Reliability of Physiological Signals induced by Sadness and Disgust

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***Abstract*—In Human Computer Interaction (HCI), acquisition of physiological signals for emotion recognition is done by emotion researches. Prior to this, one needs to identify the reliability of physiological responses. The aim of this study was to investigate the reliability of physiological responses induced by sadness and disgust using an experiment that was repeated 10 times. Twenty subjects participated in this experiment. For emotion induction, twenty different emotional stimuli were selected in a pilot experiment. Skin Conductance Level (SCL), Skin Conductance Response (SCR), and Heart Rate (HR) were measured before the presentation of stimuli as a baseline and during the presentation of the stimuli as emotional state. The results showed that physiological signals during emotional states for the 10 times the experiment was repeated were stable and reliable compared to the baseline. Our results suggest that physiological signals of sadness and disgust are reliable over time. This means that physiological signals are reliable and useful tools for emotion recognition. These results can be useful in developing an emotion theory, or profiling emotion-specific physiological responses, as well as establishing the basis for an emotion recognition system in HCI.**

Keywords-physiological signals; reliability; sadness; disgust.

I. INTRODUCTION

To recognize human's emotions and feelings, various physiological signals have been widely used in human computer interaction (HCI) [1]. Recently, physiological signals have been applied to continuous ambulatory monitoring of the affective state of individuals. For this, one needs to identify the pattern of physiological responses under specific emotional situations. This is important for basic and applied physiological research [2][3]. Although previous results have shown the temporal stability of physiological response patterns [4]-[11], they are not sufficient to verify whether or not complex patterns are stable [2]. Some results focused on the stability of the physiological responses by introducing different time intervals (e.g., 2 weeks or 4 weeks [9][10]) or using different kinds of biomarkers (e.g., blinking responses [9][11], Respiratory Sinus Arrhythmia (RSA), heart rate, salivary cortisol [12], and startle response [10]). Other studies failed to show consistent findings despite repetitive experiments [13][14]. They were limited to measuring the physiological responses only twice within a relatively short time interval with the same stimuli to examine whether or not the given conditions evoked stable emotions. The results may have possibly been subject to an adaptation effect to stimuli. Also, the methodological issue with these studies is that the stability was determined by physiological measures induced by valence (pleasant and unpleasant) not by a specific emotion. To examine the reliability of physiological responses over a relatively long period of time, we attempted to identify the stability of physiological responses induced by specific emotions (sadness and disgust) using audio-visual film clips in an experiment repeated 10 times. What differs from previous studies is the elimination of possible adaptation and learning effect (e.g., habituation) to the same stimuli by using differential emotional stimuli to effectively provoke each emotion, i.e., sadness and disgust. The rest of the paper is structured as follows. In Section 2, we provide the experimental methods used including description of the subjects, material and procedure. In Section 3, we present the experimental results and we conclude in Section 4.

II. METHODS

The emotional stimuli were 2~4 minutes long film clips, captured originally from a variety of movies and TV shows. The contents of the sadness film clips included scenes to address themes of death of parents or lover, separation, longing for mother, etc., and the contents of disgusting film clips included themes such as mutilation, butchery, and blooding. A total of 20 emotional stimuli were selected (2 emotions repeated 10 times each) by the pilot study. To examine whether the stimuli were suitable for provoking emotion, an appropriateness (the label of the experienced emotion i.e., sadness, disgust, and others) and an effectiveness (the intensity of the emotion in response to the emotional stimulus) of each stimulus were tested by the participants' ratings. The experimental procedures follow. Twenty healthy persons (10 males and 10 females) aged 21.0 (SD 1.9) years old college students participated in this experiment. They filled out a written consent before the beginning of the study and were introduced to the experiment protocols. Then, they were attached electrodes on their wrist, finger, and ankle for measurement of physiological signals, i.e., electrocardiogram (ECG) and electrodermal activity (EDA). Physiological signals were measured for 1 minute during baseline (before presentation of the stimuli) and for 2~ 4 minutes during emotional state (during presentation of stimuli) by using the MP100 (Biopac, USA). Finally, their psychological assessment was rated based on the experienced emotions. The procedures were conducted on each of the two emotions for 10 weeks on a weekly basis. To analyze physiological data, tonic level (skin conductance level, SCL, in uS) and phasic level (skin conductance response, SCR, in uS) were extracted from the

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EDA channel and heart rate (HR, in beats per minute) in the ECG. The physiological data were analyzed for each 30 seconds from the baseline and emotional states. Also, Cronbach's alpha [15], which is a measure of internal consistency, was used as a basis to determine the reliability of physiological responses observed during the 10 times.

