Internal Consistency of Physiological Responses during Exposure to Emotional Stimuli using Biosensors

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Abstract: In biomedical engineering application, mental/physical health monitoring using biosensors has been lately noticed because bio-signal acquisition by non-invasive sensors is relatively simple as well as bio-signal is less sensitive to social/cultural difference. In particular, although it is known that they are significantly correlated with human emotional state, whether the signals by various emotions are stable remains unknown. In this study, we examined the consistency of physiological responses induced by six basic emotions, happiness, sadness, anger, fear, disgust and surprise using an experiment that was repeated 10 times. Twelve college subjects participated in this experiment. For emotion induction, sixty different emotional stimuli were selected in a pilot experiment. Heart Rate (HR), Skin Conductance Level (SCL), mean of Skin Temperature (meanSKT), and mean of Photoplethysmograph (meanPPG) were measured before the presentation of stimuli as a baseline and during the presentation of the stimuli as emotional state. The results showed that physiological responses during emotional states for the 10 times the experiment was repeated were stable and consistent compared to the baseline. In particular, we could identify that physiological features such as SCL, HR, and PPG are very reliable. Our results suggest that bio-signals by six emotions are consistent over time regardless of various stimuli. This means that physiological responses are reliable and biosensors are useful tool for emotion recognition.

1 INTRODUCTION

In biomedical engineering application, recent studies have noted to improve health and wellbeing with the help of Information and Communication Technology (ICT) and in particular, mental/physical health monitoring using biosensors has mainly done because signal acquisition by non-invasive sensors is relatively simple as well as biosignal is less sensitive to social/cultural difference. Also, it is known that several biosignals are significantly correlated with human emotional state (Drummond and Quah, 2001; Tefas, Kotropoulos, and Pitas, 2001). To provide more effective wellbeing service, it is considered to understand and recognize the emotions of humans. However, a stability or reliability of physiological responses related to emotional state using biosensors remains unsolved (Hinz, Hueber, Schreinicke and Seibt, 2002). To overcome this limitation, there were many works which examine the temporal stability of physiological responses using biosensors (Lacey and Lacey, 1962; Fredrikson et al., 1985; Robinson, Whitsett, and Kaplan, 1987; Waters, Williamson, Bernard, Blouin and Faulstich, 1987; Arena, Goldberg, Saul and Hobbs, 1989; Marwitz and Stemmler, 1998). Some studies focused on proving the stability and consistency of the physiological response by introducing different time interval (e.g., 2 weeks or 4 weeks) or using different kinds of biomarkers (e.g., blinking responses, RSA, heart period, and salivary cortisol, startle response) (Manber, Allen, Burton and Kaszniak, 2000; Larson, Ruffalo, Nietert and Davidson, 2000; Bradley, Gianaros and Lang, 1995; Doussard-Roosevelt, Montgomery and Porges, 2003). However, they didn't verify the consistency of physiological responses over a relatively long period of time and the stimuli with different contexts because the physiological measures with the identical stimuli are only twice within a relatively shorter period of

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interval. Twice repeated measures with identical stimuli may have possibly resulted in potential effect of adaptation to stimuli, learning effect. To examine the consistency of physiological responses over a relatively long period of time, we identified the stability of physiological responses induced by six specific emotions (happiness, sadness, anger, fear, disgust, and surprise) using sixty different emotional stimuli in an experiment repeated 10 times. We expect our study to exclude a possible of adaptation and learning effect (e.g., habituation) that occurred in the previous studies using the same stimuli. We conducted experiments consisted often sessions across ten weeks under the same experimental conditions by using different emotional stimuli per session to induce each basic emotion.

2 EXPERIMENTAL METHODS

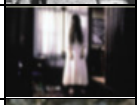
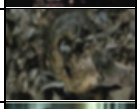
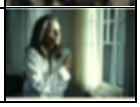
2.1 Participants

Twelve college students (6 male and 6 females, mean 21.0 years ± 1.98) who attend Chungnam National University participated in the study. None of them reported any history of medical illness or experiences of taking psychotropic medication and any medication that would affect the cardiovascular, respiratory, or central nervous system. A written consent was obtained at the beginning of the study when they were introduced to the experimental procedures, and they were also paid $200 USD to compensate for their participation.

