Detection of Anger with and without Control for Affective Computing Systems

Elena Spiridon
School of Natural Sciences & Psychology
Liverpool John Moores University
E.Spiridon@2008.ljmu.ac.uk

Stephen H. Fairclough
School of Natural Sciences & Psychology
Liverpool John Moores University
S.Fairclough@ljmu.ac.uk

Abstract

Feedback from affective computing interfaces should improve awareness and self-regulation of negative emotional states, such as anger. The aim of this study was to identify cardiovascular and electroencephalography-based indicators of anger, in combination with level of control. Forty participants were split into four experimental groups: anger/no control, anger/control, neutral/no control and neutral/control. Anger (anger state vs. neutral state) was manipulated via verbal mood induction. In addition, participants were exposed to a computer-based problem-solving task where the keyboard either worked correctly (control) or malfunctioned (no control). Various psychophysiological variables (including blood pressure, cardiovascular impedance, electroencephalography and facial electromyography), in addition to self-report variables, were obtained. Statistical analyses of self-report variables indicated that manipulation of anger and control was successful. Blood pressure and electroencephalography were found to be sensitive to the anger with no control state. Implications of the study are discussed in relation to the development of biocybernetic systems to monitor different categories of anger.

1. Introduction

Traditionally, research on affective computing systems has employed a relatively simple model of emotional valence [1,2]. Current orientations of affective computing prioritize the development of interactive systems that can diagnose states of frustration, as well as disengagement from the task, based on psychophysiological activity [3]. Although such systems are perceived as useful in the context of self-regulation [4] they lack psychological sophistication regarding the definition of *negative emotion*. Moreover, given that an interactive system can also be used as a health-monitoring tool [5] careful consideration has to be paid to what constitutes an *unhealthy* emotion, particularly in the context of performance. The experience of an emotion incorporates cognitive and motivational facets, as well as an affective dimension [6]. Therefore, the adverse health impact associated with negative emotions may be attributed to motivation or cognitions associated with a particular affective state. For instance, anger in combination with lack of coping resources creates a sense of helplessness [7], whereas anger coupled with sufficient resources increases motivation to approach a task constructively. Thus, valid definitions of *negative* emotion and *unhealthy* emotion are required for affective computing systems to trigger self-regulation and assist in health-monitoring.

Emotional systems functionally organize cognitive appraisal [8] and enable adaptive responses [9]. For example, a coping task could be appraised as a positive *challenge* when the perceived resources meet perceived demand or as a negative *threat* when perceived demand exceeds perceived resources [10]. This type of appraisal triggers motivational predispositions for action to either *approach* (to remove the obstacle) or *avoid* the threatening situation [7]. The challenge/threat dichotomy has received some support in the cardiovascular literature. Blascovich and Tomaka [10] argued that challenge is linked to a sympathetic-adrenomedullary (SAM) response whilst threat reflects a pituitary-adrenocortical response (PAC). For instance, SAM involves increased heart rate (HR), greater volume of blood expelled by the heart (cardiac output, CO), amplified contraction of the left ventricle (left ventricular ejection time, LVET) and less resistance to blood flow in the systemic circulatory system (total peripheral resistance, TPR); whereas, PAC activity entails the same kind of response but not to the same extent. This pattern of cardiovascular response was reported by Lovallo et al. [11], who studied the effects of reward/punishment incentives as manipulation of the challenge/threat dichotomy using a single task. Furthermore, the challenge/threat pattern was supported by changes in hormone levels [12]. Loss of control increased cortisol levels leading to an "effort with distress" state, as opposed to the "effort with stress" effect observed in the control condition. Hence, challenge motivation can be triggered when the individual perceives a degree of control over the task, while threat may characterize a situation where the person perceives an absence of control. Stemmler et al. [7] attempted to detach motivational disposition from affect in order to describe different affective-motivational states, such as fear and anger. Such work is based on a division between fear-withdrawal from goals

