The Research on Adaptive Process for Emotion Recognition by Using Time-Dependent Parameters of Autonomic Nervous Response

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Abstract. This study is to propose new method, called by TDP (time dependenet parameter) anlaysis, of physiological signal processing for emoiton recognition. TDP consised of delay, activation, half recovery and full recovery. TDP was determined from running average and normalization of physiological signals for finding tonic and phasic reponse according to emotion at entire time range from stimulating emotion to recovery. As the results of this study, TDP analysis and adaptive TDP analysis enhanced accuracy of emotion recognition in the comparison with tonic analysis. Speciallly, TDP analysis enhanced the accuracy while adaptive TDP analysis reduced the individual difference of the accuracy.

Keywords: Physiological signal, GSR, ECG, PPG, Skin temperature, emotion recognition, accuracy.

1 Introduction

Human emotion has been tried to be recognized by physiological measurements based on assumption that emotion was expressed by them[1]. Indentifying physiological signals to subjective emotion has been main issue of emotion recognition research. However, since the signals were vulnerable to be affected by noise, emotion has had recognition error. One of methods avoiding noise has been running average at narrow time interval of incoming signal. This signal process has been effective to treat noise in autonomic response having relatively low frequency of physiological signals [2-4].

Physiological signals have been analyzed into tonic level and phasic response which were important variables according to emotion response[5]. Data treatment should be considered to discriminate level and reaction from the signal. Physiological signal has contained information of both spontaneous and non-spontaneous response. Phasic response could provide non-spontaneous overall oscillation and specific continuous level according to stimulus[5]. Recently, normalization of stimulus state from reference state has been enabled to count both tonic level and phasic response for emotion recognition [6-8]. However, since response before and after stimulus according to time variation was not examined enough, non-specific phase response of physiological signals has less clarified to cause low accuracy of emotion recognition.

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Physiological response has been characterized by individual difference. Same emotion could be recognized by different regulation of physiological response. Therefore, the strategy or rule of emotion recognition should consider individual characteristics. Some findings showed that algorithm of emotion recognition set physiological variation automatically based on verification of subjective emotion and that this process enhances the accuracy of emotion recognition[9].

Therefore, emotion could be well recognized by considerations of noise reduction, discrimination between tonic level and phasic response of physiological signals, and individualization. Considering these issues, this study is to suggest new analysis methods of physiological signals, called by TDP (time dependent parameter) and to attempt to show effectiveness of emotion recognition when it is used.

2 Method

2.1 Research Purpose

This study is to propose new analysis methods for physiological response and to prove that this method was effective for emotion recognition. This research was proceeded to compare the accuracies of emotion recognition from different methods which were tonic analysis, TDP analysis, and adaptive TDP analysis.

2.2 Definition of TDP

TDP (Time dependant parameter) of physiological response was defined in this study as shown in Fig. 1. The delay was moment difference between stimulation and the activation. The activation meant time at peak form the beginning. The half recovery indicated the time at half peak and the full recovery did the time back to base state. The full recovery could be inferred from half recovery when it could not be measured. In this study, ECG (Electrocardiogram), RSP (Respiration), PPG (photoplethysmogram), GSR (Galvnic skin resistance) and SKT(Skin temperature) were processed to construct TDP curve as shown in Fig. 1.

