Relationship between Affective Dimensions and Physiological Responses Induced by Emotional Stimuli

Base on Affective Dimensions: Arousal, Valence, Intensity and Approach

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Abstract: In HCI, emotion recognition using physiological signals have been noticed lately because physiological signals can be simply acquired with some sensors and are less sensitive to social and cultural difference, in particular, there is strong correlation between human emotional states and physiological reactions. We have investigated the relation between affective dimensions, i.e., arousal, valence, intensity and approach, and physiological responses such as electrocardiograph (ECG), electrodermal activity (EDA), skin temperature (SKT), and photoplethysmograph (PPG). Three hundred college students participated in the experiment. To successfully provoke basic emotions (anger, fear, sadness, boredom, interest, surprise, joy, pain, and neutral), emotion-provoking film clips were excerpted for each target emotion. Physiological signals (ECG, EDA, PPG and SKT) as emotional responses were measured during participants' exposure to emotional stimuli and participants were asked to rate the specific emotions they had experienced on four affective dimensions, valence, arousal, intensity and approach. The result showed that there are correlations between affective dimensions and physiological responses. Contrary to valence and approach, arousal and intensity were positively related to heart rate (HR), skin conductance level (SCL) and skin conductance response (SCR), and showed negative relation to BVP and PTT. Our result suggests an availability of physiological signals for emotion recognition in HCI and can be helpful to provide the basis for the emotion recognition technique in HCI.

1 INTRODUCTION

Emotions are complex processes involving multiple response channels, including physiological systems, facial expressions and voices (Barrett and Bliss-Moreau, 2009; Keltner and Lerner, 2010; Larsen and Fredrickson, 1999). Since emotional events trigger sequences of neural activity, which result in changes in autonomic and neuroendocrine systems (Lovallo and Thomas, 2000; Larsen et al., 2008), physiological responses induced by emotions have been applied for emotion recognition in human computer interaction (HCI). Recently, the recognition of human's feeling or emotion using multi-channel physiological signals is one of the main topics in emotional intelligence in HCI (Wagner, Kim and Andre, 2005). Therefore, it is very important to investigate relations between human emotion and physiological responses. This relation has already supported by previous studies and may have a major influence on examination and application of emotion recognition in HCI (Eom, Park, Noh and Sohn, 2011).

Most emotion studies have focused on relation between basic emotions such as happiness, sadness, fear, etc. or affective dimension (e.g., arousal or valence) and physiological responses (Kreibig, 2010; Greenwald, Cook and Lang, 1989; Lang et al., 1998). In studies using a range of affective stimuli (perceptual or image), skin conductance increases

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vary directly with reports of arousal, independent of whether the experience is reported as pleasant or unpleasant (Bradley, Cuthbert and Lang, 1990; Cook, Hawk, Davis and Stevenson, 1991; Greenwald, Cook and Lang, 1989). Sequeira and colleagues (2009) have showed a positive correlation between arousal reports and conductance response amplitudes. Also, emotional stimuli such as recall of both pleasant and unpleasant memories prompts heart rate acceleration, implying that arousal primarily determines heart rate change (Cuthbert, Bradley, York and Lang, 1990) and other researches have suggested that positive emotions are associated with greater HR than negative emotions, thus HR is sensitive to hedonic valence (Lang et al., 1998).

A dimensional approach has focused on identifying emotions based on a small number of underlying dimensions (Russell, 1980) and four dimensions such as activation, valence, potency and intensity have been obtained in many studies to describe subjective feeling states (Smith and Ellsworth, 1985). The valence dimension relates to how well one is doing at the level of subjective experience, and ranges from unpleasant to pleasant feelings. The activation dimension, in turn, relates to a subjective sense of energy, and ranges from relaxed to exciting (Rusell and Feldman Barrett, 1999). Also, approach/withdrawal dimension are managed by two partially distinct self-regulatory systems (Gray, 1994). Also, another dimension of emotion is intensity which is of great importance for the behaviour and physiological responses of an emotion (Brehm, 1999; Sonnemans and Frijda, 1994). However, relation between physiological and two dimensions, i.e., arousal and emotion intensity, requires more attention, and relationships among them and other affective dimensions are not well understood (e.g., Laukka, Juslin and Bresin, 2010).

