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# Patterns of Autonomic Responses to Affective Visual Stimulation: Skin Conductance Response, Heart Rate and Respiration Rate Vary Across Discrete Elicited-Emotions.

# 정서시각자극에 의해 유발된 자율신경계 반응패턴: 유발정서에 따른 피부전도반응, 심박률 및 호흡률 변화

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**요 약** 이 연구의 목적은 IAPS(국제정저사진체계) 사진자극에 의해 유발된 각각의 주관적 정서상태에 특정적인 자율신경계 반응이 존재하는지를 규명하는 것이다. 부정적 정서(분노, 슬픔, 놀람)와 긍정적 정서(행복, 홍분)를 유발하는 IAPS 사진을 각 60초 동안 제시하였을 때 유발되는 심박률, 호흡률, 피부전도반응을 측정하였다. 시각자극이 주어진 초기 30초 동안 통계적으로 유의미한 심박률 감속 및 호흡률 감소를 보여주었으며, 뚜렷한 피부전도반응이 출현하였다. 심박률 감속은 혐오보다 홍분에서 더 크게 나타났고, 피부전도반응의 진폭은 혐오보다 홍분에서 더 큰 것으로 나타났다. 한편, 피부전도반응의 진폭이 상승하는 시간은 슬픔, 행복, 놀람보다 혐오에서 더 짧아지는 경향을 보여주었다. 이와 같은 자율신경계 반응(심박률, 호흡률, 피부전도반응)은 정서상태간에 뚜렷한 차이를 보여주며, 특정 정서상태에서 자율신경계 반응은 개인차가 있기는 하지만 전체적으로 매우 전형적인 반응패턴을 보여주었다. 본 연구의 결과는 정서 특정적인 자율신경계 반응이 존재할 가능성을 시사해주며, 생리신호분석을 통해서 심리적 정서를 결정할 수 있는 형판(template)의 구성을 위해서 다양한 자율신경계 정서반응의 지표를 포괄적으로 측정 분석하는 후속연구가 요구된다.

**핵심단어** : 피부전도도, 심박률, 정서유발 시각 자극, 정서-특정적 자율신경계 활동

## Introduction

The question of emotion-specificity of autonomic nervous system (ANS) responses has always been in the focus of psychophysiological research. The topic of autonomic specificity has been intensively explored for decades (Ax, 1953; Sternbach, 1962; Ekman et a., 1983; Levenson, 1992, 1994; Levenson et al., 1990; Cacioppo et al., 1993), and it was shown that ANS-mediated physiological responses are intimately tied to emotions. However, the ability to differentiate emotional states by their autonomic manifestation still remains controversial. As it was emphasized by Levenson (1994), who studied autonomic distinctions among emotions utilizing facial action and relieved emotions tasks, it was possible to identify only small number of fairly reliable autonomic differences among negative

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emotions under study (anger, disgust, fear, sadness) and also some differences between negative emotions as a group and the positive emotion of happiness.

There were applied efforts to find most reactive single autonomic variables or whole patterns of several autonomic responses associated with specific emotions in different experimental paradigms (Lawler, 1980; Schwartz et al., 1981; Winton et al., 1984; Vrana, Lang, 1990; Bloch et al., 1991; Ohman et al., 1993; Cuthbert et al., 1996; Lang et al., 1993, 1997). Comparative analysis of changes of particular ANS measures in emotions evoked by these manipulations gives certain advantages to application of electrodermal and cardiorespiratory variables and their patterns in attempt to distinguish human basic emotions (Schwartz et al., 1981; Stern, Sison, 1990; Bloch et al., 1991; Boucsein, 1992; Levenson, 1992; Lang et al., 1993, 1997; Lang, 1995). Electrodermal activity (EDA), namely skin conductance response (SCR), reflects according to a majority of the experimental data, specifically the arousal or activation aspects of emotion, while is less sensitive to its valence (Ohman et al., 1993; Lang, 1995; Cuthbert et al., 1996). SCR amplitude during emotionally evocative slides showed U-shaped course, being higher in pleasant and in unpleasant stimuli than in neutral ones (Winton et al., 1984). In other affective visual stimulation experiments, larger SCR was related to increased arousal level, but not to valence rating (Lang et al., 1993; 1997; Cuthbert et al., 1996). The effects of emotionally arousing stimuli on phasic and tonic components of electrodermal activity as well as other SCR related issues are discussed in some comprehensive reviews (Boucsein, 1992, Ohnam et al., 1993), which emphasizes the importance and usefulness of EDA implications in emotion research.

