Big Data Becomes Personal: Knowledge into Meaning: Papers from the AAAI Spring Symposium

Toward Emotional Well-Being: Staying Calm with ECG Feedback

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Abstract

Recently, recognizing emotion through physiological information has flourished. Next research interest is how such information feedback influences user's emotion, because controlling emotions is a key to emotional well-being. Aiming at effective feedback in real-time and daily-usable system, we studied the influence of physiological information feedback on user's emotion using standardized emotional movie clips. We built real-time Electrocardiogram (ECG) visualization system and studied the influence of the feedback. Subjects watched five movie clips while wearing three-lead ECG sensor and the emotions were assessed using a semantic self-report scale. Conditions without-ECG and with-ECG feedback are compared. We found that Heart Rate Variability (HRV) differs significantly when feedback is given. We believe that this study offers implications when designing real-time physiological information feedback system. Finally, a possible study direction toward augmenting emotion with wireless ECG sensor is discussed.

Introduction

Recently, recognizing emotion through physiological information has flourished (Picard 1995) (Broek 2011). Next research interest is how such information feedback influences on user's emotion. For example, we easily get into trouble when experiencing strong emotion like anger or sadness. This kind of emotion leads to misunderstanding of other person's emotion or their situation. In other words, we might not be able to act rationally with strong emotion. Augmenting emotion with physiological information such as Galvanic Skin Response (GSR), Electrocardiogram (ECG) is one possible solution. Toward designing augmented emotion system, we first investigated the effectiveness of physiological information feedback.

Our Goal

Our final goal is to design a system that augments emotion in real-time and daily-usable manner. Toward this goal, we investigated the influence of real-time physiological information feedback on user's emotion using standardized emotional movie clips.

Related Work

Affective Feedback for Emotional Well-being

Van der Veen *et. al.* studied feedback processing and remedial action in schizophrenia using fMRI (van der Veen, Röder, and Smits 2013). While their study suggests that emotion feedback plays a important role in remedial action, fMRI is difficult to use in daily-usabale manner. So we focused on ECG.

The study of Mishra *et. al.* concluded that users accept affective feedback from the computer but do not necessarily respond to it the same way as they do if they receive the same feedback from humans (Mishra 2006). While their study is suggestive in the relationship between humans and computers, our motivation is building self-feedback loop to control user's emotions.

Arapakis *et. al.* published a thought-provoking study on affective feedback while information seeking process (Arapakis, Jose, and Gray 2008). Though this research is suggestive on information seeking in front of computer, our goal is to design augmenting emotion system in real-time and daily-usable manner.

Physiological Information

In this section, we introduce physiological information that is considered to be useful in emotion estimation.

fMRI Functional magnetic resonance imaging (fMRI) is a powerful tool that can visualize brain activity in high resolution. Moreover, it can analyze deep brain activity that is difficult to analyze by EEG (Yuasa, Saito, and Mukawa 2006). However, it requires huge facility so it is difficult to be used in a daily manner.

EEG Electroencephalography is a well-used tool to analyze brain activity (Sourina, Liu, and Nguyen 2011). However, it is sensitive to environmental noise and it is difficult to analyze deep brain activity to assess emotion because of the problem of volume conduction.

GSR Galvanic Skin Response (GSR) is easier to implement and well-used in the field of affective computing (Trappl, Payr, and Petta 2003). It is said to be correlated with arousal, however, assessing emotion using GSR is itself quite a challenge.

ECG Electrocardiogram (ECG) is also well-used tool to diagnose heart problem or autonomic response (Malmivuo and Plonsey 1995). From the ECG signal, Heart Rate Variability (HRV) can be calculated. HRV is an index of emotion estimation. ECG signal is relatively strong so it could be used in a daily situation. Clinical implementation is huge, however, it can be reduced to 3-leads and can be implemented in small-sized device.