Researchers suggested additional dimensions to describe a variety of emotions, since some emotions are located closely on the dimensions. Approach/withdrawal dimension is useful to distinguish 'anger' and 'fear' which are next to each other on arousal and valence axis. It has been suggested that approach/withdrawal dimension. Recently, motivational process is known to be associated with prefrontal asymmetries (e.g., Spielberg, Stewart, Levin, Miller, Heller, 2008). In other words, left prefrontal seemed to be linked to approach behaviour and right prefrontal appeared to be withdrawal behaviour from aversive stimuli. However, there are only a few studies on approach dimension and physiological responses. Christie & Friedman (2004) reported that arousal dimension is associated with skin conductance (SC) and mean arterial blood pressures (MAP) and approach dimension is linked to cardiovascular measures such as heart period (HP), diastolic blood pressure (DBP), and mean arterial blood pressures (MAP). However, it is rarely examined the relationship between emotion dimensions and physiological signals such as photoplethysmograph (PPG) or skin temperature (SKT) that is became famous for emotion recognition in HCI. The study is to investigate the relationship between affective dimensions (i.e., arousal, valence, intensity and approach) and various physiological responses such as SKT and PPG.

2 EXPERIMENTAL METHODS

2.1 Participant

300 college students (140 male, mean age: 19.2±1.5) participated in this study. None of them reported any history of medical illness or psychotropic medication and denied use of any medication that would affect the cardiovascular, respiratory, or central nervous system. Participants were administered a hearing test, which all of them fell within the normal hearing range. A written consent was obtained at the beginning of the study when they were introduced to the experimental procedures, and they were also paid $36 USD per session to compensate for their participation.

2.2 Emotion-provoking Stimuli

To successfully provoke target emotions, one-to three-minute long emotion-provoking film clips, captured originally from a variety of movies and TV shows, were excerpted for each different emotion (i.e., anger, fear, and sadness). The rest of the stimuli were created to induce the target emotion effectively. (i.e., boredom, interest, joy, neutral, pain, and surprise). Table 1 shows the summarized emotion induction protocols. Stimuli were counterbalanced to minimize the effect of the order and intensity of each stimulus.

By administering the nine stimuli to the entire participants, the appropriateness and effectiveness of each stimulus was tested. The appropriateness was defined as the percentage of whether the given stimulus properly induced the intended emotion or not. Effectiveness was determined from the self-report results, where the participants were asked to rate intensity of the emotion that he or she felt for the stimulus on four discrete ranks. It was rated by the participants on a 9-point Likert-type scale ranging from -4 being "least" to +4 being "most") on each trial. The result of psychological responses showed that the appropriateness was 81.81% and the effectiveness was 81.80% in average. It means that more than 80% participants (240 out of total 300 participants) felt the targeted emotional states and the intensity of the emotion that they experienced was +1.38 in average. Evidence to support the effectiveness and appropriateness of the stimuli is presented in the result section.

Table 1: Summary of emotion-induction protocols.

Emotion	Stimulus protocol
Anger	The scenes involving repeated violence (Korean film, 2004)
Fear	A part of a Korean horror movie, 'A Tale of Two Sisters (2003)'
Sadness	Scenes to address themes of death of father from Ruler of Your Own World (Korean Drama, 2002)
Boredom	The auditory presentation of repeating continuously the sequence of numbers from 1 to 10 over ten times
Interest	Pictures that can create the illusion
Surprise	The presentation of the sudden noise while participants were attended to moving visual stimulus
Joy	The roulette playing in which participants could earn 2~5 dollars
Pain	A standard blood pressure cuff was applied to participant's non-dominant arm and was inflated to a maximum pressure of 250 mmHg
Neutral	Repeated scenes involving chair

2.3 Experimental Settings

The experiment was done in a sound-proof (blocked from noise 35dB and lower) room of 5m x 2.5m size. A chair for a participant was located in the center of the room and 19-inch computer monitor was placed 50 cm ahead from the chair for presentation of emotion-provoking stimuli. Closed circuit television right next to the computer monitor was installed to observe a participant's behaviour. There were a computer to present the stimuli to a participant and TV and VCR to monitor and record a participant's behaviour outside the laboratory. Also, a device (MP100) to measure the activities of autonomic nervous system (ANS), and another computer to receive all the signals from MP100 were equipped in the laboratory.

