Correlation between Psychological and Physiological Responses during Fear
Relationship to Perceived Intensity of Fear

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Abstract: The purpose of this study is to examine the physiological responses to predict the psychological level of perceived fear. Thirty male and female college students (15 male and 15 female, mean age: 22.6±1.24) participated in the experiment. EDA (electrodermal activity), ECG (electrocardiogram), and facial EMG (electromyogram) as physiological signals were measured on the subjects' hands and face for 60sec before presentation of emotional stimulus and for 120sec during presentation of stimulus. Experimental conditions consisted of emotional condition where fear was induced by a threatening film clip and neutral condition where no emotion was provoked by a neutral film clip. After presentation of the stimulus, subjects rated their experienced emotion on the emotion assessment scale. Analysis of psychological responses was performed to examine appropriateness (label of the subjects' experienced emotion) and effectiveness (intensity of their experienced emotion). In the analysis of physiological responses, the selected features were skin conductance level (SCL), skin conductance response (SCR), number of skin conductance response (NSCR), R-R interval (R-R), heart rate (HR), respiration (RESP), activation in the bilateral corrugators (COR), and bilateral orbicularis oris' (ORB). The results showed that the psychological responses to stimulus were appropriate and effective. Physiological responses showed significant increases in all features except R-R and ORB during fear condition compared to baseline condition. Also, the perceived level of fear was positively correlated with SCL, SCR, and ORB. Our result offer that the users' perceived emotion i.e., individual differences of psychological responses must be considered to recognize human emotions by physiological signals in HCI.

1 INTRODUCTION

Fear emotion plays a crucial role in adaptation (e.g., Darwin, 1872; Ekman, 1999). It's a negative withdrawal-related emotion (Coan and Allen, 2003) and has high arousal valence (Christie, 2002; Davidson, 2000; Russel and Feldman-Barrett, 1999; Nyklicek, Thayer and Van Dooornen, 1997). Izard and Buechler (1980) described fear as a particular toxic negative emotion that is experienced as apprehension, uncertainty and a sense of threat or danger. We might consider fear emotion as a subject's perceived feeling to stimulus. For example, a 'knife' is not object of avoidance as only physical stimuli (knife), but someone feels 'perceived danger (e.g., fear of being attacked)', or even physical pain as the result of attack. Regardless of what a knife is made of, it can be perceived as a threat depending on how the subject perceives it. In other words, what constitutes 'fearful responses depend on the subject's perception (or interpretation). Therefore, it is considered that not only the specific motor and physiological responses but also subjective reaction are induced by fear if anything or situation is perceived as threatening or dangerous and it then triggers coping action, i.e., the harm-avoidance function of fear (Birbaumer and Schmidt, 1999).

Researchers empathize three major domains of

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variables to measure - physiological variables (e.g., neurological, autonomic, and endocrine changes), behavioural variables (e.g., expressive behaviour, primarily facial expression, tone of voice, gesture, posture, and movement), and cognitive variables (e.g., cognitive appraisal processes, prior experience and introspective perception of feelings, or cognition of emotional experience (Lang, 1983; Ney and Gale, 1988; Leventhal and Mosbach, 1983; Scherer, Summerfield and Wallbott, 1983). The cognitive variables, e.g., perception or appraisal to a situation, influence the physiological responses in emotion (Marwitz and Stemmler, 1998).

Despite no consistency of experimental settings to induce fear, previous results showed common fear-specific autonomic responses, e.g., increased heart rate, respiration and skin conductance, and decreased skin temperature. Additionally, the prototypical facial expression of fear is that eyebrows raised and pulled together, upper eyelids raised, and lower lids tensed combining with an open mouth (e.g., Ekman and Friesen, 1978). However, there are a few studies suggesting the relationship between psychological and physiological responses during fear emotion.

In this study, we have identified physiological responses such as EDA, ECG and facial EMG activities and psychological responses induced by fearful stimulus and found relationships between physiological and psychological responses (i.e., the perceived level of fear).

2 EXPERIMENTAL METHODS

30 male and female subjects (15 males, mean age: 22.6±1.24) participated in the experiment. None of them reported any history of medical illness or psychotropic medication. They reported no use of any medication that would affect the cardiovascular, respiratory, or central nervous system. They 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 experiment protocols, and they were also paid $20 USD to compensate for their participation.

