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Development and Verification of Real Time Subjective Sensibility Evaluation System

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요 약 : 본 연구에서는 인간의 주관적 감성 변화를 실시간으로 측정할 수 있는 시스템을 개발하였다. 본 시스템은 펜 마우스와 디지타이저를 이용하여 인간의 감성 변화를 실시간으로 입력 받을 수 있는 입력 부분과, 쾌도 및 긴장도의 감성 변화를 실시간으로 측정하고 평가할 수 있는 감성평가 및 디스플레이 부분으로 구성되어있다.
본 연구에서는 본 시스템의 유효성을 검증하기 위하여 하나의 실험을 수행하였다. 28명의 20대 남녀 피험자를 대상으로 긍정 감성과 부정 감성을 유발시킬 수 있는 사진을 각각 1장식 제시하면서 실시간 주관적 감성 평가와 함께 Galvanic Skin Response (GSR)를 실시간으로 측정하였고, 실험이 종료된 후 설문지를 이용하여 비 실시간 주관적 감성 평가를 실시하였다. 이를 통해 실시간 및 비 실시간 주관적 감성 평가, 생리 신호 평가의 결과들을 비교하였다.
상관관계 계수의 비교로부터 긍정 사진 자극으로 유발된 실시간 주관적 감성 변화는 긍정 사진 자극으로 유발된 GSR 반응과, 부정 사진 자극으로 유발된 실시간 주관적 감성 변화는 부정 사진 자극으로 유발된 GSR 반응과 더 밀접한 관계가 있었다. 또한 설문지를 이용한 비 실시간 주관적 감성 평가 결과는 실시간 주관적 감성 평가의 누적된 평균 감성 값과 유사하였다.
이러한 결과로부터, 본 시스템의 가장 큰 특징은 시간에 따라 시시각각으로 변하는 인간의 주관적 감성 크기 변화를 관찰할 수 있다는 것과 자극 제시 기간 동안의 평균적인 감성 평가가 가능하다는 것이다.

Abstract : In the present study, a new Real Time Subjective Sensibility Evaluation (RTSSE) system was developed. The system is composed of two parts: a sensibility input part and sensibility evaluation part. The sensibility input part receives values, which are recorded on an input board using a stylus and digital tablet, from each subject's evaluation of his/her own subjective sensibility towards a particular stimulus. The sensibility evaluation part displays the level of pleasantness and arousal on one or two dimensions in real time. An experiment was conducted in order to investigate the feasibility and effectiveness of the RTSSE system. The present study compared Galvanic Skin Response (GSR) with the RTSSE by presenting 28 subjects in their 20s with pictures arousing either positive or negative sensibility. Following the experiment, an off-line subjective assessment using a questionnaire was given to the same subjects. According to the correlation coefficients, changes in subjective sensibility caused by the positive visual stimulus were related more closely to GSR, from the positive visual stimulus, and changes in subjective sensibility caused by the negative visual stimulus were related more closely to GSR from the negative visual stimulus. The questionnaire results showed marked similarity to the average responses of the RTSSE. In conclusion, the most remarkable characteristic of the present system is that it not only assesses the average sensibility when stimuli are presented, but also shows the changing strength of sensibility over time.

Key words : Real Time Subjective Sensibility Evaluation, Subjective assessment, Human sensibility

Introduction

For measuring human sensibility and emotion, research has mainly focused on measuring diverse aspects of human behavior, which include behavioral changes, subjective assessment, and physiological responses. In the beginning of studies on psychological states of humans, psychologists attempted to gain understanding through the discrete state theory, and argued that human emotion can be classified into a specified number of categories [1-3]. Ekman defined happiness, surprise, fear, rage, hatred, and sadness as the six basic emotions [1]. According to a dimensional model, the psychological state is continuous, and can be placed in a bipolar multi dimensional space. These studies claim that the psychological state is composed of three dimensions, or fewer than three dimensions. For example, Schlosberg asserted that emotion is composed of two bipolar dimensions, and can be placed in

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two dimensional space as a circular shape [4]. Russell, based on a statistical study of 28 words that represent psychological states, also suggested a spatial model [5]. He suggested that each emotion could be positioned in a two dimensional space, including the axes of pleasantness-unpleasantness, and arousal relaxation, in a circular shape. The two dimensional structure has been consistently found in studies that investigated the dimensions of psychological and emotional states via emotional structure, or facial expressions of different cultural backgrounds [6,7]. Therefore, the two dimensional structure is considered a fairly stable, general structure for human graphically presenting sensibility and emotion.