Biofeedback

Biofeedback is defined accurately by AAPB(Association for Applied Psychophysiology and Biofeedback) as following text: ”Biofeedback is a process that enables an individual to learn how to change physiological activity for the purposes of improving health and performance. Precise instruments measure physiological activity such as brainwaves, heart function, breathing, muscle activity, and skin temperature. These instruments rapidly and accurately ”feedback” information to the user. The presentation of this information often in conjunction with changes in thinking, emotions, and behavior supports desired physiological changes”(AAPB(Association for Applied Psychophysiology and Biofeedback))

Many research shows that heart rate variability (HRV) biofeedback is an effective approach for helping users to regulate their stress. HRV feedback with resonance frequency breathing encourages outcomes of the sport(Vaschillo, E. G. and Rishe ,N. 1999). HRV biofeedback training may help the athlete cope with the stress of competition and/or improve neuromuscular function(Leah Lagos and Evgeny Vaschillo and Bronya Vaschillo and Paul Lehrer and Marsha Bates and Robert Pandina 2008).

Our goal is suggesting a system that gives users the real-time HRV biofeedback at any time.

ECG-based Biofeedback Chair(Lee and Yoo 2008) is a one of real-time HRV biofeedback system by using ECG. The system allows users to check their ECG while they are sitting in the chair.

An ear-lead ECG based smart sensor system(Shen et al. 2008) is a ultra-wearable smart sensor system that combines electrocardiogram (ear-lead ECG). The system provides the users voice biofeedback for exercise overload warning.

emWave2(Institute of HeartMath) is a portable device of the real-time HRV biofeedback. The device notifies the user the HRV via a LED array meter.

The real-time system and portable systems have been published as described above. However the voice instruction and LED feedback require trainings to understand the heart rate rhythm from the feedbacks. In our research, raw ECG(Electrocardiogram) signal is used as the feedback to reduce training time because ECG signal is easy to read the HRV rhythm than LED feedback and voice instruction.

Heart Rate Variability (HRV)

HRV is an index calculated from ECG signal. It is variation in the time interval between heartbeats. It has psychophysiological meaning which relates to mental stress, anxiety, or cognitive load, etc. (Appelhans and Luecken 2006).

Number of methods for HRV analysis is available. The most widely used methods can be grouped under time-domain and frequency-domain. Table 1 shows the variables and its formula.

Time-domain methods Time-domain methods are based on the beat-to-beat (NN) intervals. They give variables such as SDNN, RMSSD, and pNN50.

- SDNN means the standard deviation of NN intervals. It is often calculated over a 24-hour period.

- RMSSD (”root mean square of successive differences”) means the square root of the sum of the squares of the successive differences between adjacent NNs. RMSSD is and index of parasympathetic nervous activity to control heartbeat.

- pNN50 is the proportion of NN50 (the number of pairs of successive NNs that differ by more than 50 ms) divided by total number of NNs. pNN50 also reflects the activity of parasympathetic nervous activity.

Frequency-domain methods Among the frequency-domain methods, LF/HF is most commonly used variable.

- LF/HF is the ratio of low to high frequency power. It reflects cardiac autonomic balance, greater values reflect sympathetic dominance, smaller values reflect parasympathetic dominance.

HRV variables	formula
SDNN	$SDNN = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(R_i - R_{mean})^2}$ $where R_{mean} = \frac{1}{n}\sum_{i=1}^{n} R_i$ R_i means the time of R wave.
RMSSD	$RMSSD = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(R_{i+1} - R_i)^2}$
pNN50	$pNN50 = \frac{ND_{>50}}{ND}$ where $ND_{>50}$ means number of successive NN differences that are over 50 ms ND means total number of successive NN differences
LF/HF	$LF/HF = \frac{\sum_{i=1}^{n} LFP_i}{\sum_{i=1}^{n} HFPi}$ where LFP_i means Low frequency band power HFP_i means High frequency band power

Table 1: HRV variables and formula

In this paper, we used RMSSD as an index of emotion. The reason is that 1. RMSSD can be calculated in real-time, and 2. it reflects user's parasympathetic nervous activity.

Experiments

Subjects

Eight subjects (six males and two females, 19-35 years old; M: 25.3 years, S.D.: 4.8) were recruited for participation in an experimental session lasting approximately 1.0 h.

Movie clips

Standardized movie clips from Emotional Movie Database (EMDB) were used to elicit the discrete emotions of amusement, anger, sadness, contentment, and a relatively neutral state (Carvalho et al. 2012). The clips were approximately 40 seconds each, and were presented on a 20.1-inch flat-panel display approximately 1m from the subject.