2.2 Emotional Stimuli

To successfully provoke target emotions, we have used audio-visual film clips as emotional stimuli because film clip includes dynamic information to evoke effective emotional responses than those of still pictures (Lazarus, Speisman, Mordkoff and Davidson, 1962; Davis, Hull, Young and Warren, 1987; Palomba et al., 2000). Ten of each film clips to induce six emotions were excerpted from a variety of movies and TV shows such as documentary and drama. Each clip lasted 2- to 4-minute long. They were counter-balanced to minimize the order effect. Table 1 describes the content of the stimuli to induce 6 emotions. The emotional stimuli had 91.3% appropriateness and 8.9 point effectiveness on average for the 10 times across the different emotional conditions (Park, Jang, Chung and Kim, 2013).

Table 1: Summary of emotional stimuli.

Emotion	Context of Stimuli	
HAP	joyful scenes consisted of victorious, wedding, laughing contents, etc.	
SAD	frustration or grief scenes consisted of the longing for parents, a failure in love, etc.	
ANG	deliberate harmful or unfair behaviours such as massacre, beating, or attack, etc.	
FEA	scary scenes consisted of ghost or haunted house etc.	
DIS	disgusting scenes consisted of mutilation, butchery, or dirty restroom, etc.	
SUR	sudden or unexpected screaming scenes occurred by startling accident etc.	

2.3 Experimental Settings

Prior to the experiment, participants were allowed to take time to feel comfortable in the laboratory setting and provided with instruction to experiment. Then, electrodes for acquisition of physiological signals were placed on their wrists, fingers, and ankle. They had 60 seconds before the stimulus presentation as a baseline condition during which their physiological responses were measured without any emotional stimulus. Then, they were presented the emotion provoking stimuli for 2~4 minutes. At the end of stimulus presentation, participants were asked to rate the specific emotions they had experienced during exposure to emotional stimuli on Likert scale (Likert, 1932). After the ratings, they were given 2 minutes to get debriefed and recovered from the emotional condition. The stimulus order was randomized for each participant and the experiment took roughly about an hour and a half, including a short break. This procedure was conducted on each of the two emotions for 10 weeks on a weekly basis.

2.4 Physiological Measures and Data Analysis

MP100WS of Biopac Systems Inc. (California, USA) was used to measure bio-signals and AcqKnowledge (version 3.7.1) were used to and analyse them, respectively. The sampling rate was fixed at 200 Hz for all channels, and appropriate

amplification and band-pass filtering were performed. EDA signal was measured with the use of 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. The skin conductance channel was analysed as mean level (skin conductance level, SCL, in uS) after movement and electrode contact artifacts had been edited out. 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. Heart rate (HR, in beats per minute) was analysed by a program that detects R-waves in the ECG and calculates consecutive R–R intervals. 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. meanPPG and meanSKT were calculated by averaging raw PPG and SKT amplitude values during 30-seconds, respectively.

To analyse the physiological data, we chose the most stable 30-seconds section from the baseline and the most emotional 30-seconds section from each emotional states. The emotional conditions were determined based on the results of the participant's self-reporting, in which an emotion was most strongly expressed during the presentation of a stimulus. A t-test was conducted to examine any statistically significant (alpha level at .05) differences between two conditions which is before (baseline) and during the presentation of emotional stimulus (emotional condition). Cronbach's alpha (Cronbach, 1951), which means internal consistency was also used to examine the reliability of physiological responses observed during the 10 sessions. Cronbach's alpha is a useful coefficient for assessing internal consistency. The formula is:

$$\alpha = \frac{k}{k-1}\left(1 - \frac{\sum S^2 i}{S^2 \tau}\right) \quad (1)$$

where k is the number of items (session), s_i^2 is the variance of the ith item (session) and s_T^2 is the variance of the total score formed by summing all the items (sessions).