For evaluating human sensibility and emotion, both subjective assessment and analysis of physiological signals have been used. Subjective assessment is a method that measures emotions retrospectively using questionnaires. The first step in subjective assessment using questionnaires is setting the goal of the investigation. The second step involves assembling adjectives that represent a specific area of interest. The third step involves selecting the proper adjectives from the existing pool, and the final step entails evaluating emotions for the presented stimulus.

Research on measuring electrical/physiological signals as a method for objective evaluation of emotion has been various [8-14]. Heart Rate Variability (HRV), Galvanic Skin Response (GSR), skin temperature, and Electroencephalogram (EEG) are known to be physiological signals showing different emotional properties. In particular, GSR sensitivity reflects levels of arousal [15]. Some research reports that GSR also reflects levels of orienting response, awareness and attention [16]. In addition, GSR responses to pleasant and unpleasant stimuli have been studied [17,18]. Patterns of GSR varied according to the type of emotional stimulation, but the research produced consistent results showing that physiological excitement increases along with the intensity of GSR.

Objective evaluation of emotion using physiological signals is able to show trends of emotional change over time as well as average emotional changes for the whole duration of the presentation of the stimuli. In contrast, questionnaires are limited in observing trends of emotional change over time. Therefore, results from the subjective assessment cannot be compared to physiological signals because of differences in the time of measurement. That is, subjective evaluation can neither be compared with the physiological signals on a one to one basis, nor can it measure the emotion felt at the moment of presentation of the stimulus.

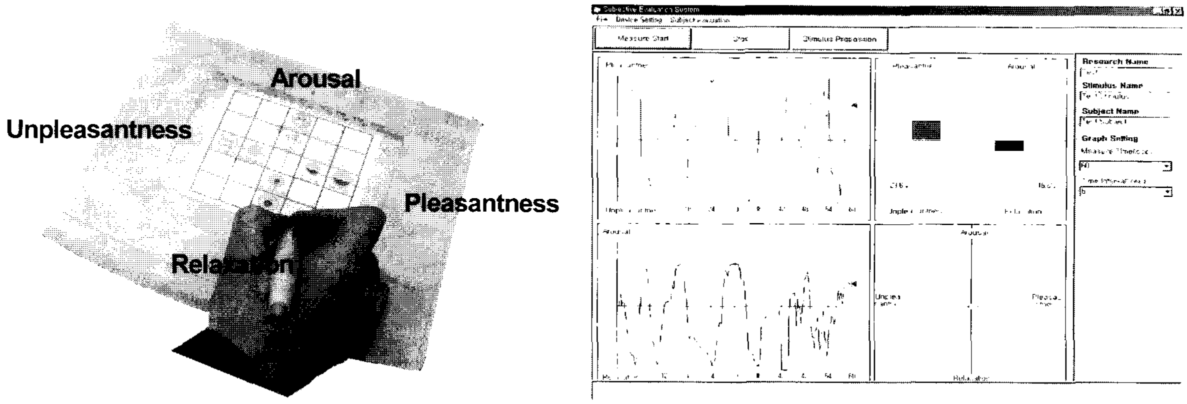
The present study developed a Real Time Subjective Sensibility Evaluation (RTSSE) system to overcome limitations in traditional subjective assessment using questionnaires. Russell's model, which shows two-dimensions of pleasantness-unpleasantness and arousal-relaxation, was used for the present study [5]. The present study developed the system that allows subjects to express their emotions on a digitized input board having two-axes; one for pleasantness-unpleasantness and the other for arousal-relaxation. Subjects place the pen-mouse at the exact position of the input board the moment they experience the foresaid emotion. The results are processed and displayed on a monitor in real time.

The present study measured GSR with the RTSSE with a picture that aroused positive sensibility and one that aroused negative sensibility. Following the experiment, a subjective assessment using a questionnaire was completed. This study compared the results of the RTSSE, questionnaire assessment and physiological signal assessment.

