtraction Task in Medical Undergraduates

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ABSTRACT

Background: Skin conductance has not only been studied to predict the outcome of autonomic nervous function in peripheral nervous diseases additionally, activation of sympathetic system to cognitive load has also been attributed in behavioral activation system by the study of galvanic skin response. In the light of autonomic function changes either in disease process or physiological response, the sympathetic nervous system activation is better studied without chemical analysis from body fluids by means of waveforms recorded by galvanic skin response.
Aim: The objective of our study is to enquire, does during the arithmetic cognitive load causes behavioral activation of autonomic nervous system. If so, whether such activity brings about the activation of sympathetic nervous system in all the subjects or in some.
Methods and materials: Twenty individuals were subjected for the study. Subject was to mentally perform the subtractions which was not the time bound exercise. During this cognitive load, the skin conductance was recorded and the recording obtained was said to be skin conductance response (SCR).AD instrument was used to record the skin conductance.
Results: Mean ±Std. Error of amplitude of SCL waveforms of 20 subjects was 1.56±0.18 and SCR waveforms amplitude in these subjects was 3.03±0.31. Pearson Correlation and Significant (2-tailed) of total mean amplitude of SCL waveforms and total mean amplitude of SCR waveforms from 20 subjects were 0.083 and 0.077 respectively.
Conclusion: There occurs activation of sympathetic nervous system during the cognitive load but this need not be true in all individuals.

Index terms: Skin Conductance Sympathetic Sweat glands Cognitive.

INTRODUCTION

Physiologist study the signs of covert changes in autonomic function by skin conductance before, the overt symptoms are apparent in the disease process. In the light of autonomic function changes either in disease process or physiological response, the sympathetic nervous system activation is better studied without chemical analysis from body fluids by means of waveforms recorded by galvanic skin response. [1]

The autonomic nervous system controls the blood pressure, respiration, gastrointestinal contractions, heart rate and sweat gland secretions. Sweat glands are innervated by sympatho-cholinergic system. Activation of sympathetic system causes release of acetylcholine resulting into the contraction of smooth muscles of glands in dermis, to empty the fluid and electrolytes over the skin surface, which calls upon

increased electric flow, reducing the resistance, recorded by the transducer as the greater skin conductance.[2] It is well known that when physical, mental and emotional challenge or stress is perceived by the body, hypothalamus, the part of limbic system, causes the autonomic nervous system activation in response. [3]

The regulation of cortex over the limbic system in human brain is not established to the fullest. Number of studies has been performed in relation to mental task, cognitive load, and academic performance for activation of sympathetic nervous system as arousal response by the nervous system. [4-6]

There are two types of skin conductance, tonic and phasic. Tonic skin conductance is the baseline level of skin conductance, in the absence of specific external stimuli, which is referred as skin conductance level (SCL). Phasic skin conductance is the response in the presence of external stimuli and is referred as skin conductance response (SCR). [5]

The objective of our study is to enquire, does during the arithmetic cognitive load causes behavioral activation of autonomic nervous system. If so, whether such activity brings about the activation of sympathetic nervous system in all the subjects or in some.

Due to the challenge of cognitive load the behavior activation or inhibition system would bring about the response. [7-9] and, this response should be detected objectively as increase in the skin conductance in otherwise healthy students who perceive the mental arithmetic task as stress. [10,12] This study utilizes a parameter, the 'amplitude', to distinguish the increase in skin conductance of the recorded waveforms of skin conductance level and skin conductance response. We surmise that post habituation increased skin conductance level in students; refer to the pre-test anxiety, activation of sympathetic nervous system in anticipation of the arithmetic task.

MATERIALS AND METHODS

AD instrument was used to record the skin conductance. Twenty individuals were subjected for the study. Study was conducted for four months at the department of physiology, KUSMS, from July to October, 2015. Subjects were randomly selected and written informed consent was collected prior to the procedure was performed. Ten female and ten male subjects volunteered for the study. All volunteers aged between 18-23 years. They were undergraduate students of first and second year at pre-clinical science in KUSMS.

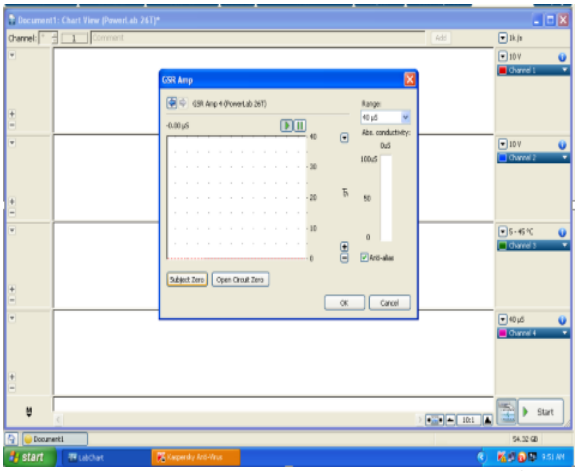

Fig 1: Zeroing obtained prior to the recording of skin conductance. The maximum amplitude can be detected up to 40 µS

Recording of skin conductance

Subject was asked to wash and dry the hand and was allowed to rest for five minutes. Subject was explained the entire procedure thereafter he/she was seated facing away from the screen.