Questionnaires

Experienced affect was assessed using an 18-item affect self-report scale. The scale is consistent with a hybrid model of affective space and contains items traditional to both discrete (amused, fearful, angry, sad, disgusted, and content) and dimensional (good, calm, unpleasant, passive, excited, negative, relaxed, active, positive, agitated, bad and pleasant) models. Responses to all items were based upon a 7-point Likert scale assessing the degree to which the word accurately described affective experience.

ECG recording and Feedback system

Electrocardiogram (ECG) was recorded with the e-Health Sensor Platform (e-H) (Figure 1). The ECG was obtained through Arduino on-board ADC (9600Hz) and the signal is visualized with Heart Rate. (Figure 2)

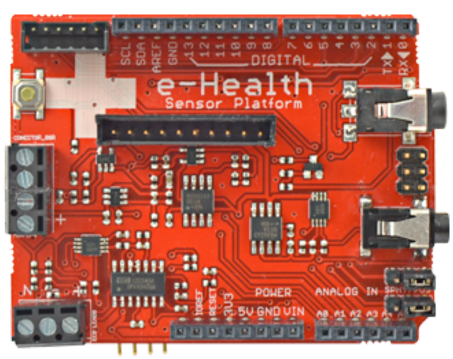

Figure 1: e-Health Sensor Platform

Procedure

First, subjects were told to watch their ECG signal while sitting for about 3 minutes. They had chance to check if their heartbeat is synchronized with the signal drawn in the monitor. This time, experimenter did not lecture the meaning of (or how to read) the ECG signal. Then subjects were told they would be watching a number of short movie clips with different emotional content and that they were told to pay attention to stay calm while watching. Experiment was conducted in a quiet room and subjects were told to wear earmuff for reducing noise. The affect self-report scale was completed after presentation of each movie clip to assess affective responses during the film. Following completion of the scale, a 30-seconds rest was given to subjects. The next stimulus presentation then commenced. This procedure was repeated for the five stimulus conditions. The experimental procedure was divided into two sessions; without-ECG session and with-ECG session. In a with-ECG condition, subjects can look at their ECG signal and heart rate while watching the movie clips. Subjects are divided into two groups; group 1 does without-ECG session followed by with-ECG session, group 2 does with-ECG session followed by without- ECG session. Averaging two groups conditions, the effect of learning was canceled.

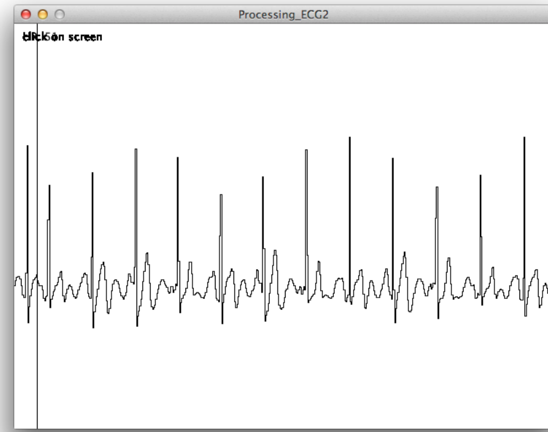

Figure 2: Visualized feedback of real time ECG and Heart Rate.

Results

Elicitated Emotions We observed that elicitated emotions are consistent with the ones EMDB anticipates (Carvalho et al. 2012). The results between conditions (with-ECG and without-ECG) does not show differences. Figure 3 shows the result of questionnaire of Amusement condition as a representative image. The horizontal axis denotes the question number. The order of the question of affect self-report scale is, 1. amused, 2. fearful, 3. angry, 4. sad, 5. disgusted, 6. content, 7. good, 8. calm, 9. unpleasant, 10. passive, 11. excited, 12. negative, 13. relaxed, 14. active, 15. positive, 16. agitated, 17. bad and 18. pleasant. The scores of 1. amused, 6. content, 7. good, 11. excited, 14. active, 16 agitated, and 18. pleasant are higher than other scales.

On the other hand, scores between conditions does not differ greatly. As experimental session lasts only within 1 hour, subjects' impression on the movie clips would not differ significantly between conditions. Other questionnaires in different emotions also show similar result between conditions.