978-1-4244-4799-2/09/$25.00 ©2009 IEEE

(noradrenergic response) and anger-approach towards goals (adrenergic response). As expressed by Stemmler et al [7] approach motivation serves to stay actively engaged in order to narrow the distance to a challenging task-induced goal. On the other hand, withdrawal motivation serves to increase the distance to a threatening event. This model of emotion-motivation was questioned by Harmon-Jones' [13] work, which distinguishes approach from avoidance responses in an anger-provoking situation based on asymmetrical frontal brain activity. In this case, a single negative emotional category is split by considering two different motivational dispositions as context. Therefore, brain activity could index psychophysiological correlates of anger in combination with approach-avoidance tendencies. Nonetheless, this is an example of how anger can be experienced while challenged as well as while threaten by a lack of control. Specifically, left hemisphere activation is associated with anger/approach whilst right hemisphere activation characterizes anger/avoidance. In sum, research from asymmetrical brain activity supports the motivational model, whereas cardiovascular research confounds emotion and motivation. Hence, a complete cardio-encephalic model of anger and motivational direction has yet to be agreed upon for its effective use in the promotion of healthy behaviour.

To date, a number of interactive computing systems have been developed to account for human error that arises due to dealing with emotions while negotiating a task [1]. However, such systems provide feedback in relation to only loosely-defined emotional states during human-computer interaction [1,3] and fail to consider motivational disposition (i.e., threat, challenge) during the performance of the task. An interactive system that identifies physiological expressions of motivation and emotion and offers biofeedback could raise self-awareness as a strategy for effective emotion regulation based on an accurate appraisal of available coping resources [14]. Thus, the aim of the present study was to identify psychophysiological indicators of anger, in combination with either a sense or a lack of control. The findings may be used to develop a prototype computer system and construct a complete cardio-encephalic algorithm capable of distinguishing between dichotomous states of anger-approach and anger-avoidance.

2. Method

2.1. Participants

Forty one participants, 17 males (age = 27.18 ± 8.91 years) and 24 females (24.79 ± 7.15 years) took part in the study. Personality differences (Ten-Item Personality Inventory validated by Gosling et al. [15]) were controlled, whereby neuroticism and extraversion were equivalent across all four groups; $F(3,37) = .35$, $p > .05$ and $F(3,37) = .47$, $p > .05$, respectively.

2.2. Study design

A between-participant design was employed with a combination of emotion (anger/neutral) and motivation (control/no control) factors resulting in 4 experimental conditions (anger/no control, anger/control, neutral/no control and neutral/control) [7]. Dependent variables included self-reported measures (anger, control and confidence) physiological responses (blood pressure, cardiac activity and facial muscle activity) at two levels (baseline and test), and electroencephalographic (EEG) measures at three levels: baseline 1(eyes–open), baseline 2 (eyes-closed) and test.

2.3. Self-report measures

The State Anger Expression Inventory 2 [16] was used to measure differences in anger levels between pre and post test. The UWIST Mood Adjective Check List [17] was utilized to indicate post-test changes in valance. Confidence and control while performing the task were indexed using the Confidence & Perceived Control Scale from the Dundee Stress State Questionnaire [18].

2.4. Physiological responses

Cardiac activity was recorded using a 4-dual electrode configuration that resembled band electrodes placed on each side of the neck and thorax (adapted from Stemmler et al. [7]). The raw impedance magnitude (zo) and the first derivate (impendence cardiograph (ICG) wave) were measured in real-time. The ICG wave was analyzed using Acknowledge 4 software (BIOPAC Inc.) to calculate a number of cardiovascular impedance parameters including: CO, LVET and TPR. HR was calculated from R–R intervals in the electrocardiogram (ECG). The electronic signal was amplified using BIOPAC TEL 100C with the filters set at 0.5 Hz and 35 Hz, respectively [19]. Other measures included systolic and diastolic blood pressure (BP) obtained using the Dinamap apparatus.

Facial electromyographic activity (fEMG) was obtained from the Corrugator muscles (located just above the eyebrows) using two external electrodes [20] as an indicator of negative emotion. Recorded fEMGs were filtered using BESA software at 0.53 Hz and 30 Hz and transferred to Acknowledge software at a sampling rate of 512 Hz. Artifacts on the fEMG signal due to eye blinks were removed and the final fEMG data was treated using root-mean-square signal processing.

2.5. Electroencephalic measures

Thirty two EEG channels were recorded in order to capture frontal EEG asymmetry (expressed as alpha suppression from left and right frontal sites) [21]. The EEG signals were amplified using BIOSEMI apparatus. The high and low bandpass filters were set at 0.1 Hz and 35 Hz, respectively [19]. The EEG signal was analysed via Fast Fourier Transformer in steps of 2 seconds. Mean percent-power-amplitude values were obtained for the alpha band (8.2-12.9 Hz).