Transducer was placed in either ring or middle finger of right hand. The subject was instructed to remain calm and silent, and the recording was collected. Before obtaining the recordings the open circuit zero and subject zero was made in the software of AD instrument as per protocol. The largest amplitude was selected up to 40µS and skin conductance level (SCL) was recorded for a minute. Thereafter subject was asked for his/her name three times to habituate and the difference in the waveforms was noted. Now, the volunteer

was provided with the task, wherein list of numerical subtractions task was printed.

Subject was to mentally perform the subtractions which was not the time bound exercise. During this cognitive load, the skin conductance was recorded and the recording obtained was said to be skin conductance response (SCR).

Analysis of waveforms of SCL and SCR

There have been various methods studied for the recording of skin conductance where, latency, rise time and amplitude are calculated. [4] However; we wanted to adopt the simple method to observe the activation of skin conductance during the subtractive task for cognitive load. Thereby, we observed the difference in amplitude for change in skin conductance of the recorded waveforms before and during the cognitive load task.

Activation of SNS is closely linked to behavior activation system in psychophysiology and behavior neuroscience. Number of studies has found the amplitude difference between SCL and SCR as standard parameter to identify the activation of sympathetic nervous system (SNS). [1-3,5] Three waveforms recorded after habituation of the volunteer was noted for the largest amplitude and mean amplitude of those three waveforms was the indicator for the skin conductance level for the subject. Likewise, three largest amplitude of the waveforms obtained while performing subtractive task was noted and mean amplitude of those three waveforms was the indicator for the skin conductance response. Mean of amplitude of SCL and mean of amplitude of SCR was compared for the subject and the activation of sympathetic nervous system whether had occurred in the subject while performing cognitive task was analyzed by paired t-test.

RESULTS

The data analysis was carried out using SPSS version 16.0 software. Wave numbers and amplitude are two different parameters obtained from recorded waveforms of skin conductance level (SCL) and skin conductance response (SCR). Recording of SCL and SCR is made for one minute each during the experiment, in all subjects. The amplitude of waveforms is expressed in micro Siemens (μS) and duration of waveforms are recorded in seconds.

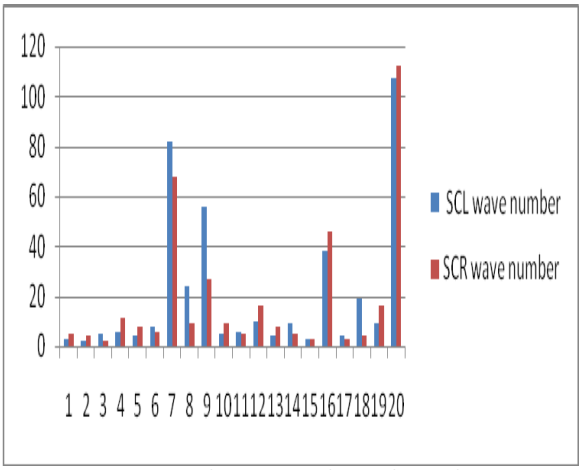

Fig 2: Comparison of numbers of waveforms for SCL and SCR in individuals

Mean ±Std. Error of amplitude of SCL waveforms of 20 subjects was 1.56±0.18 and SCR waveforms amplitude in these subjects was 3.03±0.31.

Pearson Correlation and Significant (2-tailed) of total mean amplitude of SCL waveforms and total mean amplitude of SCR waveforms from 20 subjects were 0.083 and 0.077 respectively.

Table 1: Mean of amplitude comparison for SCL waveforms and SCR waveforms in male and female subjects.

Individuals	Amplitude	Male		Female	
		Mean	P-value	Mean	P-value
1	SCL	1.10	0.001	1.82	0.002
	SCR	1.42		1.03	
2	SCL	1.46	0.007	0.68	0.114
	SCR	0.21		0.08	
3	SCL	6.46	0.604	2.85	0.002
	SCR	7.98		1.13	
4	SCL	2.06	0.000	-2.81	0.000
	SCR	1.16		2.29	
5	SCL	-2.24	0.000	0.78	0.010
	SCR	2.32		4.14	
6	SCL	7.55	0.000	2.01	0.000
	SCR	-1.41		0.07	
7	SCL	0.17	0.000	-2.04	0.004
	SCR	2.22		1.91	
8	SCL	6.23	0.000	0.40	0.000
	SCR	1.37		1.25	
9	SCL	-0.84	0.000	-0.35	0.000
	SCR	3.02		1.38	
10	SCL	0.07	0.001	1.02	0.437
	SCR	-1.37		1.74	

Table 2: Comparison of mean of amplitude and mean of waveform numbers of male to female

		Mean	P-value
SCL amplitude	Male	2.27	0.000
	Female	0.93	
SCL wave number	Male	26.05	0.006
	Female	33.44	
SCR amplitude	Male	3.77	0.027
	Female	2.38	
SCR wave number	Male	26.05	0.006
	Female	33.43	