3 RESULTS

3.1 Validity of Emotion Induction

The results of appropriateness and effectiveness by the participants' ratings mean their psychological responses to emotional stimuli. Results on psychological responses of each session showed that the emotional stimuli have the appropriateness of 93.3% and an effectiveness of 9.4 points on average for 10 times. Also, the results showed that the appropriateness ranges from 75% to 100 % and the effectiveness ranges from 8.7 points up to 10.8 points on emotions (Table 2). These results show that our stimuli appropriately and effectively provoked both emotions.

Table 2: Participants' mean ratings of intensity for each intended emotion condition.

	Emotion						M
	HAP	SAD	ANG	FEA	DIS	SUR	
1	100 (8.4)	92 (9.5)	75 (9.7)	75 (10)	75 (10.2)	75 (9.3)	83 (9.5)
2	100 (8.9)	100 (9.1)	75 (9.9)	100 (9.9)	92 (10.8)	92 (9.7)	94 (9.6)
3	100 (8.8)	100 (8.7)	75 (9.7)	83 (9.8)	92 (9.9)	100 (9.7)	93 (9.3)
4	100 (9.6)	100 (9.7)	75 (9.5)	92 (9.6)	100 (10.4)	100 (9.9)	95 (9.7)
5	100 (9.6)	100 (9.3)	92 (9.8)	92 (9.7)	92 (9.7)	83 (9.6)	94 (9.6)
6	100 (9.3)	100 (9.3)	92 (9.4)	92 (9.7)	100 (10.3)	83 (9.6)	95 (9.5)
7	100 (9.3)	75 (8.9)	92 (8.9)	83 (9.6)	100 (9.3)	100 (9.5)	92 (9.3)
8	92 (8.0)	100 (9.0)	83 (9.2)	100 (9.3)	83 (10.2)	83 (9.4)	92 (9.2)
9	100 (9.7)	100 (9.2)	92 (9.5)	100 (9.3)	100 (10.1)	83 (8.6)	96 (9.4)
10	92 (8.8)	100 (9.3)	92 (9.7)	75 (8.7)	100 (10.1)	75 (10.3)	91 (9.5)
M	98 (9.1)	96 (9.2)	84 (9.5)	89 (9.6)	94 (10.1)	89 (9.5)	93.3 (9.4)

Abbreviations of each emotion are as follows. HAP happiness, SAD sadness, ANG anger, FEA fear, DIS: disgust, SUR: surprise

3.2 Reliability of Bio-Signals Induced by Emotional Stimuli

To examine the reliability of the physiological data obtained during the 10 sessions, Cronbach's alpha was used as the reliability coefficients. Table 3 to table 8 show the descriptive statistics (mean and standard deviation) and Cronbach's alpha to physiological parameters from 12 participants during each emotion over 10 sessions. The results showed that Cronbach's alpha of emotional conditions had the range from .42 to .96 and they were greater than that of baseline ranging from .10 to 71. Figure 1 shows Cronbach's alpha of physiological parameters during six baselines

and emotions. In all parameters, coefficients during emotional states are higher than baseline.

Table 3: Cronbach's alpha of physiological features during happiness.