Experimental procedures were as follows: Prior to the experiment, participants were allowed to take time to feel comfortable in the laboratory setting and instruction to experiment was carefully explained to the participants. Then, electrodes for acquisition of physiological signals were placed on their wrists, fingers, and ankle. They had 60 seconds before the stimulus presentation as baseline state during which their physiological responses were measured without any emotional stimulus. Then, they were presented the emotion-provoking stimuli for 1~3 minutes. At the end of stimulus presentation, participants were asked to rate the emotions they had experienced during exposure to emotional stimuli on four affective dimensions, valence, arousal, approach, and intensity. Specifically, participants were asked the following questions to rate each dimension: 1) did you feel 'unpleasant' or 'pleasant' during exposure to the stimuli, 2) did you feel 'relaxed' or 'aroused' 3) did you feel like you wanted to 'withdraw' from or 'approach' the scene (or situations you went through in boredom, surprise, joy, and pain conditions) 4) how strong was the emotion you experienced. The ratings were based on scales ranging from -4 (, negatively valenced, relaxed, withdrawal, and weak, respectively) to +4 (positively valenced, aroused, approach, strong, respectively). After the ratings, they were given 2 minutes to get debriefed and recovered from the emotional state. The stimulus order was randomized for each participant and the experiment took roughly for an hour and a half, including short breaks.

2.4 Physiological Measures and Data Analysis

Biopac Systems Inc. (California, USA) was used to measure physiological responses and MP100WS and AcqKnowledge (version 3.7.1) were used to acquire the data and analyse them, respectively. The sampling rate was fixed at 250 Hz for all channels, and appropriate amplification and band-pass filtering were performed. ECG electrodes were placed on both wrists and the left ankle using two kinds of electrodes, sputtered and AgCl. The electrode on left ankle was used as a reference. EDA signal was measured with 8 mm AgCl electrodes placed on the volar surface of the distal phalanges of the index and middle fingers of the non-dominant hand. The electrodes were filled with a 0.05 molar isotonic NaCl paste to provide a continuous connection between the electrodes and the skin. PPG sensor was attached to the first joint of the non-dominant thumb and SKT signals were acquired by an SKT electrode attached to the first joint of the non-dominant ring finger.

Table 2: Physiological features analysed in this study.

ANS features	Abbreviation	Perceptual attribute
Heart rate (M)	HR (M)	the number of heartbeats per minute
Blood Volume Pulse (M)	BVP (M)	the phasic change in blood volume
Pulse Transit Time (M)	PTT (M)	the time it takes a pulse wave to travel between two arterial sites
Skin Conductance Level (M)	SCL (M)	the tonic levels ranging from 10-50uS
Skin Conductance Response (M)	SCR (M)	the phasic change of skin conductance or "peaks" in the skin conductance
mean of Skin Temperature (M)	SKT (M)	the average temperature of skin surface

Data for 30 sec from the baseline and another 30 sec from emotional state by emotion-provoking stimulus were used for the data analysis. Heart rate (HR) was extracted from ECG measuring heart activity. Skin conductance level (SCL) and skin conductance response (SCR) were analysed as EDA indicators, which represents changes in the electrical properties of the skin due to the activity of sweat glands and is physically interpreted as conductance. Blood volume pulse (BVP) was extracted from PPG and pulse transit time (PTT) was from ECG and PPG by measuring the elapsed time between the R-wave of the ECG and the arrival of the pulse wave at the finger. Also, the mean SKT was obtained from the skin temperature measurements. Table 2 shows the autonomic nervous system (ANS) features included in the present study. Difference between baseline state and emotional state was used for the data analysis. Correlation analysis was done to find the relationship between the physiological signals and the four affective dimensions of arousal, valence, intensity and approach.

