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TDP(time-dependent parameters)를 적용하여 분석한 자율신경계 반응에 의한 감성인식에 대한 연구

The study on emotion recognition by time-dependent parameters of autonomic nervous response

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Abstract : Human emotion has been tried to be recognized by physiological measurements in developing emotion machine enabling to understand and react to user's emotion. This study is to find the time-dependent physiological measurements and their variation characteristics for discriminating emotions according to dimensional emotion model. Ten university students were asked to watch sixteen prepared images to evoke different emotions. Their subjective emotions and autonomic nervous responses such as ECG (electrocardiogram), PPG (photoplethysmogram), GSR (Galvanic skin response), RSP (respiration), and SKT(skin temperature) were measured during experiment. And these responses were analyzed into HR(Heart Rate), Respiration Rate, GSR amplitude average, SKT amplitude average, PPG amplitude, and PTT(Pulse Transition Time). TDPs (Time dependent parameters) defined as the delay, the activation, the half recovery and the full recovery of respective physiological signal in this study have been determined and statistically compared between variations from different emotions. The significant tendencies in TDP were shown between emotions. Therefore, TDP may provide useful measurements with emotion recognition.

Keywords : Emotion, Psychophysiological response, PPG, GSR, SKT

요약 : 감성을 인식하고 반응하는 감성컴퓨터를 개발하기 위한 감성인식에 대한 연구가 활발하다. 본 연구는 2차원으로 정의한 감성을 측정하기 위해서 시간에 따른 생리신호의 반응 변수를 정의하고 그 변수로 인한 감성을 구분하고자 하였다. 10명의 대학생에게 16장의 감성을 유발

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시킬 수 있는 이미지를 제시하였다. 그리고 자율신경계 반응으로 ECG(electrocardiogram), PPG(photoplethysmogram), GSR(Galvanic skin response), RSP (respiration), 그리고 SKT(skin temperature)를 측정하였다. 본 연구는 자율신경계 반응에 대해 Delay, Activation, Half recovery 그리고 Full recovery로 이루어진 TDP(Time Dependent Parameters)를 정의하고 감성을 구분할 수 있는지에 대한 통계적 유의성을 검증하였다. 그 결과, TDP가 감성을 구분할 수 있는 유의미한 변수로 확인하였고 특징적 경향을 보임을 알 수 있었다. 그러므로 본 연구는 TDP가 감성 인식을 위한 유효한 변수일 가능성을 보였다.

주제어 : Emotion, Psychophysiological response, PPG, GSR, SKT

1. INTRODUCTION

People who have emotion shared and agreed together can often communicate better than ones who have not. They have been impressed by one who knew their emotion without any saying and who responded to their emotion without any asking. By the same token, computer user may have better communication and impression with a computer which is enable to share emotion, called by a emotion computer. Therefore, the emotion computer needs the function of recognizing and responding to user emotion. The emotion computer has been constructed by using physiological measurements resulted in emotion [1, 2]. Since physiological measurements have showed a possibility of recognizing human emotion, they were studied to enhance it's accuracy and effectiveness. Still, the accuracy was dependant on the number of emotions classified and of physiological measurement [3-5]. So far, recognition accuracy has been reported between fifty and eighty percentage [5-7].

Although physiological signal included both tonic and phasic response, the approach to emotion recognition has mainly focused on determining and analyzing the activation level of each physiological parameter on tonic response. However, emotion state has been maintained after stimulation and provided physiological parameters with time-dependent variation of phasic level. Physiological states were activated and recovered in the different pattern according to levels and modes of emotion [3]. Therefore, the time-dependent activation level could be assumed to affect on the accuracy of emotion recognition. This study is to determine the physiological parameters of the time-dependent activation and analyze the significance showing emotion recognition. Physiological measurements in this study were limited to use autonomic response because they were more appropriate in finding TDP.

2. METHOD

2.1 Emotion model

Emotion was generally determined from either discrete approach or dimensional approach. The formal definition includes six basic emotions such as anger, disgust, fear, joy, sadness and surprise [8]. The latter approach was to find the independent dimensions of categorizing emotions. Two-dimensional emotion model was used in this study. The model consisted of two independent axes such as valence and arousal

[9]. The model resulted in four categories of emotion which were pleasantness- arousal, pleasantness-relaxation, unpleasantness-arousal and unpleasantness-relaxation.