Time	SCL		HR		meanSKT		meanPPG	
	BAS	EMO	BAS	EMO	BAS	EMO	BAS	EMO
1	5.13 (3.07)	5.14 (4.74)	72.21 (10.34)	72.75 (11.07)	90.31 (0.03)	90.31 (0.01)	-8.38 (0.84)	-8.36 (0.86)
2	3.46 (3.27)	3.76 (3.11)	72.87 (11.25)	70.93 (10.10)	90.33 (0.04)	90.30 (0.04)	-8.39 (0.61)	-8.26 (0.70)
3	4.71 (2.69)	4.48 (2.91)	71.62 (8.84)	70.24 (9.36)	90.31 (0.02)	90.28 (0.03)	-8.17 (0.81)	-8.21 (0.66)
4	3.64 (2.01)	4.16 (2.57)	74.96 (9.08)	73.08 (9.38)	90.31 (0.03)	90.29 (0.02)	-8.69 (0.93)	-8.68 (0.98)
5	3.97 (2.99)	4.31 (2.81)	72.36 (10.68)	73.08 (11.77)	94.22 (1.96)	94.52 (1.31)	-8.82 (0.61)	-8.72 (0.66)
6	4.42 (2.97)	4.10 (3.61)	76.04 (9.58)	76.80 (12.22)	94.26 (1.72)	94.49 (1.53)	-8.20 (0.63)	-8.21 (0.57)
7	4.38 (2.78)	3.14 (2.68)	76.41 (10.36)	75.72 (9.01)	94.65 (1.44)	93.46 (2.79)	-8.27 (0.61)	-8.21 (0.67)
8	4.69 (3.13)	3.91 (3.88)	74.38 (10.51)	72.67 (11.89)	94.09 (1.90)	94.08 (2.52)	-8.10 (0.71)	-8.62 (0.74)
9	4.05 (2.85)	2.96 (2.02)	79.06 (11.78)	76.52 (16.09)	94.54 (1.62)	94.71 (2.83)	-8.21 (0.64)	-8.50 (0.67)
10	4.35 (2.81)	3.29 (3.73)	80.00 (14.37)	78.60 (13.24)	94.50 (1.53)	95.07 (1.84)	-8.35 (0.59)	-8.85 (0.65)
M	4.28 (2.86)	3.93 (3.21)	74.99 (10.68)	74.09 (11.72)	92.8 (1.03)	92.75 (1.29)	-8.35 (0.70)	-8.46 (0.72)
α	.61	.95	.44	.92	.10	.76	.63	.95

Table 4: Cronbach's alpha of physiological features during sadness.

Time	SCL		HR		meanSKT		meanPPG	
	BAS	EMO	BAS	EMO	BAS	EMO	BAS	EMO
1	4.99 (2.87)	5.48 (4.42)	70.54 (10.15)	70.79 (10.20)	90.31 (0.02)	90.31 (0.02)	-8.48 (0.91)	-8.38 (0.92)
2	3.90 (2.48)	3.33 (2.50)	69.19 (8.57)	68.05 (8.32)	90.30 (0.02)	90.31 (0.04)	-8.11 (0.85)	-8.14 (0.80)
3	4.65 (2.62)	3.84 (2.42)	69.42 (7.78)	68.98 (8.74)	90.30 (0.04)	90.29 (0.01)	-8.07 (0.80)	-8.12 (0.84)
4	4.13 (2.03)	3.60 (2.15)	73.27 (9.84)	74.49 (11.83)	90.32 (0.03)	90.28 (0.04)	-8.52 (0.87)	-8.48 (0.85)
5	4.54 (2.46)	4.23 (2.89)	72.90 (10.07)	71.66 (11.61)	93.44 (3.39)	93.86 (3.45)	-8.63 (0.91)	-8.60 (0.98)
6	4.36 (3.21)	4.44 (2.68)	73.11 (9.56)	73.33 (10.57)	93.17 (2.86)	94.84 (1.78)	-8.19 (0.76)	-8.25 (0.70)
7	4.32 (2.55)	4.27 (3.20)	75.17 (9.57)	71.05 (10.07)	93.99 (1.84)	92.57 (4.74)	-7.93 (0.75)	-8.10 (0.87)
8	4.18 (2.89)	4.21 (2.97)	74.56 (10.31)	70.01 (9.98)	92.78 (4.93)	93.36 (3.75)	-8.29 (0.75)	-8.47 (0.94)
9	4.49 (2.56)	3.70 (2.05)	75.14 (10.77)	71.72 (11.32)	93.99 (2.51)	95.27 (1.25)	-8.02 (0.73)	-8.25 (0.91)
10	3.94 (3.41)	3.83 (2.84)	76.96 (12.14)	75.54 (11.15)	92.66 (4.40)	94.60 (2.52)	-8.21 (0.89)	-8.58 (0.99)
M	4.35 (2.71)	4.09 (2.79)	73.03 (10.18)	71.56 (10.88)	92.13 (2.00)	92.57 (1.76)	-8.25 (0.83)	-8.34 (0.88)
α	.63	.95	.48	.96	.22	.53	.57	.96

Table 5: Cronbach's alpha of physiological features during anger.