Real Time Subjective Sensibility Evaluation (RTSSE) System

The RTSSE system using digitizer is composed of sensibility input part, connection between digital tablet and host computer (RS232C), and sensibility evaluation and display parts.

The input part is a digital tablet (Wacom Intuos, Japan), the size of an A4 sheet of paper. It is designed in such a way that is can be marked with a digital stylus for input (possible area of recognition: 127 × 99 mm, recognition of resolution: 0.01 mm, recognition accuracy: ±0.25 mm, highest speed of recognition: 200 points/sec). As shown in Fig. 1(a), the digital tablet was designed so that subjects could express their sensibility easily and correctly. Subjects were instructed to mark the digital tablet by placing the stylus on the two-dimensional input board with the pleasantness/unpleasantness dimension on the horizontal axis, and the arousal/relaxation dimension on the vertical axis in real time. The sampling rate for data collection from the stylus was 10 points/second. The bipolar 5 point scale (2, 1, 0, +1, +2) was used for the input board. Subjects were instructed that when the stimulus was very pleasant, point +2 should be marked on the horizontal axis, and that when the stimulus was



(a) (b)

Fig. 1. The RTSSE System. (a) The input board of the digital tablet equipped with stylus input device. (b) The part for the evaluation of human sensibility and display

very unpleasant, point -2 should be marked on the horizontal axis. When the stimulus was very arousing, point +2 should be marked on the vertical axis, and when the stimulus was very relaxing, point -2 should be marked on the vertical axis. The two dimensional input board was composed of 25 separate areas on an 18 mm^2 square grid.

As in Fig. 1(b), both the results from the one-dimensional and two dimensional evaluation can be displayed in real time on the monitor. The upper-left hand side displays the time series for pleasantness/unpleasantness, and the lower-left side displays the time series for arousal/relaxation (x axis represents the flow of time, y axis represents the value of human sensibility). The lower right hand side displays the change in emotion in real time on the two dimensional space as a line. The upper right area displays the cumulative results of emotion for each dimension during the time of the presentation of the stimuli. The cumulative evaluation of emotion for each dimension was derived by integrating the values in the dimension of emotion with time. For the present system, a technique was developed to measure the change in emotion as well as the cumulative degree of change in emotion in real time.

Real time subjective evaluation for positive and negative visual stimuli

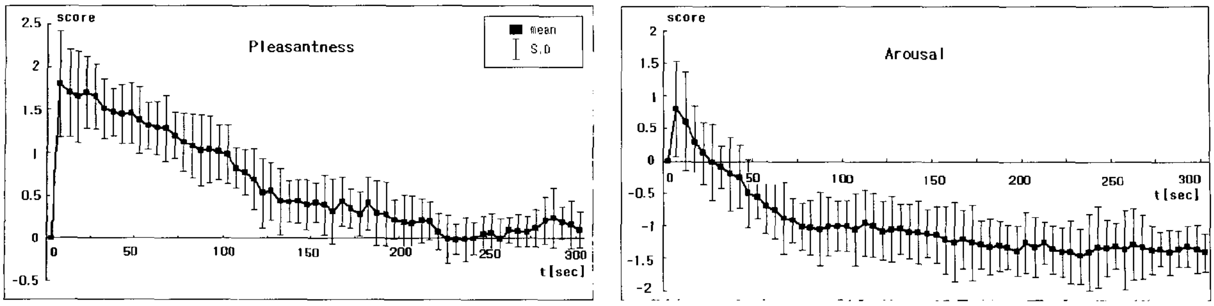
1. Subjects and procedure

The subjects for this study included 28 college graduates; 14 males within the age range of 25.3 ± 3.5 and 14 females between the ages of 24.2 ± 3.1. The subjects participated in the experiment after receiving instructions about the contents of the experiment in detail and by practicing expressing sensitivity on the digital tablet for 30 minutes. They were told not to move, to make themselves comfortable, to concentrate on the stimulus, and to express their emotions as accurately as possible. They all reported that they had neither any kind of stress or mental workload nor problems in expressing their emotions on the digital tablet.