2.2 Emotion Induction

Emotion was tried to be induced by image pictures for the experiment in this study. Forty five image pictures have been prepared and tried to be classified into four categories of two dimensional emotion in pre-experiment. One hundred university students (sixty seven males and thirty three females) averaged at twenty eight age were asked to score both valence and arousal level after experiencing the images. Presenting the images and analyzing the subjective scores were automated by web system specially constructed for this study as shown Figure 1 in order to minimize the interruption from experimenter involvement during experiment. Significant six images were selected for evoke unpleasantness-arousal emotion and ten for pleasantness-relaxation emotion as shown Figure 2. The rest of twenty nine images were discarded due to individual difference of subjective emotion evaluation. Therefore, this study could get only two emotions by the prepared images.

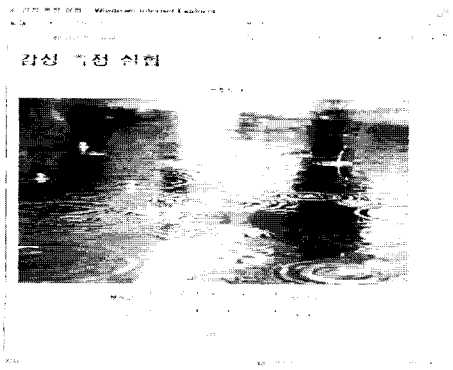

Figure 1. Automation of web system for emotion induction.

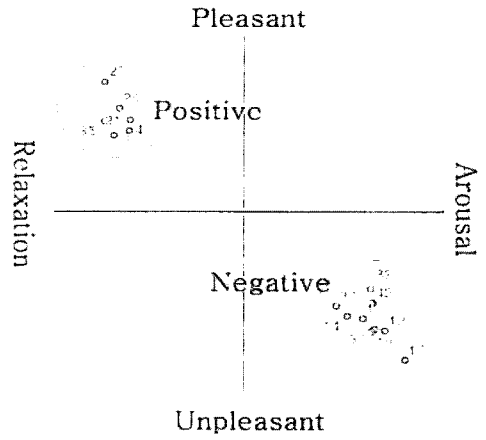

Figure 2. The images classified into two emotion categories.

2.3 Experiment

During presenting sixteen images, physiological data and subjective score of emotion were measured. The physiological data was ECG (electrocardiogram), PPG (photoplethysmogram), GSR (Galvanic skin response), RSP (respiration), and SKT(skin temperature). This study suggested new TDP (time-dependent parameters) of each physiological signal. Figure 6 showed TDP defined in this study. The delay was moment difference between image presentation and the activation. The activation meant time at peak form beginning. The half recovery indicated the time at half peak and the full recovery did the time back to base state. The half recovery could get full information of recovery even though the full recovery could not be measured [3].

Ten university students (five males and five females) participated in the main experiment. They watched the sixteen images for ten seconds with blank image for thirty seconds as a reference state. This sequence repeated four times as shown in Figure 3.

Experimental system was specially designed to

be automated in controlling two systems for presenting images and measuring physiological signals as shown Figure 4. It consisted of windows for participants and for an experimenter.

Data was collected by USB-6015(National Instrument, USA) and Biopac system and its sampling rate was set at 200Hz. The display system was LCD monitor sized at seventeen inch with 600*450 pixel image resolution. The participants were seated at the distance sixty to seventy centimeters from the monitor.

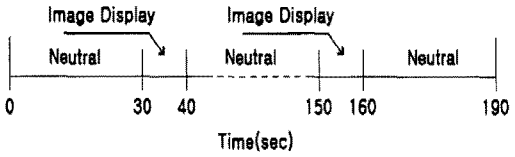

Figure 3. Time sequence of the experiment.