Time	SCL		HR		meanSKT		meanPPG	
	BAS	EMO	BAS	EMO	BAS	EMO	BAS	EMO
1	5.22 (3.36)	4.92 (3.00)	71.50 (9.45)	70.99 (11.13)	90.32 (0.04)	90.29 (0.03)	-8.42 (0.91)	-8.37 (0.90)
2	4.05 (2.42)	3.56 (2.33)	71.35 (9.31)	68.57 (10.47)	90.32 (0.05)	90.30 (0.03)	-8.14 (0.78)	-8.18 (0.71)
3	4.64 (2.63)	4.29 (3.11)	71.01 (8.91)	68.12 (9.99)	90.30 (0.05)	90.30 (0.05)	-8.07 (0.79)	-8.27 (0.78)
4	3.91 (2.21)	3.77 (2.69)	73.07 (9.62)	71.82 (10.33)	90.31 (0.05)	90.32 (0.03)	-8.55 (0.94)	-8.62 (0.95)
5	4.25 (2.39)	4.45 (3.15)	70.80 (11.11)	68.60 (9.93)	94.36 (1.64)	94.40 (2.03)	-8.64 (0.92)	-8.58 (0.95)
6	4.17 (3.43)	3.93 (2.73)	74.33 (9.06)	74.67 (11.42)	93.13 (3.74)	94.23 (2.05)	-8.64 (0.92)	-8.22 (0.60)
7	4.56 (3.39)	4.11 (3.12)	74.12 (10.23)	71.28 (8.94)	92.15 (4.16)	93.86 (2.10)	-8.34 (0.81)	-8.11 (0.86)
8	3.56 (2.54)	4.80 (3.19)	73.08 (11.06)	70.92 (10.43)	93.55 (4.23)	94.08 (2.22)	-8.26 (0.80)	-8.46 (0.90)
9	3.72 (3.03)	3.31 (2.18)	75.50 (11.79)	73.45 (12.18)	91.80 (4.52)	94.84 (1.98)	-8.29 (0.81)	-8.26 (0.79)
10	4.22 (2.68)	4.23 (3.31)	78.15 (14.77)	75.29 (13.70)	92.56 (3.21)	95.26 (1.27)	-8.27 (0.72)	-8.59 (0.87)
M	4.23 (2.81)	4.14 (2.88)	73.29 (10.53)	71.37 (11.05)	91.88 (2.17)	92.79 (1.13)	-8.31 (0.84)	-8.37 (0.83)
α	.47	.96	.26	.96	.43	.57	.41	.96

Table 6: Cronbach's alpha of physiological signal during fear emotion.

Time	SCL		HR		meanSKT		meanPPG	
	BAS	EMO	BAS	EMO	BAS	EMO	BAS	EMO
1	5.07 (3.11)	5.56 (4.06)	72.77 (10.09)	70.80 (12.05)	90.32 (0.02)	90.29 (0.02)	-8.40 (0.90)	-8.33 (0.90)
2	3.93 (2.75)	4.80 (3.66)	70.49 (7.86)	69.27 (9.55)	90.33 (0.02)	90.27 (0.04)	-8.32 (0.77)	-8.20 (0.74)
3	4.61 (2.86)	4.82 (3.07)	71.60 (7.52)	71.59 (8.77)	90.31 (0.02)	90.29 (0.03)	-8.17 (0.64)	-8.21 (0.64)
4	3.97 (2.00)	4.63 (2.37)	73.84 (10.17)	71.99 (10.39)	90.30 (0.03)	90.29 (0.04)	-8.59 (0.87)	-8.47 (0.85)
5	4.53 (2.27)	5.10 (2.74)	71.77 (10.65)	67.23 (11.02)	94.01 (1.87)	93.86 (1.75)	-8.64 (0.86)	-8.60 (0.90)
6	3.68 (2.59)	5.35 (3.12)	75.30 (11.05)	73.51 (9.46)	94.27 (2.62)	94.35 (1.85)	-8.47 (0.89)	-8.18 (0.69)
7	3.43 (2.19)	4.74 (3.13)	75.99 (10.11)	73.98 (9.19)	92.81 (4.88)	92.44 (3.98)	-8.35 (0.64)	-8.30 (0.85)
8	3.92 (2.64)	5.83 (3.43)	73.33 (10.27)	68.99 (9.98)	94.82 (1.15)	93.63 (2.48)	-8.55 (0.81)	-8.50 (0.82)
9	4.07 (2.51)	4.21 (2.25)	78.05 (6.74)	75.27 (12.91)	94.37 (1.89)	94.90 (1.23)	-8.34 (0.94)	-8.17 (0.87)
10	3.83 (2.83)	4.09 (2.04)	77.58 (12.94)	73.59 (12.04)	95.10 (1.23)	95.14 (1.77)	-8.37 (0.94)	-8.59 (0.93)
M	4.10 (2.58)	4.91 (2.99)	74.07 (9.74)	71.62 (10.54)	92.66 (1.37)	92.55 (1.32)	-8.42 (0.84)	-8.35 (0.82)
α	.57	.94	.46	.96	.37	.71	.71	.96