For the experiment, two pictures from the International Affective Picture System (IAPS) previously verified to evoke positive and negative emotions were used as the visual stimuli [19]. Visual stimulation appeared at random, for 300 seconds each time. The presentation of the stimulus was projected (SANYO, PLC-5600N, Japan) on a screen 1.5×1.8 m in size. During the period the subject evaluated his/her emotions for the stimulus on the digital tablet and GSR was measured at the same time. Biopac MP100 was used to measure GSR from the index and middle fingers on the left hand. The sampling rate of the physiological data was 256Hz. At the end of the experiment, subjective evaluation was completed using a questionnaire for one minute.

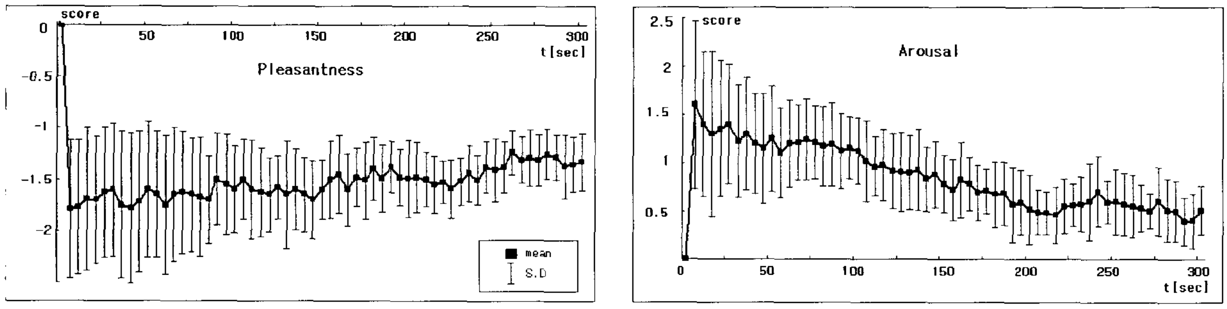
2. Subjective assessment using the questionnaire

For subjective assessment using the questionnaire, 12 adjectives, considered proper adjectives to evaluate the degree of pleasantness and arousal, were used on a bipolar 5-point scale. The adjectives for the pleasantness dimension were despaired-hopeful, boring-peaceful, unpleasant-pleasant, dragged-contented, miserable-happy, dissatisfied-satisfied as the 6 pairs of adjectives. The



(a) (b)

Fig. 2. Results of RTSSE on positive visual stimuli. (a) Changes in the level of pleasantness over time. (b) Changes in the level of arousal over time



(a) (b)

Fig. 3. Results of RTSSE on negative visual stimuli. (a) Changes in the level of pleasantness over time. (b) Changes in the level of arousal over time

adjectives for the arousal dimension following the adjectives were numb nervous, languid-excited, dull animated, not awake at all-wide awake, calm down restless, drowsy not drowsy at all. The averaged score of the 6 pairs of adjectives for each dimension of pleasantness and arousal was calculated.

Results

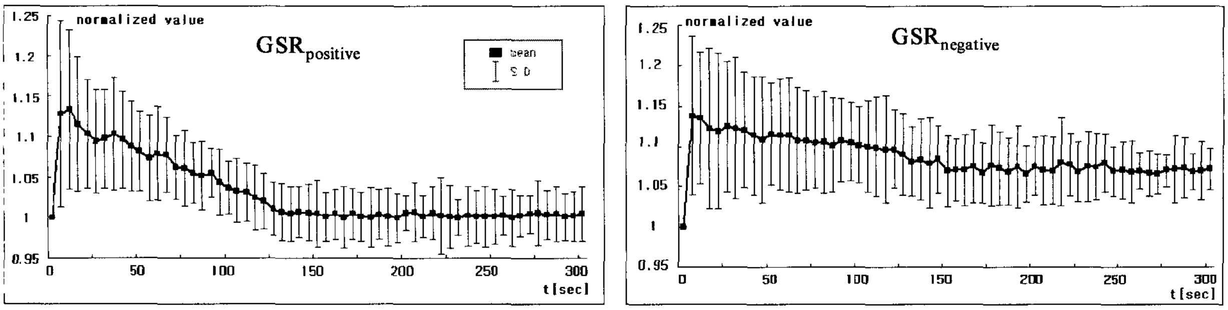
1. Results of RTSSE

The results of the real time subjective sensibility evaluation obtained from presenting the positive and negative visual stimuli continuously for 300 sec. are shown in Fig. 2 and 3, respectively (averaged for 28 subjects). Data was collected at 10 points/sec., with the presented data averaged for each five second interval. The results are shown in such a way that the two dimensional axes of pleasantness/unpleasantness and arousal/relaxation were separated, and displayed as one dimension.