2.6. Procedure

Using a blind protocol to elicit the desired emotional reactions, participants were informed that their task required "participation in a cognitive task". The main experimenter carried out the set-up by acting as an assistant (placing the physiological apparatus, taking baseline measures and asking the participants to fill in the pre-test questionnaires) and then passed the participant into the hands of a fictitious unseen experimenter who could only communicate with the participants by an intercom. All verbal instructions originating from the imaginary experimenter had been prerecorded. The computer task comprised of a 3-minute Number Stroop task, whereby the participants are required to press the keyboard number that corresponds to the number of digits presented on the computer screen. Emotional reactions and motivational directions were manipulated during the performance of the cognitive task. Participants in the anger condition heard three warnings in an increasingly angry tone that told them that they were moving too often (adapted from Stemmler [22]). Participants in the no-control condition experienced problems with the keyboard (one key did not respond) and received erroneous feedback on the computer screen for half of the answers; adapted from Partala and Surakka [23]. At the end of the computer task, the fabricated "assistant" came into the room and asked participants to complete the designated post-test questionnaires avoiding any conversation that may influence the subjective measures. Physiological measures were recorded prior (baseline) the task for five minutes and during the task.

3. Results

The physiological data were corrected for skewness using natural logarithm transformation [19]. The experimental data were subsequently analyzed using SPSS version-16 and any outliers (± 3 SD) removed. A Mixed ANOVA for each individual physiological variable was carried out to investigate differences between the four experimental conditions at two levels (baseline and test). Post-hoc tests were performed using a Bonferroni procedure.

3.1. Self-report measures

Anger manipulation was successful (F(1,37) = 10.88, p < .001). Bonferroni pairwise comparisons revealed that anger state increased significantly (ps < .02), and with higher magnitude in the anger/no control (M = 26.30, SD = 8.81) and anger/control (M = 29, SD = 5.93) conditions, compared to the neutral/control condition (M = 16.18, SD = 3.92). The effect of control was significant (F(3,37) = 36.59, p < .001). Bonferroni-adjusted pairwise comparisons showed that participants in the anger/no control group (M = 4.92, SD = 2.57) reported significantly less control (ps < .001) than participants in the two control groups (anger/control: M = 12.40, SD = 3.03; neutral/control: M = 13.55, SD = 2.25, respectively).

3.2. Cardiovascular responses

The results associated with BP showed significant differences in systolic BP between baseline and test (F(1,37) = 21.25, p < .01). The interaction was also significant (F(3,37) = 3.35, p < .05). The same pattern of results was obtained for diastolic BP (Fs > 1, ps < .03); Figure 1.

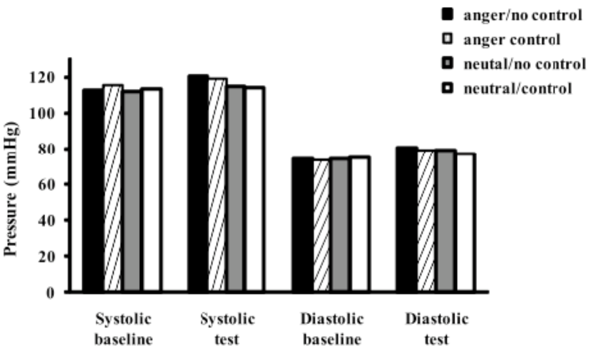

Figure 1: Mean blood pressure according to condition.

Bonferroni-corrected post-hoc t-tests (p < .02) showed that BP (systolic and diastolic) increased significantly in the anger/no control conditions (ps < .01). In the anger/control condition, diastolic BP during the task increased significantly relative to the baseline (t(9) = 7.24, p < .001), while systolic BP almost reached significance (p = .032). Only diastolic BP was found to be significant in the neutral/no control condition (t(9) = 3.40, p < .01). In the neutral/control condition no significant differences were found.

978-1-4244-4799-2/09/$25.00 ©2009 IEEE

Table 1: Mean (± standard deviation) of cardiovascular measures.