Table 7: Cronbach's alpha of physiological signal during disgust emotion.

Time	SCL		HR		meanSKT		meanPPG	
	BAS	EMO	BAS	EMO	BAS	EMO	BAS	EMO
1	5.07 (3.11)	5.56 (4.06)	72.77 (10.09)	70.80 (12.05)	90.32 (0.02)	90.29 (0.02)	-8.40 (0.90)	-8.33 (0.90)
2	3.93 (2.75)	4.80 (3.66)	70.49 (7.86)	69.27 (9.55)	90.33 (0.02)	90.27 (0.04)	-8.32 (0.77)	-8.20 (0.74)
3	4.61 (2.86)	4.82 (3.07)	71.60 (7.52)	71.59 (8.77)	90.31 (0.02)	90.29 (0.03)	-8.17 (0.64)	-8.21 (0.64)
4	3.97 (2.00)	4.63 (2.37)	73.84 (10.17)	71.99 (10.39)	90.30 (0.03)	90.29 (0.04)	-8.59 (0.87)	-8.47 (0.85)
5	4.53 (2.27)	5.10 (2.74)	71.77 (10.65)	67.23 (11.02)	94.01 (1.87)	93.86 (1.75)	-8.64 (0.86)	-8.60 (0.90)
6	3.68 (2.59)	5.35 (3.12)	75.30 (11.05)	73.51 (9.46)	94.27 (2.62)	94.35 (1.85)	-8.47 (0.89)	-8.18 (0.69)
7	3.43 (2.19)	4.74 (3.13)	75.99 (10.11)	73.98 (9.19)	92.81 (4.88)	92.44 (3.98)	-8.35 (0.64)	-8.30 (0.85)
8	3.92 (2.64)	5.83 (3.43)	73.33 (10.27)	68.99 (9.98)	94.82 (1.15)	93.63 (2.48)	-8.55 (0.81)	-8.50 (0.82)
9	4.07 (2.51)	4.21 (2.25)	78.05 (6.74)	75.27 (12.91)	94.37 (1.89)	94.90 (1.23)	-8.34 (0.94)	-8.17 (0.87)
10	3.83 (2.83)	4.09 (2.04)	77.58 (12.94)	73.59 (12.04)	95.10 (1.23)	95.14 (1.77)	-8.37 (0.94)	-8.59 (0.93)
M	4.10 (2.58)	4.91 (2.99)	74.07 (9.74)	71.62 (10.54)	92.66 (1.37)	92.55 (1.32)	-8.42 (0.84)	-8.35 (0.82)
α	.57	.94	.46	.96	.37	.71	.71	.96

Table 8: Cronbach's alpha of physiological signal during surprise emotion.