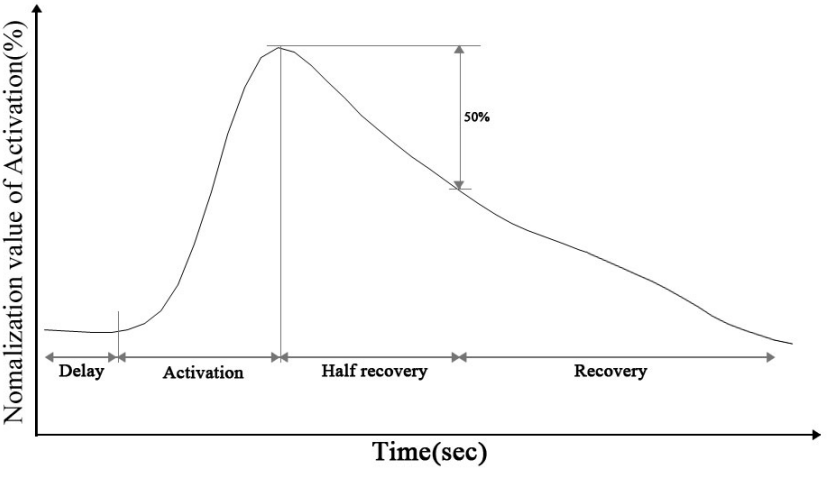

Fig. 1. TDP (time dependent parameter) of physiological measurement

2.3 Emotion Induction

Emotion was tried to be induced by image pictures. The images were chosen by previous study [8]. 100 university students (33 females and 67 males) participated, and were not visually handicapped. Participants were asked to score subjective emotion after watching the images. Significant images of emotion induction were categorized into 2 dimensional emotion model[10]. 6 images were selected for evoking unpleasantness-arousal emotion and 10 for pleasantness-relaxation emotion as shown Fig. 2. The pleasantness-relaxation was called as the positive emotion, and the unpleasantness-arousal was called as the negative emotion in this study.

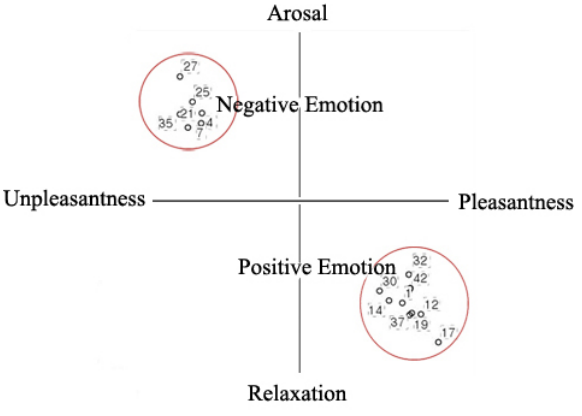

Fig. 2. The images evoking emotions

2.4 Experiment

4 university students (average 26.5 years old) participated in the experiments and were healthy with no problem of vision. 24 prepared images were presented to participants for inducing emotion. PPG, GSR, RSP and SKT were measured during presenting images. Experiment procedure was shown as fig. 3. Participant experienced first non-image state as a reference state for 30 seconds followed by presenting the image for 10 seconds. Then, non-image state called by neutral state was presented for 30 seconds. A procedure consisted of presenting 4 images and a participant experienced 6 times a procedure. The experiment took 190 seconds for a procedure and total experimental time was 1440 seconds for a participant.

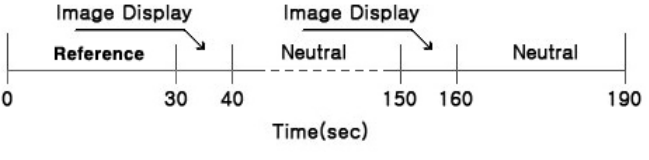

Fig. 3. Experimental procedure

3 Analysis

3.1 Data Acquisition

Collected were 6 sets consisting of 4 physiological signals and subjective score of emotion. For purpose of analysis, data unit was set at 70 seconds including neutral state for 30 seconds, stimulation for 10 seconds and another neutral state for 30 seconds. Total 74 data (6 set * 4 pictures * 4 participants) were prepared for tonic analysis, TDP analysis, and adaptive TDP analysis.

3.2 Running Average for Noise Reduction and Normalization

The running average has been effective to reduce noise [3]. In this research, the time interval for running averaging was determined by response rate of each signal. Time intervals of physiological signals were tried to be set for noise reduction. The determination was done by visual scanning for confirming signal stability.

The time interval of GSR and SKT was set at 0.5 seconds while one of RSP was at 3 seconds. PPG was analyzed to convert HR by frequency analysis. Therefore, time intervals for PPG and HR were set 2 seconds. Running average was performed by sliding window method at the pre-determined time interval on all the physiological signals.