In order to conclude that there is no difference between conditions, two-sided paired-t test of affect self-report scale between with-ECG condition and without-ECG condition are conducted. Confidence intervals are set to 95%. Table 2 shows the result of the test. For any emotions, $p > 0.05$ is true. That means there is no significant difference between with-ECG and without-ECG conditions.

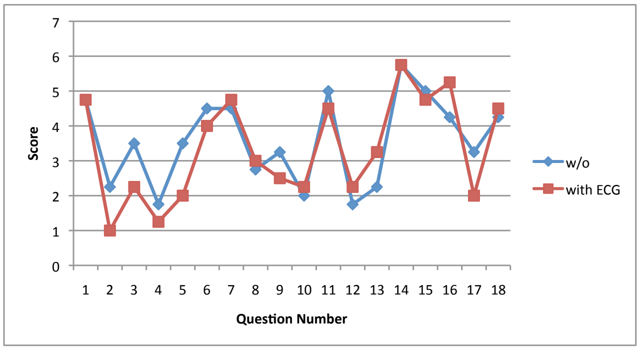

Figure 3: Result of Questionnaire of the Amusement condition.

Elicitated Emotion	p value
Amusement	0.529
Anger	0.427
Sadness	0.83
Contentment	0.091
Neutoral	0.132

Table 2: The result of paired-t test.

HRV differences with feedback Figure 4 shows the result of HRV differences between conditions of all subjects. HRV itself means variance of the heartbeat intervals, so it differs greatly between participants. In this paper, we plotted all the subjects' result in a scatter plot. The differences of averaged HRV is plotted as a black line.

The result shows that HRV significantly decreases with-ECG condition among all emotional stimuli. This suggests the possibility that ECG visual feedback moderates user's HRV.

Discussion

In this paper, we investigated the possibility of augmenting emotion through real time ECG feedback.

The result shown in Figure 3 and Table 2 means that emotions elicitated by movie clips are strong enough that the questionnaires shows no significant differences.

On the other hand, HRV shows significant difference between without-ECG and with-ECG conditions. Together with the result of questionnaire, it suggests tiny emotional differences that subject does not notify are made while watching their physiological information feedback in real time. This implies the possibility of augmenting emotion through real time feedback.

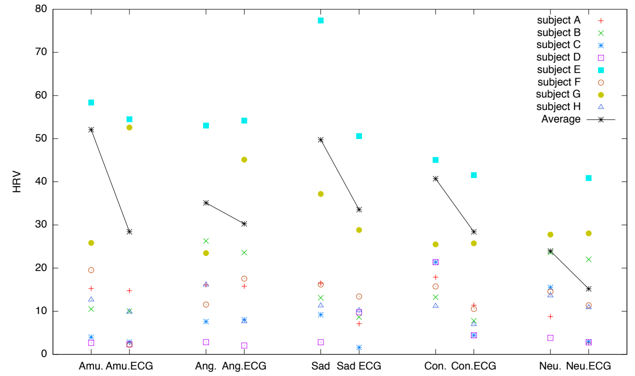

Figure 4: Result of HRV differences. Vertical axis denotes HRV. Key: Amu, Amusement; Ang, Angry; Con, Contentment; Neu, Neutral.

There is a possibility that the user's attention was split between ECG and the movie, therefore the HRV drops. So we are doing quick survey of the difference between visual ECG feedback and simple Gaussian noise feedback (Figure 5). Paired t-test of all conditions shows that $p = 0.0320 < 0.05$, which means that in 95% confidence intervals, there is a significant difference between user's ECG feedback and simple noise feedback.

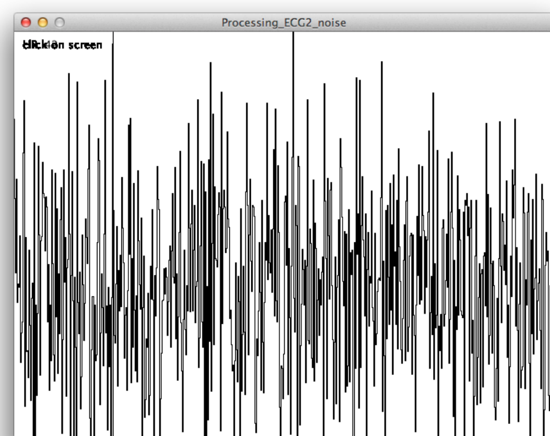

Figure 5: ECG window that displays noise.