Time	SCL		HR		meanSKT		meanPPG	
	BAS	EMO	BAS	EMO	BAS	EMO	BAS	EMO
1	5.06 (3.45)	6.52 (3.11)	71.08 (11.06)	70.46 (10.52)	90.32 (0.03)	90.30 (0.03)	-8.33 (0.86)	-8.33 (0.95)
2	4.03 (2.85)	4.62 (2.26)	72.96 (9.13)	69.71 (8.49)	90.32 (0.04)	90.30 (0.03)	-8.29 (0.83)	-8.22 (0.74)
3	3.85 (3.39)	3.68 (3.11)	72.04 (7.19)	69.85 (8.17)	90.29 (0.04)	90.30 (0.02)	-8.29 (0.71)	-8.40 (0.59)
4	3.95 (3.03)	4.82 (1.98)	73.75 (8.71)	73.83 (10.51)	90.30 (0.03)	90.31 (0.04)	-8.70 (0.86)	-8.57 (0.87)
5	4.09 (2.21)	4.11 (2.35)	72.44 (13.69)	68.19 (10.48)	93.96 (1.97)	93.87 (2.01)	-8.71 (0.81)	-8.65 (0.87)
6	4.16 (2.90)	5.84 (3.01)	74.75 (10.90)	72.36 (10.94)	94.57 (2.24)	94.38 (1.90)	-8.49 (0.86)	-8.17 (0.71)
7	3.66 (1.55)	4.63 (3.09)	75.60 (11.40)	74.20 (10.11)	94.37 (1.52)	92.40 (4.28)	-8.62 (0.93)	-8.12 (0.75)
8	3.96 (2.38)	5.89 (3.02)	75.94 (11.75)	71.06 (12.19)	93.93 (3.24)	93.02 (4.38)	-8.37 (0.98)	-8.51 (1.00)
9	4.50 (3.14)	4.73 (2.52)	73.68 (10.91)	72.51 (10.93)	94.97 (1.65)	94.71 (1.08)	-8.52 (0.94)	-8.28 (0.98)
10	3.91 (2.50)	4.74 (2.45)	77.85 (11.84)	75.41 (14.23)	94.59 (1.33)	94.89 (2.34)	-8.36 (0.89)	-8.58 (0.96)
M	4.12 (2.74)	4.96 (2.89)	74.01 (10.66)	71.76 (10.66)	92.76 (1.21)	92.45 (1.61)	-8.47 (0.88)	-8.38 (0.84)
α	.79	.92	.54	.96	.10	.54	.71	.96

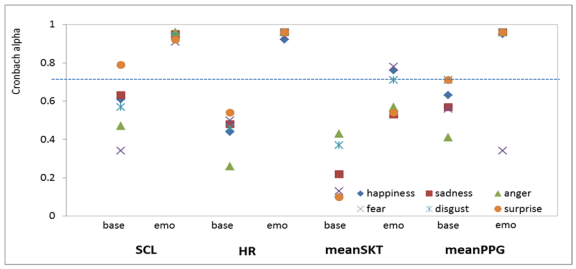


Figure 1: Cronbach's alpha of physiological signal during all emotions.

4 CONCLUSIONS

We have attempted to investigate the consistency on changes of bio-signals induced by emotional stimuli. The used emotional stimuli have been proved to be appropriate and effective in inducing targeted emotions regardless of variety of stimulus (Table 2). They were not only designed to produce active and vivid images, even more effective than those of static emotional stimuli (e.g., facial expressions, slides, and imagery), but also considered particularly advantageous for the clips have already been standardized for conditioning purposes, require little or no deception, and possess a high degree of ecological validity in so far as to effectively evoke emotions via dynamic auditory and visual situations external (Gross and Levenson, 1995; Christie and Friedman, 2004).

In physiological results, despite a small sample size (n=12), Cronbach's alpha, coefficient of internal consistency had range from .10 to .71 in responses during baseline. The lower consistency during baseline may reflect the inter-individual differences of physiological responses. Nevertheless, except for meanSKT, the coefficients of SCL, HR, and meanPPG during each emotional condition were very high, having the range from .91 to .96. The value of alpha greater than .9 means that internal consistency is excellent and alpha value from .7 to .9 is good (George and Mallery, 2003; Kline, 2000). Our result means that physiological responses during emotional conditions are very stable and consistent regardless of variety of emotional stimuli over time.

In conclusion, we have identified the reliability of physiological responses induced by emotional stimuli regardless of various stimuli and time. Our results suggest that physiological responses such as SCL and HR induced by emotional stimuli are very stable and consistent. They can be useful in emotion recognition, developing an emotion theory, or profiling emotion-specific physiological responses,

as well as establishing the basis for an emotion recognition system in human-computer interaction.

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