3 RESULTS

3.1 Participants' Perception of Affective Dimensions

The participants' psychological ratings of intended emotion were shown as descriptive statistics. Table 3 shows participants' mean ratings of intended emotion intensity ranged from +1.41 to +2.35 (on 9-point scale). This means that intended emotions are induced effectively.

Table 3: Participants' mean ratings of intensity for each intended emotion condition.

	ANG	BOR	FEA	INT	JOY	NEU	PAI	SAD	SUR
M	2.3	1.9	2.2	1.4	1.8	0	1.7	1.6	2.4
SD	0.7	0.8	0.8	0.6	0.8	0	0.7	0.7	0.7

Abbreviations of each emotion are as follows. ANG: anger, BOR: boredom, FEA: fear, INT: interest, JOY: joy, NEU: neutral, PAI: pain, SAD: sadness, SUR: surprise

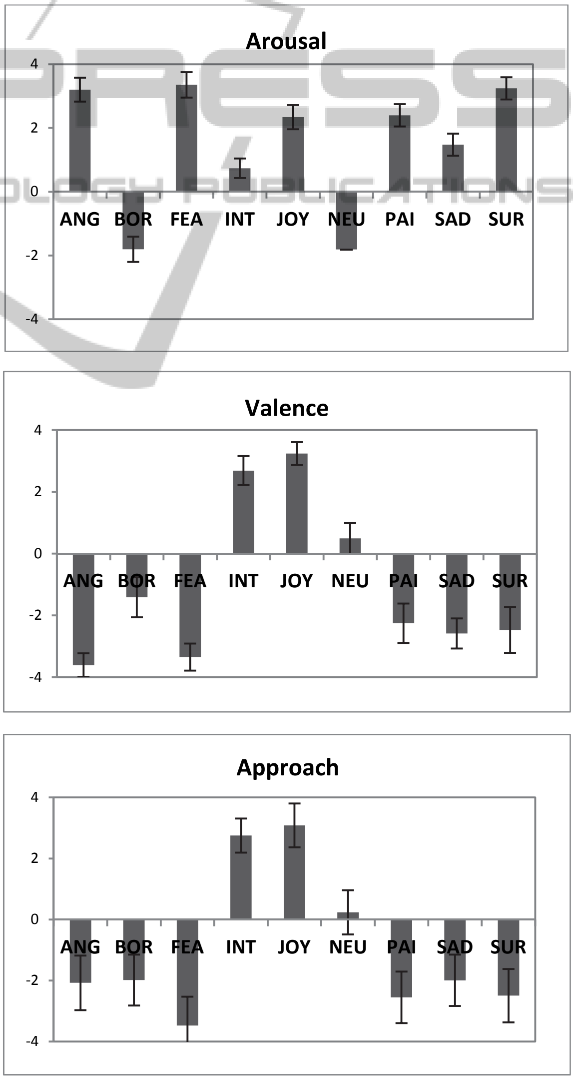

Figure 1: Participants' ratings of emotion portrays on affective dimensions.

Figure 1 shows how the participants' ratings on each affective dimension were varied according to the intended emotion. Participants rated that they felt relaxed during the boredom and neutral emotion, and aroused during anger, fear and surprise emotion. Across levels of arousal, fear, anger and surprise portrayed higher, and boredom and neutral lower on arousal than the other emotions. For the valence and approach dimensions, joy, interest, and neutral emotions were portrayed more positively valenced and approach and the rest of other emotions were more negatively valenced and withdrawal.

3.2 Inter-correlation among Affective Dimensions

Table 4 presents the correlation among the mean ratings of each portrayal on the four affective dimensions, i.e., arousal, valence, intensity and approach. The results showed there were positive correlations between arousal and intensity, and between valence and approach. Also, arousal and intensity were negatively related to valence and approach. In other words, the data suggest that emotions high in arousal and intensity tended to be unpleasant and withdrawal.

Table 4: Inter-correlation among affective dimensions using participants' ratings (** p<.01).