	Cardiac output (ml/min)		Left ventricular ejection time (min)		Total peripheral resistance (mmHg/ml/min)	
Condition	**Baseline**	**Test**	**Baseline**	**Test**	**Baseline**	**Test**
anger/no control	6.2 ± 1.4	6.1 ± 1.3	0.31 ± 0.03	0.31 ± 0.03	7.02 ± 0.29	7.09 ± 0.25
anger/control	5.2 ± 1.4	5.5 ± 0.9	0.31 ± 0.03	0.32 ± 0.06	7.19 ± 0.29	7.10 ± 0.18
neutral/no control	5.8 ± 1.1	5.7 ± 0.8	0.31 ± 0.04	0.32 ± 0.04	7.05 ± 0.23	7.10 ± 0.23
neutral/control	5.1 ± 1.1	5.3 ± 2.0	0.30 ± 0.03	0.30 ± 0.03	7.19 ± 0.29	7.23 ± 0.45

Descriptive statistics of cardiological measures (Table 1) indicated CO increase, higher LVET and a decline in TPR in the control (challenge) condition. Suppressed cardiovascular activity was observed in the no-control (avoidance) conditions. However, the differences between baseline and test across conditions did not reach statistical significance (ps > .05).

Normalized corrugator activity showed a slight increase from baseline (M = 2.92, SD = .38) to test (M = 2.98, SD = .43) in the anger and no control conditions and a decrease from baseline (M = 3.01, SD = .29) to test (M = 2.89, SD = .17) in the neutral condition. The EMG responses across conditions (F(3,33) = .085, p > .97) and between baseline and test (F(1,33) = .08, p > .78) did not achieve statistical significance.

3.3. Electroencephalic measures

A difference in scores between Ln (right) – Ln (left) alpha power was calculated for the frontal brain sites (FP2-FP1, F4-F3, AF4-AF3, FC2-FC1) with higher scores demonstrating relatively greater left frontal activity, thus indicative of approach motivation. The power in the alpha bandwidth at the frontal peripheral (FP) site decreased significantly during the task (relative to the baseline) regardless of condition (F (2,64) = 10.02, p < .001, $\eta^2 = .24$); Figure 2.

At the Bonferroni-adjusted p < .03, the only significant difference found was between baseline 2 (eyes-closed) and test in the anger/no control condition (t(9) = 2.82, p < .03).

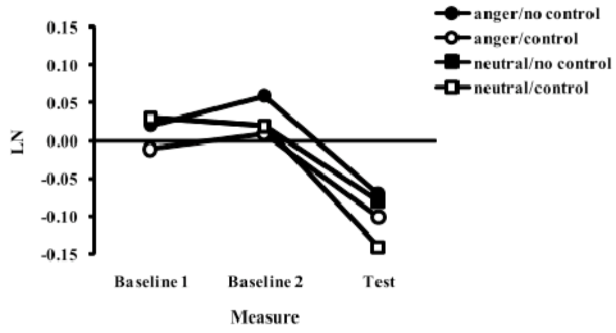

Figure 2: Mean electroencephalography measures.

However, the pattern of results found at the FP site was neither replicated at the mid frontal site (F3-F4) nor at the anterior frontal site (AF3-AF4). In fact, the pattern was reversed with an increased alpha power trend. Specifically, increased alpha power during the test (M = .068; SE = .05) compared to baseline 1 (eyes open) (M = .044; SE = .031) was observed in the anger/no control condition, but the increase was not significant at the F site. At the AF site, the increase was statistically significant regardless of condition (F(1.63; 50.5) = 32.56, p < .001, $\eta^2 = .51$), however post hoc tests did not reveal any significant changes in any of the conditions. At the FC site no significant statistical differences were obtained.

4. Discussion

The present study demonstrates a distinction in terms of BP-related measures between the subjective states of anger/approach and anger/avoidance. The pattern found is partially consistent with the dual model proposed by Blascovich and Tomaka [10] in that higher BP (mainly diastolic) occurs during avoidance/no control situations. However, the fact that systolic BP responded to anger/no control, but not to the absence of control in the neutral affective state, could underline a possible heightening of SAM activity by the combination of anger and the absence of control. The SAM pattern observed for the BP was mirrored by the cardiac parameters (CO, LVET, TPR), however the impedance data failed to significantly discriminate between groups. Such findings could be an indicator of either reduced effectiveness of the manipulations or reduced sensitivity of the measures compared to systolic BP. However, considering that previous studies [7,14] also found it difficult to predict emotion/motivational states from the cardiodynamic variables, the present results cast some doubt over the motivational model put forward by Blascovich and Tomaka [10] and emphasize the need to better characterize the multidimensionality of emotion and motivation.