2.1 Emotion-provoking Stimuli

To induce fear and neutral emotions, audio-visual film clips were used in this experiment (see Figure 1). Audio-visual film clip is known to effectively portray dynamic information to induce the integrated and sustained emotional responses than those of still pictures (Palomba, Sarlo, Angrilli, Mini and Stegagno, 2000). Parts of a Korean horror movie, ‘A Tale of Two Sisters (2003)’ were selected as stimuli. The stimulus consists of two parts, one part with 60 second-long neutral condition and the other 60 second-long fear condition as shown in the Fig 1. It has been revealed that it has effectiveness of 5.5 on 7-point Likert scale (1 being least effective and 7 being most effective) and appropriateness of 100% by preliminary experiment.

Figure 1: The example of the experimental stimulus. (above: neutral, below: fear)

2.2 Experimental Settings

The laboratory was 5mx2.5m big sound-proof (lower than 35dB) of the noise level where any outside artifacts are completely blocked. A couch for a subject was located on the center of the room and 38’ TV was placed 2 meters ahead from the couch to present the stimuli designed to induce emotions, fear and neutral. On the right side of the couch, interphone was installed. CCTV right next to TV was installed to observe subjects behaviors. Outside the laboratory, a computer connected to the TV inside for the presentation of the film clips to the subjects, VCR and another TV to monitor and record behaviors of the subjects, a device (MP100) to measure autonomic and facial EMG, and another computer to receive all the signals from the measuring equipment were all installed.

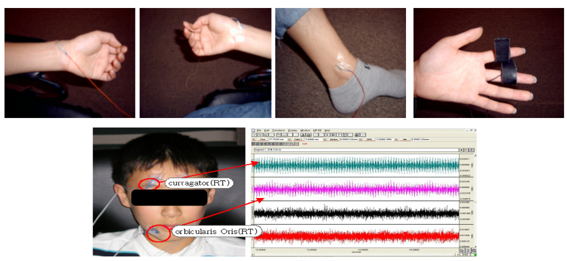

Figure 2: The attachment of electrodes for measure of physiological signals. (above: ECG and EDA, below: facial EMG)

Biopac Systems Inc. (California, USA) was used to measure physiological responses. MP100WS and AcqKnowledge (version 3.7.1) were used to input acquire the data and analyze them. ECG was measured on the left wrist where the pulse can be detected. EDA was measured on the forefinger and middle finger of the left hand. And facial EMGs were measured in the corrugators and orbicularis oris (Figure 2).

Prior to experiment, subjects were allowed to take time to feel comfortable in the laboratory setting. Then electrodes were put on their forehead, wrist, finger, and ankle to measure physiological signals. They had resting period for 60 seconds before the presentation of stimulus as baseline and then they were exposed the stimuli for 2 minutes while their physiological responses were measured. After this stimulus presentation period, they were given 30 seconds to get rested and then were to evaluate their psychological responses on emotion assessment scale.

2.3 Data Acquisition and Analysis

Data for 30 seconds from the baseline and each 30 seconds from two emotional conditions, i.e., neutral and fear were also used in the analysis. Skin conductance level (SCL), skin conductance response (SCR), and number of skin conductance response (NSCR) were analysed as EDA indicators, which were used to measure sweat secretion responses of peripheral nervous system. ECG parameters measuring heart activity were R-R interval (RRI), heart rate (HR) and respiration (RESP). To quantify facial EMG response of bilateral corrugators (CORs) and orbicularis oris' (ORBs), EMG signals were filtered at 20-450Hz, sampled at 1000 Hz, and maximal EMG was calculated as the average signal during each condition. A paired t-test for statistical analysis was done to compare the neutral to fear state. And correlation coefficient analysis was performed to identify relation between psychological and physiological responses induced by fear.

3 RESTULTS

3.1 Result of Psychological Responses

The psychological responses to fear stimulus were analyzed to examine the appropriateness and effectiveness based on the subject's rating. Appropriateness means the consistency between the target emotion and emotion experienced by the subjects. Effectiveness is the experienced emotional intensity. The results showed that appropriateness is 96.7% and effectiveness 5.00±0.86. In other words, 29 of all subjects reported they experienced fear when exposed to emotional stimulus and mean intensity of the experienced emotion was 5.00±0.86.