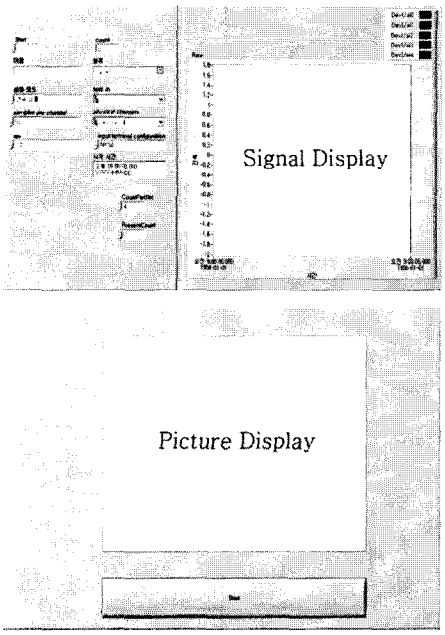

Figure 4. Synchronization system of image presentation and data measurement (a window for participants and b window for an experimenter)

3. ANALYSIS

The collected data was forty sets consisting of four repetitions by ten participants and including five physiological signals. The data was analyzed into pulse rate, respiration rate, GSR activation, skin temperature, and blood pressure. Figure 5 showed the examples of GSR sequential variation between stimulation and non-stimulation. One of GSR TDP was shown in Figure 6. The dotted line indicated the moment of image presentation.

3.2 Analysis of physiological data

Heart rate (HR) was obtained by frequency analysis from both ECG and PPG filtered at one Hz- two Hz band pass. The reparation rate (RSP) was its frequency. The GSR activation and the skin temperature were the level of amplitude. Blood pressure was defined from peak difference between ECG and PPG. As the results, forty data sets were determined at every five physiological data.

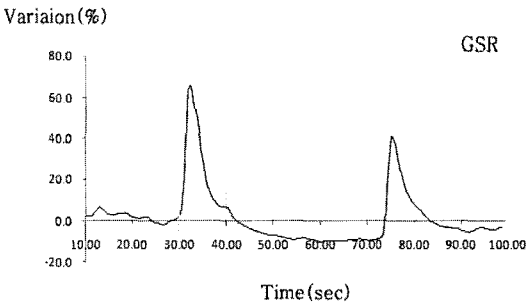

Figure 5. GSR response

3.3 TDP Analysis

Each physiological parameter was classified into four duration levels from the moment of image presentation, which consisted of delay, activation, half recovery and full recovery as shown in Figure 6. Data normalization was needed due to individual difference of physiological response. Qualitative comparison based on non-stimulated state, called neutral state, was performed according to equation 1, where the interval of n second was 0.25. All the variations of physiological signals were calculated into percent changes from neutral state. Data was one hundred sixty which consisted of forty physiological data multiplied by four times repetition. Independent t-test was performed to find significant difference of TDP according to different emotions such as the arousal-unpleasantness and the relaxation-pleasantness.

$$Var_n = (Value_n - Mean_{nu})/Mean_{nu} \cdot 100 \quad (1)$$

Var_n: % change at n second

$Mean_{nu}$: Mean from 1second to 30 second

$Value_n$: Measurement value at n second

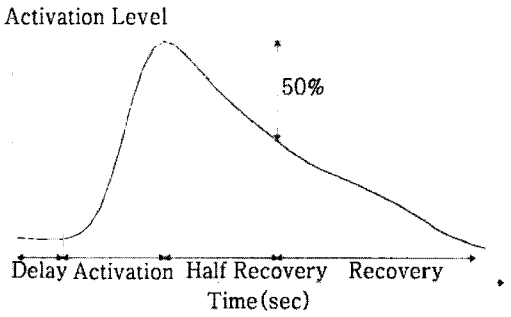

Figure 6. Four parameters of time-dependent activation of physiological response.

4. RESULTS

The significant differences of TDP were found between emotions as shown in Table 1 and Figure 7. All the observations were shown in Table 1 and Figure 8. The arousal-unpleasantness emotion was denoted by AU and the relaxation-pleasantness by RP. Heart rate (HR) has greater delay in RP than in AU while PPG has less delay. In other words, PPG show faster response than HR in AU. In the activation, SKT, GSR, and PPG were faster in RP than in AU but HR was not. Therefore, all the physiological signals except HR had rapid amplitude in RP. However, in the recovery they showed different pattern. GSR and PPG were recovered longer in RP than in AU but SKT and Respiration rate (RR) were not.