As shown in Fig. 2, positive visual stimulus aroused pleasant and relaxed subjective sensibility in general, and the average sensibility aroused during the stimulation were 0.63 ± 0.31 and 0.99 ± 0.45 respectively. A negative visual stimulus aroused unpleasant and arousal sensibility in general, and the average sensibility aroused during the stimulation was -1.54 ± 0.41 and 0.86 ± 0.39 respectively (Fig. 3). In addition, the difference in the change of sensibility over time was observed for the two visual stimuli. Sensibility caused by the positive visual stimulus decreased significantly over time compared to that caused by the negative visual one.

2. Comparison of results between GSR and RTSSE

GSR data was collected at 256 points/sec., and the present data was the average of each five second interval (Fig. 4). In addition, the data was normalized based on t = 0, and the average for all 28 subjects was calculated. GSR responses to both positive and negative visual stimuli rose significantly at the beginning and gradually decreased over time. However, there was a difference. When the positive visual stimulus was presented, the GSR response decreased rapidly over time and reached baseline after 130 seconds. When the negative visual stimulus was presented, the GSR response decreased gradually over time, and stayed at a constant value after



(a) (b)

Fig. 4. Results of GSR on positive and negative visual stimuli. (a) Changes in GSR on positive visual stimuli. (b) Changes in GSR on negative visual stimuli

Table 1. Correlation between changes in RTSSE and GSR responses aroused by positive and negative visual stimuli (** p<0.01)

RTSSE \ GSR		Positive	Negative
Positive	Pleasure	0.966**	0.904**
	Arousal	0.875**	0.637**
Negative	Pleasure	-0.494**	-0.784**
	Arousal	0.879**	0.942**

about 130 seconds. Similar to the results of the RTSSE, GSR responses to positive visual stimulus decreased more rapidly over time than those to negative visual stimulus. The result suggests that negative visual stimulus arouses physiological excitement longer than positive visual stimulus. Table 1 shows the correlation coefficients (r value) between changes in subjective assessment caused by visual stimuli and measured GSR responses, which were obtained through the Pearson correlation coefficient. Because both changes in RTSSE and GSR response for each visual stimulus increased significantly at the beginning of the stimulation and decreased over time, the correlation between the two appeared extremely high as in Table 1.

However, when comparing it with the correlation of the change in RTSSE and GSR for each emotional stimulus, the following differences were found. Change in the subjective sensibility of pleasantness when a positive visual stimulus was presented, the correlation with GSRpositive (0.966**) was higher than that with GSRnegative (0.904**), and similarly, change in the subjective sensibility of arousal was more closely correlated with GSRpositive (0.875**) than with GSRnegative (0.637**). Change in the subjective sensibility of pleasantness when a negative visual stimulus was presented, the correlation with GSRnegative(0.784**) was higher than that with GSRpositive (-0.494**), and similarly, change in the subjective sensibility of arousal was more closely correlated with GSRnegative (0.942**) than with GSRpositive (0.879**). Here, GSRpositive and GSRnegative are the results of GSR measured with positive and negative visual stimuli respectively. These results suggest that change in subjective sensibility over time observed using RTSSE system is meaningful.

Table 2. Comparison of the results of RTSSE and subjective evaluation using the questionnaire on positive and negative visual stimuli

Visual \ Subjective Assessment		RTSSE	Questionnaire
Positive	Pleasure	0.63±0.31	0.98±0.52
	Arousal	-0.99±0.45	-0.84±0.63
Negative	Pleasure	-1.54±0.41	-1.47±0.47
	Arousal	0.86±0.39	0.85±0.67

3. Comparison of results between subjective evaluation using the questionnaire and RTSSE

The cumulative values of emotion for each axis of pleasantness and arousal for the two subjective evaluations were compared. As shown in Table 2, for the positive visual stimulus, no significant difference was found between the two on pleasantness (RTSSE = 0.63 ± 0.31, Questionnaire = 0.98 ± 0.52), and on arousal (RTSSE = -0.99 ± 0.45, Questionnaire = -0.84 ± 0.63) ($p > 0.05$). For the negative stimulus, the value of pleasantness (RTSSE = -1.54 ± 0.41, Questionnaire = -1.47 ± 0.47), and arousal (RTSSE = 0.86 ± 0.39, Questionnaire = 0.85 ± 0.67) were similar to each other for the two methods, and, as for the case of positive stimulus, there was no significant difference between the two methods ($p > 0.05$).