The pattern of EEG power in the alpha bandwidths was not always consistent with the expected pattern of EEG frontal asymmetry described by Harmon-Jones [13]. Although the FP site showed the expected right brain activation in the anger/no control condition, indicating an avoidance motivation, the F and AF sites showed the contrary. Nonetheless, the only statistically significant result was regarding the Fp site in the anger/no control condition. Considering that systolic BP was also sensitive to the latter condition, it can be assumed that emotion and motivation interact with each other intensifying biological reaction. However, it remains unclear whether emotion enhances motivation or motivation deepens the experience of a negative emotion. Corrugator muscle activity, an indicator of negative affect as claimed by previous research [20], did not distinguish between the anger and neutral conditions. The null results of the corrugator muscle activity in the anger condition could be explained by the fact that the present work tested for differences between negative and neutral emotional states; whereas in the literature differences have been reported between negative and positive affect. The increased pattern of corrugator activity in the anger conditions reflected self-reported anger, but the non-significant results indicated possible confounded motivation with negative emotion.

A limitation of the present study was the exclusion of subjective differences in the appraisal skills. As described by Mauss et al. [14] compared to individuals who are low on reappraisal (not efficient at decreasing negative emotional experience), high reappraisers (successful at down-regulating negative emotion) display relatively adaptive responses; that is, approach when they have control, and avoidance when they lack control. Another possible limitation was the use of a large spectrum of apparatus used. Employing different apparatus to measure BP and cardiovascular indicators of SAM and PAC may have led to lack of consistency of significant findings; as pointed by Wright and Kirby [24] different methodologies yield different results. Nonetheless, the analysis of cardiac measures was performed manually and with a high degree of accuracy, hence the cardiovascular results can only point to an unpersuasive theory [24]. These issues need further investigation to expand on the range of dimensions of emotion and motivational predispositions explained by cardiovascular activity.

On the light of the present findings, the design of future bio-feedback systems should take into consideration that the motivational direction in the analysis of emotion is of great importance and that there might be a trade-off between sophistication of measures and reliability. The simpler measures (systolic BP) are the most sensitive, whereas sophisticated measures such as cardio-impedance may not be sufficiently reliable to be useful. The psychophysiological characterization of anger/control vs. anger/no control may be applied to a safety-relevant task, such as car driving. In situations when the driver is limited in the possibilities of maneuvering the vehicle for advancing purposes (traffic congestions, slow moving traffic) the experience of having no control over the vehicle can lead to an intensified biological reaction, especially if reaching the destination is crucial. Such reactions are not only damaging for health [7] but can also lead to disengagement from the task [3] or rushed actions [25]. In this context, on-board sensors of blood pressure, heart rate, respiration and facial expressions may detect the driver's psychophysiological state and provide feedback by means of a visual message on the dashboard when a negative emotional state reaches undesirably high levels. Future studies are needed towards the development of an on-board biocybernetic system and evaluation of its impact on the driving experience.

5. Acknowledgements

The work was founded by the European Commission within the 7th Framework Programme (FP7) as part of the FET Pervasive Adaptation (PERADA), REFLECT project.