III. RESULTS

The results of psychological assessment on emotional stimuli showed appropriateness ranging from 83 to 100 percent and effectiveness ranging from 8.7 to 10.4 point (on an 11-point Likert scale [16]). Sadness, in particular, had an average of 96 percent appropriateness and 9.2 point of effectiveness, and disgust showed 94 percent appropriateness and 10.1 point of effectiveness. Also, as Tables 1 and 2 illustrate, SCL and HR showed that Cronbach's alpha was greater than .90 for both sadness and disgust emotions.

TABLE I. RELIABILITY OF PHYSIOLOGICAL RESPONSES DURING BASELINE AND SADNESS

	SCL		SCR		HR	
	Baseline	**Emotion**	**Baseline**	**Emotion**	**Baseline**	**Emotion**
1	4.67±3.18	4.49±3.88	0.02±0.06	1.29±2.86	71.17±11.70	70.07±12.86
2	3.62±2.24	3.37±2.66	0.03±0.07	0.18±0.35	68.81±9.52	66.56±9.69
3	4.10±1.81	3.21±1.72	0.04±0.11	0.29±0.55	69.08±9.32	69.68±9.19
4	3.97±1.84	3.35±1.97	0.04±0.07	0.10±0.14	72.37±10.61	71.70±11.91
5	4.55±2.47	3.91±2.94	0.02±0.05	0.46±0.78	71.43±11.20	68.72±9.99
6	4.79±2.84	5.15±3.30	0.10±0.30	0.27±0.24	72.65±9.20	73.64±14.51
7	3.75±3.06	3.78±3.56	0.00±0.00	0.65±0.96	72.77±8.36	70.26±9.87
8	4.56±3.01	3.74±2.91	0.08±0.20	0.26±0.55	71.83±10.97	69.43±12.85
9	3.38±1.45	3.05±1.70	0.09±0.21	0.31±0.47	73.98±14.37	71.67±12.56
10	4.60±3.13	3.79±3.05	0.13±0.33	0.39±0.59	74.82±12.95	73.31±12.18
M	4.20	3.66	.08	.42	71.90	70.50
α	.96	.97	.58	.79	.96	.97

TABLE II. RELIABILITY OF PHYSIOLOGICAL RESPONSES DURING BASELINE AND DISGUST

	SCL		SCR		HR	
	Baseline	**Emotion**	**Baseline**	**Emotion**	**Baseline**	**Emotion**
1	4.59±3.05	6.45±5.31	0.01±0.02	1.15±1.62	72.83±11.41	68.63±12.19
2	3.58±2.11	4.65±3.28	0.03±0.09	0.62±0.64	70.01±9.41	63.31±11.28
3	3.85±1.69	3.94±2.62	0.07±0.20	0.43±0.59	73.66±7.69	71.31±9.72
4	3.84±1.85	4.53±2.70	0.02±0.07	0.33±0.36	72.02±8.64	66.35±14.84
5	4.60±1.75	5.24±2.61	0.02±0.06	0.98±1.39	71.82±10.06	66.25±10.69
6	4.72±2.53	5.15±3.30	0.13±0.04	0.51±0.31	73.66±10.42	71.52±14.75
7	4.25±3.50	4.29±3.54	0.12±0.25	0.53±0.56	70.07±9.51	70.56±11.63
8	3.95±3.17	5.47±3.73	0.07±0.13	0.77±0.49	71.31±11.14	67.10±12.83
9	3.27±1.54	3.41±1.72	0.12±0.24	0.35±0.36	76.23±12.95	74.32±14.53
10	4.57±3.79	3.06±2.37	0.07±0.22	0.02±0.05	75.60±13.60	69.56±16.13
M	4.12	4.62	.06	.57	72.72	68.89
α	.94	.95	.70	.61	.95	.96

IV. CONCLUSION

This study attempted to verify the reliability of physiological responses associated with specific emotions, namely sadness and disgust, across experiments repeated 10 times. Despite a small sample size, we identified that the physiological responses are stable during the experiment repeated 10 times using different stimuli evoking an emotion (e.g., sadness). In particular, SCL and HR having values higher than .95 indicate stability and consistency. Although the limitations of this study such as small sample size may affect the generalization, the results can be useful in developing an emotion theory, or profiling emotion-specific physiological responses, as well as establishing the basis for emotion recognition system in HCI.

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