Future work

Appropriate feedback

In this paper, we used simple ECG graph and Heart Rate display as a feedback. This is because participants can recognize their own heartbeat rhythm without special knowledge. Different feedback system could be considered using other HRV variable (pNN50, LF/HF, etc.), or other modality (audio feedback, haptic feedback, etc.) We will study on the effectiveness of different feedback systems.

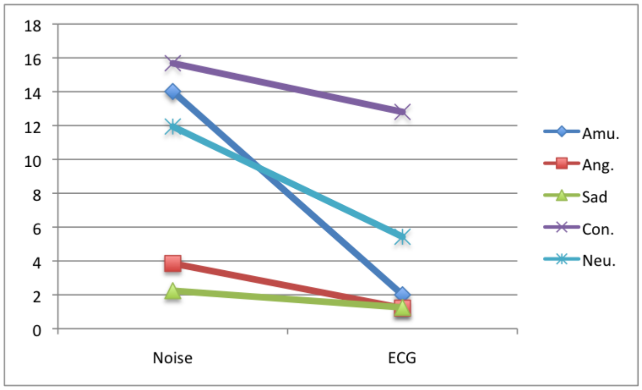

Figure 6: HRV between ECG and Noise feedback

When designing new interface from this, we have to design well. For example, users may not stay calm if HRV variables that is hard to grasp the meaning are displayed. They would feel stressful when they try to grasp the meaning. Or, if the system tells the user's state straight, some of them could become more upset. Some could benefit from pseudo-feedback. Telling ”You are not upset” contrary to real mental state would benefit for users. In conclusion, the application system should make individual difference into consideration.

Wireless ECG sensor

We are designing and implementing small and wireless ECG sensor board that can be used in a daily-life. (Figure 7) The size is 2.5cm x 8 cm x 1.5cm. Our goal is to design augmenting emotion system in real time, daily-usable manner. We will work on this project toward that goal.

Effect on social interaction

In this study, we investigated well-studied one-person emotion analysis using Emotional Movie Database. However, social interaction among two or more persons is crucial for emotion elicitation. We believe this kind of multi-person and real-time emotion analysis should be investigated in this field. We will study this topic using wireless ECG sensor described above.

Acknowledgements

We thank all the subjects who participated in this research. This experiment was conducted under the supervision of the University of Tokyo ethics committee. We also thank EMDB authors who kindly offered the movie clips as stimuli. As for the experimental design, Emi Tamaki gave a useful suggestion for us.

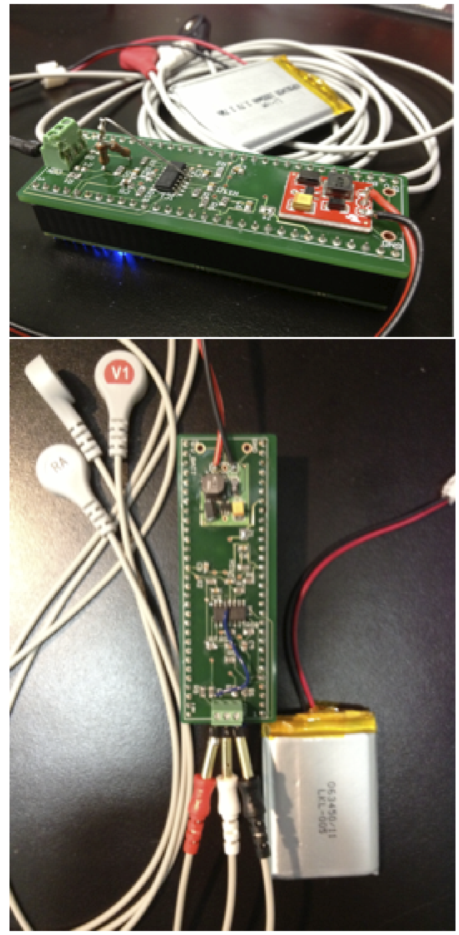

Figure 7: Wireless ECG sensor.

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