Table 1. Independent T-test result.

Physiological signal	Parameter	Mean of AU	Mean of RP	p
HR	Delay	1.55	4.08	0.000
PPG		2.25	3.90	0.034
HR	Activation	4.05	3.08	0.015
SKT		15.85	20.00	0.032
GSR		2.65	3.69	0.013
PPG		4.37	8.00	0.002
SKT	Half Recovery	5.60	16.00	0.001
RR		3.67	1.00	0.000
GSR		2.15	4.51	0.041
PPG		5.20	6.03	0.064
HR	Recovery	2.85	1.92	0.011
RR		3.33	1.00	0.000

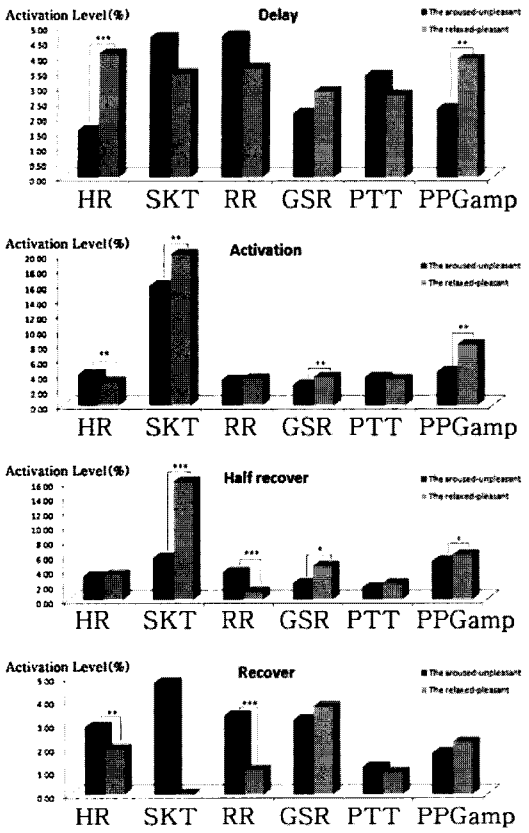

Figure 7. Significant difference of time-dependent activation according to difference emotions (*:p<0.1, **:p<0.05, ***:p<0.001).

5. CONCLUSION AND DISCUSSION

This study suggested new parameters of physiological response for differentiating emotions. four time-dependent parameters were defined as delay, activation, half recovery and full recovery from the moment of inducing emotion. For emotion induction, sixteen images out of forty five images were selected according to subjective significant evaluation and mapped into AU and RP in two dimensional emotion model [9]. Interestingly, only two emotion domain was obtained even though one hundred images were used. This study could get two completely opposite emotion in both valence and arousal such as positive (RP) and negative (AU) emotion. The results showed negative emotion reacted faster than positive emotion according to PPG. However, HR did not showed this pattern and faster in positive emotion rather than in negative emotion. The peripheral vascular system reacted faster in negative emotion but main cardiovascular system may be tried to be maintained in the same emotion. Two systems were controlled by same source such as heart and blood circulation but showed completely different response. The activation showed consistent pattern increasing faster in negative emotion than in positive emotion. Negative emotion may have stronger and more intense component for induction. However, this was not the case in HR. The half recovery showed different pattern of physiological signals in different emotion. In negative emotion, the half recovery in SKT and RR took longer in negative emotion while one in GSR and PPG shorter. The full recovery pattern was different from the half recovery one. HR recovered slower in positive emotion than in negative emotion while RR did faster. Based on the results of this study, the parameters of time-dependent activation according to emotion were summarized as the followings.

1. PPG in negative emotion reacts, delay, activates, and half recovers faster than one in positive emotion
2. GSR and SKT in negative emotion reacts, activates and half recovers faster than one in positive emotion
3. HR in negative emotion reacts, activates and recovers slower than one in positive emotion
4. RR in negative emotion reacts, recovers in

both half and full slower than one in positive emotion

This study found that autonomic response showed more intense response in negative emotion that in positive emotion in overall data pattern. The results could provide the key information of physiological response with classifying emotion dimension. More detail pattern recognition classifying more emotion remains in the future study.

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