	Arousal	Valence	Intensity	Approach
arousal	1	-.324**	.289**	-.237**
valence	-.324**	1	-.302**	.836**
intensity	.289**	-.302**	1	-.253**
approach	-.237**	.836**	-.253**	1

3.3 Relationship between Affective Dimensions and Physiological Responses

Table 5 presents the correlation between affective dimensions and physiological responses. Arousal and intensity dimensions were positively related to SCL, SCR and HR and negatively toBVP, PTT and SKT. Contrary to the result, valence and approach dimensions hadthe negative correlation with HR, SCL and SCR, and the positive relation to BVP, PTT and SKT. The negative correlation between valence and approach dimensions with HR, SCL and SCR means that the more unpleasant and withdrawal, the greater changes in HR, SCL and SCRindexes.

Table 5: Correlation between affective dimensions and physiological responses (** p<.01).

	HR	BVP	PTT	SCL	SCR	SKT
arousal	.17**	-.27**	-.29**	.30**	.37**	-.12**
valence	-.15**	.20**	.15**	-.23**	-.27**	.03
intensity	.21**	-.03	-.22**	.23**	.24**	.00
approach	-.18**	.16**	.14**	-.24**	-.28**	.03

4 CONCLUSIONS

We identified the inter-correlation among four affective dimensions, arousal, valence, intensity and approach by the participants' ratings and the relation between affective dimensions and physiological responses induced by emotional stimuli. Our results showed that arousal and intensity have similar properties, explaining the intensity has great importance for the behaviour and physiological responses of an emotion. Also, valence and approach are affective dimensions indicating the higher scores on them are pleasant and approach, and lower unpleasant and withdrawal, respectively. Consistent with Christie and Friedman (2004), our results supports that valence is more accurately described as approach–withdrawal when applying autonomic responses during discrete emotion conditions. Results of correlation between affective dimensions and physiological responses indicated that two affective dimensions of arousal and intensity are positively related to HR, SCL and SCR, and negatively to BVP and PTT. These results mean that the higher arousal and intensity indicate greater sympathetic activation reflected by HR, SCL and SCR. On the other hand, there was negative correlation between valence and approach dimensions with physiological responses of HR, SCL and SCR, and positive correlation with BVP and PTT. It shows that unpleasant and withdrawal emotions are positively related to sympathetic activation. Although previous researches have reported that EDA is a marker of cortical arousal, our results suggested the significant relations between affective dimensions and BVP and PTT, which means that the value of changes in BVP and PTT could be used as indirect markers of cortical arousal. Also, in SKT index, it was only related to arousal dimension. Given to strong relationships between physiological responses and other affective dimensions, SKT is reliable less than other physiological signals such as EDA or HR.

This study has a few limitations. Firstly, this study only used very simple statistical analysis, primarily correlation method. In the further study, the results in a more sophisticated way might be presented instead of just showing graphs and correlation results. If linear regression model is applied for the data, strong statistical predictor of the reported emotional response can be obtained based on these physiological responses. Secondly, this study applied relatively loose threshold on the p-value of 0.01 for the correlation results. If more strict and robust statistical threshold is applied for the data, e.g., p-value of 0.002, it is expected to find noticeable physiological responses strongly associated with emotional dimensions.

Despite a few limitations above, this study could examine an availability of physiological signals for emotion recognition in HCI and our result can be helpful to provide the basis for the emotion recognition technique in HCI. Further, we will expand the approach of examining other affective dimensions such as coping potential or novelty.

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REFERENCES

Barrett, L. F., Bliss-Moreau, E., 2009. Affect as a psychological primitive, *Advances in Experimental Social Psychology*, vol. 41, pp. 167.

Keltner, D., Lerner, J.S., 2010. *Emotion*, In: Gilbert DT, Fiske ST, Lindsay G, editors. The handbook of social psychology, New York: McGraw Hill. pp. 312.

Larsen, R. J., Fredrickson, B. L., 1999. *Measurement issues in emotion research*, In: Kahneman D, Diener E, Schwartz N, editors. Well-being: The foundations of hedonic psychology. New York: Gilford. pp. 40.