6. References

1. R.W. Picard. Affective computing: challenges. International Journal of Human-Computer Studies, 59: 55-64, 2003.
2. R.W. Picard, and J. Klein. Computers that recognize and respond to user emotion: theoretical and practical implications. Interacting with Computers, 14: 141-169, 2002.
3. A. Kapoor, W. Burleson, and R.W. Picard. Automatic prediction of frustration. International Journal of Human-Computer Studies, 65: 724-736, 2007.
4. M.W. Scerbo, F.G. Freeman, P.J. Mikulka, R. Parasuraman, F. Di Nocero, and L.J. Prinzel, The efficacy of psychophysiological measures for implementing adaptive technology. Report No. NASA/TP-2001-211018.NASA, Hampton, VA., 2001.
5. V. Gerasimov, T. Selker, and W. Bender. Sensing and effecting environment with extremity-computing devices. Offspring, 11: 1-9, 2002.
6. G. Matthews, S.E. Campbell, S. Falconer, L.A. Joyner, J. Huggins, K. Gilliland, et al. Fundamental dimensions of subjective state in performance settings: task engagement, distress and worry. Emotion, 24: 315-340, 2002.
7. G. Stemmler, T. Aue, and J. Wacker. Anger and fear: separable effects of emotion and motivational direction on somatovisceral responses. International Journal of Psychophysiology, 66: 141-153, 2007.
8. J.A. Gray. Integration of emotion and cognitive control. Current Directions in Psychological Science, 13: 46-48, 2004.
9. A.R. Damasio. Emotion in the perspective of an integrated nervous system. Brain Research Reviews, 26: 83–86, 1997.
10. J. Blascovich, and J. Tomaka. The biopsychosocial model of arousal regulation. In M.P. Zanna (Ed.), Advances in Experimental Social Psychology, 29: 1–51. New York: Academic Press. 1996.
11. W.R. Lovallo, G.A. Pincomb, and M.F. Wilson. Predicting response to a reaction time task: heart rate reactivity compared with type A behavior. Psychophysiology, 23: 648– 656, 1986.
12. M. Frankenhauser. A psychobiological framework for research on human stress and coping. In: M.H. Appley and R. Trumbull (Eds.), Dynamics of Stress: Physiological, Psychological, and Social Perspectives. Plenum Press: New York: 1010–1016, 1986.

13. E. Harmon-Jones. On the relationship of anterior brain activity and anger: examining the role of attitude toward anger. Cognition and Emotion, 18: 337–361, 2004.
14. I.B. Mauss, C.L. Cook, J.Y.J. Cheng, and J.J. Gross. Individual differences in cognitive reappraisal: experiential and physiological responses to an anger provocation. International Journal of Psychophysiology, 66: 116-124, 2007.
15. S.D. Gosling, P.J. Rentfrow, and W.B. Swann. A very brief measure of the Big Five personality domains. Journal of Research in Personality, 37: 504–528, 2003.
16. C.D. Spielberger. Manual for the State-Trait Anger Expression Inventory-2. Odessa, FL: Psychological Assessment Resources, 1999.
17. G. Matthews, D.M. Jones, and A.G. Chamberlain. Refining the measurement of mood: Personality UWIST mood adjective checklist. British Journal of Psychology, 81: 17-42, 1990.
18. G. Matthews, and P.A. Desmond. Personality and multiple dimensions of task-induced fatigue: a study of simulated driving. Personality and Individual Differences, 25: 443-458, 1998.
19. S.H. Fairclough, and L. Venables. Prediction of subjective states from psychophysiology. A multivariate approach. Biological Psychology, 71: 100-110, 2006.
20. J.T. Cacioppo, L.K. Bush, and L.G. Tassinary. Microexpressive facial actions as a function of affective stimuli: replication and extension. Personality and Social Psychology Bulletin, 18: 515-426, 1990.
21. J.J.B. Allen, J.A. Coan, and M. Nazarian. Issues and assumptions on the road from raw signals to metrics of frontal EEG asymmetry in emotion. Biological Psychology, 67: 183-218, 2004.
22. G. Stemmler. Selective activation of traits: boundary conditions of the activation of anger. Personality and Individual Difference, 22: 213-233, 1997.
23. T. Partala, and V. Suraka. The effects of affective interventions in human-computer interaction. Interacting with Computers, 16: 295-309, 2004.
24. P. Rainville, A. Bechara, N. Naqvi, and A.R. Damasio. Basic emotions are associated with distinct patterns of cardiorespiratory activity. International Journal of Psychophysiology, 61: 5-18, 2006.
25. R.A. Wright, and L.D. Kirby. Cardiovascular correlates of challenge and threat appraisals: A critical examination of the biopsychosocial analysis. Personality and Social Psychology Review, 7(3): 216-233, 2003.
26. G. Beeli, S., Koeneke, K. Gasser, and L. Jancke. Brain stimulation modulates driving behaviour. Behavioural and Brain Function, 4: 1-7, 2008.