The results showed that there was no difference between the results of both the method for subjective evaluation using the questionnaire after the presentation of the stimulus, and the RTSSE method. From these results, it was concluded that the subjective evaluation using a questionnaire could represent the average level of emotion for the entire time of the presentation of the stimulus.

Discussion

The present study investigated the Real Time Subjective Sensibility Evaluation (RTSSE) system, and the feasibility and effectiveness of RTSSE. RTSSE is composed of two parts: the sensibility input part and the evaluation and display part. The input part allows subjects to express their emotions on an A4 size digital tablet using a stylus. The input board of RTSSE has two-dimensional axes; the pleasantness/unpleasantness axis and the arousal/relaxation axis. The evaluation of the input is done in real time. The evaluation and display part interfaces with the input part, and analyzes and displays the results for each dimension separately in real time. It also displays the averaged emotion for the elapsing time of the presentation in two-dimensional space. The advantage of the present system is that it is able to obtain human sensibility in real time and make comparisons on physiological signals on a one to one basis, as well as averaging values for human sensibility. The system is also able to create a file that can be used as part of a database.

For the present study, the subjects evaluated their sensibility for the presented positive and negative stimuli to verify the feasibility and effectiveness of RTSSE. In addition, this study attempted to determine if change in subjective sensibility over time observed using the RTSSE system was meaningful. For this purpose, both RTSSE and the measurement of GRS, a representative physiological signal closely related to physiological excitement, were performed and their results were compared. After the termination of the stimuli, the subjective assessment using a questionnaire was performed for comparing with the results of RTSSE.

The results of the experiment using the RTSSE system showed that positive visual stimulus generally showed pleasant and relaxed sensibility, and the negative visual stimulus showed unpleasant and arousal sensibility. Difference in the change of sensibility over time was observed between the two visual stimuli. That is, sensibility caused by the positive visual stimulus decreased significantly over time compared to that caused by the negative visual stimulus.

GSR response is closely related with physiological excitement, so too with change in emotional sensitivity over time. Compared to the negative, when the positive visual stimulus is presented, GSR response as well decreased rapidly over time. According to the comparison of correlation coefficients, change in subjective sensibility caused by the positive visual stimulus was related more closely with GSR reaction caused by stimulation of the positive visual stimulus, and changes in subjective sensibility caused by the negative visual stimulus was related more closely with GSR reaction caused by stimulation with the negative visual stimulus. These results show that the RTSSE system is a viable method for objectively representing changes in subjective sensibility over time.

Traditional subjective evaluation using the questionnaire produced similar values to the averaged value of the RTSSE. Comparisons in terms of the numerical values of sensibility from the on-line and off-line methods of subjective evaluation may need more thorough discussion in the future, but it is argued in the present study that subjective evaluation using the questionnaire reflected averaged sensibility for the entire duration of the presentation of the stimulus. Hence, RTSSE could be used widely for measuring human sensibility since it is able to measure changes in the level of sensibility in real time as well as the averaged value of the subjective evaluation for the entire time of the presentation of the stimulus.

The greatest concern was given to "the degree of subjective workload", and "the degree of accuracy" in expressing sensibility. Subjects for the present experiment reported that they didn't feel any type of workload or stress, though any type of workload or stress can be an interfering factor in sensibility evaluation. Continuous development or improvement of the system is necessary for subjects able to express sensibility more easily. Also, the present study used the fixed two-dimensional space that has axes of pleasantness/unpleasantness and arousal/relaxation for the positive and negative stimulus, but a different study with different experimental goals and evaluation may use other diversified dimensions different from the two dimensions used in the present study.

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