Then, the stimulus state of physiological signal was normalized from the neutral state. This process was able to observe activation level (tonic level) of physiological signal. Normalization was determined by equation 1 and performed at every 0.5 seconds.

$$\text{Normalized state} = (\text{Stimulus state} - \text{Neutral state}) / \text{Neutral state} \quad (1)$$

3.3 TDP Rule for Emotion Recognition

TDP rule for emotion recognition was determined from previous study [8]. Visual stimulus from the prepared images induced their emotion as shown Fig 2. Then, physiological signals were analyzed into TDP and their threshold values of emotion recognition were set for constructing rule of emotion recognition as shown Table 1. Table 1 showed mean and standard deviation of physiological response time of emotion based on TDP definition. The range was defined by mean plus and minus standard deviation for recognizing respective neutral, positive and negative emotion.

3.4 Adaptive TDP Rule for Individualization

Since physiological response on same emotion was individually different, TDP rule for emotion recognition needed to be developed for individualization. The process of adaptive TDP rule was shown as Fig. 4. First, emotion was recognized by non-adaptive TDP rule. Second, difference between measured subjective emotion and emotion by physiological signals was calculated. Then, if difference existed, TDP rule was adaptively set by individual input of subjective emotion. Otherwise, emotion recognition was performed. Through these processes, it became individual and accurate adaptively for a particular person.

Table 1. The TDP rule (unit: seconds)

	t1(Delay)			t2(Activation)			t3(Half Recovery)			t4(Recovery)		
	Neg.	Neu.	Pos.	Neg.	Neu.	Pos.	Neg.	Neu.	Pos.	Neg.	Neu.	Pos.
HR	1.55 ±0.92	1.92 ±1.00	4.08 ±2.91	5.79 ±2.31	1.57 ±0.17	3.08 ±1.40	-	-	-	2.85 ±1.20	1.44 ±0.24	1.92 ±1.68
SKT	-	-	-	15.85 ±10.00	9.61 ±0.40	20.00 ±9.21	5.60 ±5.09	5.83 ±0.74	16.00 ±6.57	-	-	-
RR	-	-	-	-	-	-	3.67 ±1.80	-	1.00 ±0.05	3.33 ±2.50	-	1.00 ±0.05
GSR	-	-	-	2.65 ±1.16	1.56 ±0.40	3.69 ±1.95	0.79 ±11.06	-	4.51 ±6.55	-	-	-
PPG amp	2.25 ±2.74	2.43 ±0.31	3.90 ±2.91	4.37 ±1.97	3.45 ±1.48	8.00 ±4.93	1.75 ±12.06	-	6.03 ±6.03	-	-	-

Neg.: Negative, **Neu.:** Neutral, **Pos.:** Positive

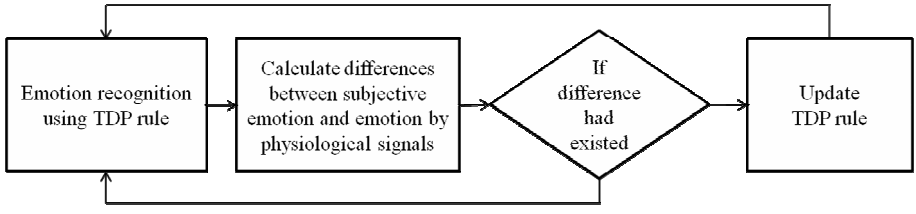

Fig. 4. The process of adaptive TDP rule for individualization

4 Result

Results showed the accuracies of emotion recognition from three different methods such as tonic analysis, TDP analysis and adaptive TDP analysis as shown table 2-5. The accuracy was determined by match rate between subjective emotion and emotion determined by physiological signals. Tonic response rule was determined from previous research of autonomic response pattern for emotion[5, 11]. If negative emotion was evoked, electrodermal and cardiovascular response were increased and thermal response was decreased and vice versa [11].