3.2 Result of Physiological Responses

To compare physiological responses induced by fear and neutral emotion, paired t-test was done for the two conditions (i.e., neutral and fear conditions) and normality check for the data was done using SPSS ver. 15.0 (see Table 1). In the results, there were increases in SCL, SCR, NSCR, HR, RESP and activation in the bilateral COR and decrease in RRI during the fear condition compared to the neutral condition (see Figure 3).

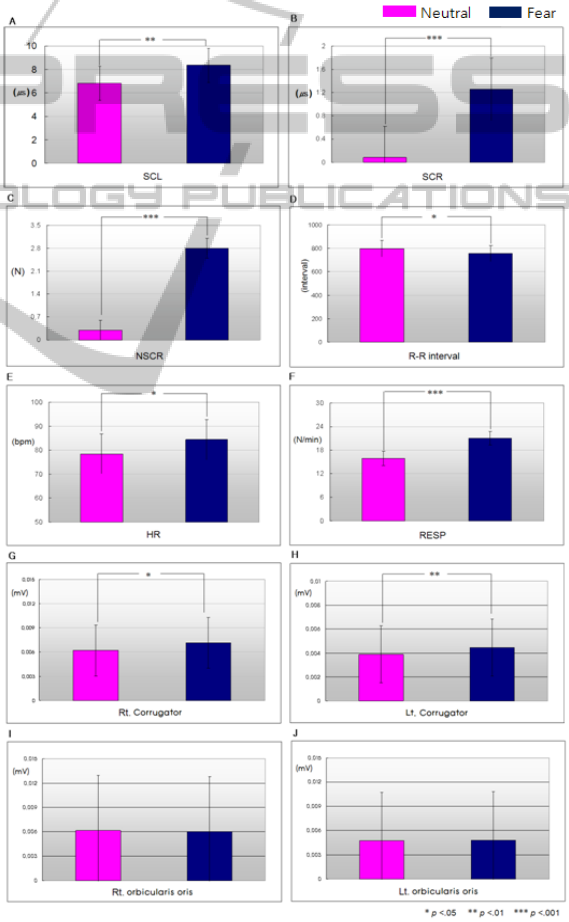

Figure 3: Difference of physiological responses between neutral and fear (A. skin conductance level, B. skin conductance response, C. number of skin conductance response, D. R-R interval, E. heart rate, F. respiration rate, G. Rt. corrugator, H. Lt. corrugator, I. Rt. orbicularis oris, J. Lt. orbicularis oris).

Table 1: Differences of physiological responses between neutral and fear emotions.

feature		neutral		fear		T
		M	SD	M	SD	
SCL (μs)		6.84	2.92	8.63	3.52	3.80**
SCR (μs)		0.08	0.21	1.26	1.08	5.89***
NSCR (N)		0.3	0.60	2.8	2.07	6.86***
R-R (interval)		796.89	135.94	755.29	163.36	2.48*
HR (BPM)		78.43	16.64	84.40	20.11	2.68*
RESP (N/min)		15.87	3.52	21.00	5.11	4.76***
COR (mV)	Lt.	0.0039	0.0048	0.0045	0.0057	2.37*
	Rt.	0.0062	0.0063	0.0072	0.0073	2.80**
ORB (mV)	Lt.	0.0048	0.0120	0.0048	0.0121	0.71
	Rt.	0.0062	0.0136	0.0060	0.0136	1.08

* p < .05, ** p < .01, *** p < .001 (N=30)

3.3 Correlation between the Perceived Intensity and Physiological Responses of Fear

For correlation coefficient analysis, Spearman rank correlation coefficient which is appropriate for both continuous and discrete variables, including ordinal variables was analysed to examine correlation between psychological, i.e., perceived fear and physiological responses induced by fear. The result is shown in the Table 2. The perceived fear showed a positive correlation with physiological responses, i.e., SCL, SCR, as well as activation in the CORs.

Table 2: Correlation between the subjects' perceived fear and physiological responses.

features	SCL	SCR	NSCR	R-R	HR	RESP
fear level	0.54**	0.49**	0.29	0.07	-0.12	-0.20

* p < .05, ** p < .01

features	Rt. COR	Lt. COR	Rt. ORB	Lt. ORB
fear level	0.37*	0.25	0.21	0.32

* p < .05, ** p < .01

4 DISCUSSIONS

This study investigated fear-specific physiological responses and physiological features related to the subjects' perceived fear. The used stimulus turned out to have 96% of appropriateness and more than 5.0 points of effectiveness, which indicates the used stimulus proved to be effective in producing fear. Our film clip when compared to the pre-existing one is a more effective tool to induce stable emotion with less individual difference as shown in the subjects' emotion assessment (Alto et al., 2002; Iwase et al., 2002) and it helps subjects experience vivid emotion (Gross and Levenson, 1995).