Lovallo, W. R., Thomas, T. L., 2000. Stress hormones in psychophysiological research: Emotional, behavioral, and cognitive implications. In J. T. Cacioppo, L. G. Tassinary, & G. G. Berntson (Eds.), *Handbook of psychophysiology* (2nd ed., pp. 342–367). Cambridge, England: Cambridge University Press.

Larsen, R. J., Mercer, K. A., Balota, D. A., Strube, M. J., 2008. Not all negative words slow down lexical decision and naming speed: Importance of word arousal, *Emotion*, vol. 8, pp. 445.

Wagner, J., Kim, J., Andre, E., 2005. From physiological signals to emotions: Implementing and comparing selected methods for feature extraction and classification, *IEEE International Conference on Multimedia and Expo*.

Eom, J. S., Park, H. J., Noh, J. H., Sohn, J. H., 2011. Cardiovascular response to surprise stimulus, *Korean Journal of the Science of Emotion & Sensibility*, vol. 14, pp. 147.

Kreibig, S. D., 2010. Autonomic nervous system activity in emotion: A review, *Biological psychology*, vol. 84, pp. 394.

Greenwald, M. K., Cook, E. W., Lang, P. J., 1989. Affective judgment and psychophysiological response: Dimensional covariation in the evaluation of pictorial stimuli, *Journal of Psychophysiology*, vol. 3, pp. 51.

Lang, P. J., Bradley, M. M., Cuthbert, B. N., 1998. Emotion, motivation, and anxiety: Brain mechanisms and psychophysiology, *Biological Psychiatry*, vol. 44, pp.1248.

Bradley, M. M., Cuthbert, B. N., Lang, P. J., 1990. Startle reflex modification: emotion or attention?, *Psychophysiology*, vol. 27, pp. 513.

Cook, E.W., Hawk, L. W., Davis, T. L., Stevenson, V.E., 1991. Affective individual differences and startle reflex modulation, *Journal of Abnormal Psychology*, vol. 100, pp. 3.

Sequeira, H., Hot, P., Silvert, L., Delplanque, S., 2009. Electrical autonomic correlates of emotion, *International Journal of Psychophysiology*, vol. 71, pp. 50.

Cuthbert, B. N., Bradley, M. M., York, D. J., Lang, P. J., 1990. Affective imagery and startle modulation, *Psychophysiology*, vol. 27, S24.

Russell, J. A., 1980. A circumplex model of affect, *Journal of Personality and Social Psychology*, vol. 39, pp. 1161.

Smith, C. A., Ellsworth, P.C., 1985. Patterns of cognitive appraisal in emotion, *Journal of Personality and Social Psychology*, vol. 48, pp. 813.

Rusell, J.A., Barrett, F., 1999. Core affect, prototypical emotional episodes, and other things called emotion: Dissecting the elephant, *Journal of Personality and Social Psychology*, vol. 76, pp. 805.

Gray, J. A., 1981. Three fundamental emotion systems. In P. Ekman & R.J. Davidson (Eds.), *The nature of emotion: Fundamental questions* (pp. 243–247). New York: Oxford University Press.

Brehm, J. W., 1999. The intensity of emotion, *Personality and Social Psychology Review*, vol. 3, pp. 2.

Sonnemans, J., Frijda, N. H., 1994. *The structure of subjective emotional intensity*, Cognition & Emotion, vol. 8, pp. 329.

Laukka, P., Juslin, P., Bresin, R., 2010. A dimensional approach to vocal expression of emotion, *Cognition & Emotion*, vol. 19, pp. 633.

Spielberg, J. M, Stewart, J. L., Levin, R. L., Miller, G. A., Heller, W., 2008, Prefrontal Cortex, Emotion, and Approach/Withdrawal Motivation, Social and Personality Psychology Compass, vol. 2, pp. 135-153.

Christie, I. C., Friedman, B. H., 2004, Autonomic specificity of discrete emotion and dimensions of affective space: a multivariate approach, *International Journal of Psychophysiology*, vol. 51, pp. 143-153.