As shown in Table 2, the accuracy of emotion recognition was about 62% in negative emotion recognition and about 50% in positive emotion. In the same condition, the accuracy was enhanced up to 60% when TDP analysis was used as shown in Table 3. It was about 70% in recognition of both positive and negative. Therefore, the accuracy of emotion recognition by TDP analysis could observe responses more than one by tonic analysis. There were findings for individualization of emotion recognition as shown Table 5. Adaptive TDP rule made the accuracy enhanced little more. Interestingly, the participants having the accuracy lower than 70% increased up to 70% or more. Therefore, adaptive TDP analysis could be effective to increase accuracy of a particular person who was low. Figure 5 showed overall accuracies from three analyses. TDP analysis showed improvement of accuracy but adaptive TDP did not much. Since accuracy improved in individual showing low, overall accuracy did not contribute improvement.

Table 2. Accuracy of emotion recognition from tonic analysis

participants	Negative emotion		Positive emotion		Accuracy
	Subjective emotion	Emotion by physiological signals	Subjective emotion	Emotion by physiological signals	
A	8	5	10	6	61.1%
B	6	3	9	4	46.7%
C	7	4	8	4	53.3%
D	8	6	9	4	58.8%
Sum	29	18	36	18	55.0%
Accuracy	62.1%		50.0%		

Table 3. Accuracy of emotion recognition by TDP rule

Participants	Negative emotion		Positive emotion		Accuracy
	Subjective emotion	Emotion by physiological signals	Subjective emotion	Emotion by physiological signals	
A	8	7	10	7	77.8%
B	6	3	9	6	60.0%
C	7	4	8	7	73.3%
D	8	6	9	5	64.7%
Sum	29	20	36	25	69.0%
Accuracy	69.0%		69.4%		

Table 4. Accuracy of emotion recognition by adaptive TDP rule

Participants	Negative emotion		Positive emotion		Accuracy
	Subjective emotion	Emotion by physiological signals	Subjective emotion	Emotion by physiological signals	
A	8	6	10	7	72.2%
B	6	4	9	6	66.7%
C	7	4	8	7	73.3%
D	8	6	9	6	70.6%
Sum	29	20	36	26	70.1%
Accuracy	69.0%		72.2%		

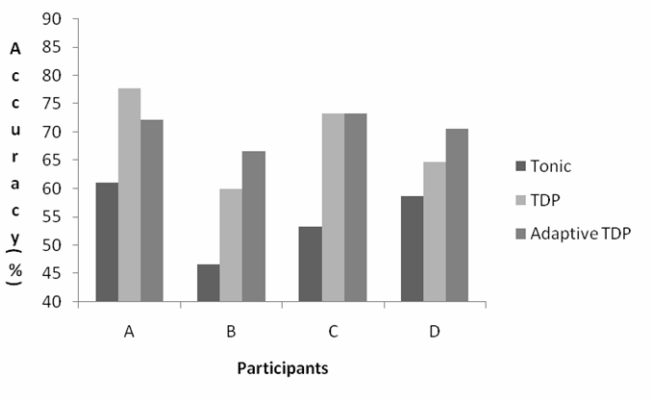

Fig. 5. Accuracy comparison of three analyses such as tonic, TDP and adaptive TDP analysis

5 Conclusion

TDP and adaptive TDP were newly proposed to analyze physiological response for emotion recognition. The methods were successful of enhance its accuracy. The adaptive TDP was effective to count individual difference of physiological response. Comparing accuracies of emotion recognition among tonic analysis, TDP analysis, and adaptive TDP analysis, this study concluded the followings.

First of all, TDP analysis enhanced the accuracy more than tonic analysis. Accuracy by tonic analysis was an average of 55%, and one of TDP analysis was of 69%.

Second, the accuracy of adaptive TDP analysis reduced the individual difference. In the case of analysis by using TDP rule, the accuracy of individual difference was between 60% and 77% while in the case of adaptive TDP rule, the accuracy of individual difference was between 66.7% and 73.3%. Results showed adaptive TDP could enhance accuracy that was relatively low but work less for a participant whose accuracy was already high.

Therefore, TDP and adaptive TDP method may be useful of emotion recognition and observe detail significant response of physiological response.

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