The results of physiological responses showed statistically significant increases in SCL, SCR, NSCR, HR, RESP and activation in the CORs except RRI. This supports previous results (Main, Shelton-Rayner, Harkin and Williams, 2003; Lundgren, Berggren and Carlsson, 2004), reflecting activation of sympathetic responses indicating fear-specific responses, e.g., increased HR and respiration, sweat secretion, and visceral arousal (James, 1884).

EDA, unlike other physiological signals, was not affected by parasympathetic response but by sympathetic (Dawson, Schell and Filion, 1990). An increase in EDA in fear means activation of sweat glands, and directly indicates an increased sympathetic arousal (Boucsein, 1992). On the other hand, HR and RESP are affected by both sympathetic and parasympathetic. Sympathetic activity is responsive to arousal or excitement, while parasympathetic is responsive to relaxed or resting states. An increase of HR and RESP can be caused by either sympathetic activation or parasympathetic inhibition. In particular, the increased HR indicates an increased sympathetic activation but decreased parasympathetic (Hugdahl, 1995), and previous studies supported an increase in HR (RRI deceleration), lower amplitude and shorter wave of RESP (Rainville et al., 2006; Blosh et al., 1991; Rainville et al., 2006) during fear. Increases of activation in the bilateral corrugators support reports by previous studies (Hu & Wan, 2003; Magnee, Stekelenburg, Kemner & deGelder, 2006; Thomkins, 1963; Vrana, 1993). Activation in the COR is fear-specific as supported by Ekman and Freisen's study (1978). However, no activation in ORB (the muscle arrowed lips) is reported.

Psychological response by fear showed a positive correlation with physiological responses, i.e., SCL, SCR, as well as activation in the COR. The reported intensity of fear goes higher, SCL, SCR and CORs activity tend to increase but HR decreased and these are consistent with previously results (Palmer, 2008; Gilissen et al., 2006; Castaneda and Segerstrom, 2004).

According to Bradley et al. (1993) and Detenber et al. (1998), arousal and valence have association with SCR, HR, activation in the ORB (zygomatic major) and CORs activity. Dimberg (1986)'s results indicate that facial muscle activity is closely related to emotional response and especially facial EMG reflects emotional characteristics. Particularly, SCR showed positive relations with arousal, HR and valence, but a negative relation with activation in the CORs. This suggests the followings; more changes in the SCR have something to do with higher level of arousal; higher HR has a relation with positive emotions; lower HR has a relation with negative emotions; and an increased activation in the CORs has a negative relation with valence.

In sum, our results are that as the perceived fear level goes higher, SCR and CORs activity increases, and yet HR decreases, all of which suggest a relation with negative valence (Dimberg, 1986). Also, this study showed that more intense fear caused more sympathetic arousal as well as increased activation in the right CORs. CORs of facial muscle has a negative relation with valence and its activation increases when experience the negative emotion such as fear (Bradley et al., 1993; Detenber et al., 1998; Dimberg, 1986). Although HR is known to be related to valence, no significant change in the HR by the level of fear was detected.

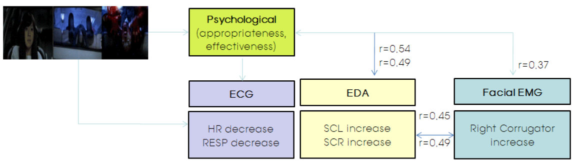

Figure 4: Correlation between psychological responses by the subjects' rating and physiological responses during fear. The arrows show relations among measures.

5 CONCLUSIONS

We have identified a positive relation between the intensity of subjects' perceived fear and SCR, and CORs activity. Our results support that there is correlation between psychological and physiological responses induced by fear. They have also provided that the intensity of perceived fear effects on physiological responses significantly. Although our results are limited to fear emotion, they offer that the users' perceived emotion i.e., individual differences of psychological responses must be considered to recognize human emotions by physiological signals in HCI. The analysis of emotional responses induced by other basic emotions such as happiness, sadness, anger, etc. are in progress and in further study, we will develop more detailed algorithms for emotion classification based on our results.

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