DISCUSSION

This study was conducted to find the sympathetic activation for cognitive task. It was also to utilize the skin conductance response for the detection of stress response, additionally, whether the known cognitive load serve as the adequate stimulus for the sympathetic system activation. Skin conductance has not only been studied to predict the outcome of autonomic nervous function in peripheral nervous diseases additionally, activation of sympathetic system to cognitive load has also been attributed as arousal response in behavioral activation system and galvanic skin response has been implemented to study the phenomenon. [4,8,11]

In our obtained recordings of GSR, numbers of waveforms among individuals varied considerably. Numbers of SCR waveforms were greater than numbers of SCL waveforms in ten different subjects. The least waveforms recorded in a subject had 2 SCL and 4 SCR, whereas the maximum waveforms counted in an individual during SCL recording was 107 and SCR recording was 112, among studied subjects. Discrepancies in numbers of obtained waveforms among subjects can be conjectured that the tonic and phasic conductance among different individuals vary normally. Five male and five female subjects had greater numbers of waveforms during the performance of subtractive cognitive load, namely SCR. Remaining 50% of subjects had greater numbers of tonic waveforms recorded, namely SCL.

Despite performing habituation in subjects, the greater numbers of SCL waveforms in 50% of subjects, could not be explained at this stage in the study. As we know the numbers of waveforms is not the indicator for sympathetic stimulation for the change in stimuli that is to the subtractive cognitive load in this study, we must analyze the further parameter of the recorded waveforms. Hence the amplitude difference was noted in the studied subjects in their recorded SCL and SCR waveforms.

Difference in the amplitude of SCL and SCR was utilized to observe the change in conductance for mental subtraction task. However, this study does not contradict to findings where galvanic skin response in normal and retarded young adults was studied under various conditions of stimulus intensity, duration, and repetition. [13] It was demonstrated, duration scores to be most sensitive to changes in stimulus conditions, latency scores found to be least sensitive, and amplitude scores occupying an intermediate position. Since the stimulus provided in the study was the mental subtraction task and not the startling stimulus, the intensity grading for stimulus was not performed. Moreover, the inter-individual comparison for the differences in conductance for same cognitive load was not performed, thus the study lacks the intensity grading of stimulus.

When we compared the mean of amplitude of SCL to mean of amplitude of SCR, it was evident that mean SCR amplitude was greater. Thereby, the significance of the difference between mean amplitudes of tonic and phasic recordings for subtractive cognitive load is apparent in our study. This was the indicator of sympathetic activation during performance of the cognitive task in the studied population.

One male subject has p-value greater than 0.05 i.e. not significant; remaining nine values are significant. Therefore, among male subjects, there is significant amplitude difference between mean of SCL waveforms and mean of SCR waveforms. Mean of SCR waveforms amplitude in an individual is greater than mean of SCL waveforms amplitude in five different male subjects. Our study found that not in every

individual the SCR amplitude tend to rise higher than SCL amplitude. This was perhaps due to the fact that the anticipatory tonic conductance was greater and the sympathetic stimulation was not subsided despite the habituation performed prior the mental task. Additionally, it can be stated, the stimulus of mental subtractive load was not strong enough to activate the sympathetic nervous system in 50% of the studied male subjects, thereby they had no increased skin conductance during the performance of task itself, rather were anxious prior to performance of the subtractive task. And, once these individuals were engaged in task performance the sympathetic activation was subsided gradually.

In our study, the stimulus applied was not startling stimulus, thereby the change in amplitude of SCR was perhaps not obvious in these five males. Similarly, mean of SCR waveforms amplitude is greater than mean of SCL waveforms amplitude in six different female subjects. Four of the studied females did not show the sympathetic activation during the mental subtractive task.

Tonic skin conductance rise was apparent prior to the arithmetic task in nine subjects, as we found greater mean amplitude in SCL than that of SCR in them. It may be said that the pre-test anxiety cause the sympathetic activation before the cognitive load is applied in these nine subjects. However, this needs to be confirmed in larger numbers of individuals with appropriate statistical analysis.

Total mean amplitude of SCL waveforms and total mean amplitude of SCR waveforms from 20 subjects has positive correlation but not significant. Male has highly significant larger mean of SCL amplitude compared to female mean SCL amplitude.

The limitation of the study is that it entirely relies on skin conductance for identification of changes occurring in the autonomic nervous system during the cognitive task. Thus, the study is unable to comprehend probable changes occurring in autonomic nervous system in studied subjects if other measures were applied to detect responses. Hence, further study is required to develop the complete physiological or psycho physiological explanation behind the phenomenon. Additionally, why all subjects do not respond to the cognitive load by activation of sympathetic nervous system in this study is the topic for further enquiry.

CONCLUSION

There occurs activation of sympathetic nervous system during the cognitive load but this need not be true in all individuals. The response to the cognitive subtractive task is subjectively processed by individuals and may not cause the activation of sympathetic nervous system uniformly in all individuals. The cognitive load may or may not call upon the autonomic nervous system activation and arithmetic task may not be perceived as stress when the non-time bound mental exercise is performed.

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