Heart rate data in examination of psychophysiology of emotion are more complex. It has been reported that HR accelerated in studies manipulating facial expression (Ekman et al., 1983; Levenson et al., 1990; Levenson, 1992, 1994), and also in those manipulating imagery (Schwartz et al., 1981; Vrana, Lang, 1990; Sinha et al., 1992) and affective situation (Ax, 1953; Sternbach, 1962). Increased HR to visual traumatic stimuli was reported for all subjects by some authors (Christianson, 1987), or only for phobic individuals by others (Hare, 1973; Klorman, 1975). In passive viewing paradigms HR has shown to vary more strongly with valence values during affective picture stimuli, whereas phasic HR response showed deceleration for all affective pictures, with the greatest decrease for unpleasant pictures and the least for pleasant pictures (Braucli et al., 1995; Cuthbert et al., 1996; Lang et al., 1993, 1997). HR deceleration to negative film stimulation and mutilated bodies slides or negative emotional scenes was also reported by several researchers ( Hare, 1973; Klorman, 1975; Winton et al., 1984; Hubert, de Jong-Myer, 1990; Spence et al., 1996). Attention, orienting and emotions may interact in affective picture viewing paradigms and this interaction should be taken into consideration with regard to HR deceleration interpretation, since effects of the above processes are not so easy to separate ( Lacey, Lacey, 1970; Libby et al., 1973; Hare, 1973; Sandman et al., 1977; Jennings, 1986; Ohman et al., 1993; Lang, 1995; Vila et al., 1997).

Respiratory measurements have been shown to differentiate between emotions to certain extent, and also respiration can modulate HR by well-known respiratory influences on HR (Bloch et al., 1991; Rayes, Vila, 1993; Boiten et al., 1994). Analyzing autonomic response patterns during voluntary facial actions, Boiten (1996) concluded, that HR changes are not a consequence of the capacity of facial expression manipulations to recruit emotion-specific activity but might be modulated by physical effort-related changes in respiration pattern and that facial expressions most difficult to produce (anger, sad) showed a larger cardiac acceleration than those easy to produce (disgust and surprise). Decreased respiration frequency and increased amplitude are also other typical responses observed during orienting reaction (Stern, Sison, 1990).

Considerations listed above argue for utility of simultaneous use of HR (as valence sensitive), SCR (arousal sensitive) and respiration rate (HR modulator) parameters in assessment of ANS-mediated responses in affective visual stimulation mode. Physiological specificity cannot be expressed sufficiently in terms of any single variable, but rather a multivariable assessment approach may lead to a better differentiation of emotions in the form of physiological response profiles. Individual differences in cardiac, respiratory and electrodermal reactivity should be encountered by taking into account their tendency to depend on personal psychophysiological profiles and disposition to react consistently under specific stimulation conditions (Stern, Sison, 1990; Boucsein, 1992; Cacioppo et al., 1993).

The aim of this study was to test the assumption that autonomic responses are specific during affective visual stimulation and also to test the capability of recorded ANS parameters or their patterns to distinguish each emotion from other. Another goal of the experiment was to analyze the patterns of autonomic responses and their consistency across and within different affective stimuli.

## Method

***Subjects and procedure.*** Thirty six college students (20-26 years old) of both genders (women 20, men 16) participated in the study. No known neurological disorders or medication were reported. After psychometric tests, brief introduction to experimental situation and attachment of electrodes they were placed in recliner-chair in a sound-proof chamber with dim light. They were instructed to sit quietly with eyes open and watch the screen where pictures were to be presented by a Kodak slide-projector. Participants were left alone for 10 min long adaptation period. Next, baseline measurements of physiological signals were taken. Fourteen slides for 7 discrete emotions were selected from the International Affective Picture System (IAPS). The IAPS numbers for pictures used were: happiness #2340 #2040; sadness #2800 #3350; disgust #3140 #3071; surprise #3170 #3051; exciting # 4460 #4232 ; anger #6550 #9252; fear #3130 #1330. Selected pictures had the highest subjective rating scores for each emotion in our previous study. Baseline values were recorded during 30 s periods, and each picture was presented during 60 s long trial. Two sets of slides were presented in the same order for each subject. Data reduction was carried out for 30 s and 60 s of exposure to stimulus with 30 s long inter-trial resting baselines. Changes of parameter values were computed as compared to relevant baseline levels.

***Equipment.*** Physiological signals were acquired by BIOPAC MP100 hardware with AcqKnowledge III (v.3.2) software. Three Ag/AgCl electrodes were attached for measurement of Lead I Electrocardiogram (512 samples/sec), thoratic pneumogram was recorded with strain gauge transducer, and electrodermal activity was recorded with Ag/AgCl electrodes filled with isotonic Unibase gel. The constant voltage technique was employed to measure skin conductance response (SCR). All signals were processed and mean heart rate (HR), respiration rate (RSR), both on per minute basis, and skin conductance response (SCR) amplitude and amplitude rise time were calculated and averaged in 30 s and 60 s windows. The minimum amplitude of scorable SCR was defines as 0.025 μS phasic change of skin conductance level (SCL). After the preliminary processing of all data, in-depth analysis was carried out for single pictures with the highest subjective rating scores from the pairs preselected for each emotion, namely set of # 2340, # 3140, # 3350, # 3170, # 4232 pictures representing happiness, disgust, sadness, surprise and excitation, respectively. Anger and fear data were excluded from final reduction in the present paper due to the failure of most responses of these emotions to meet criteria of a normal distribution on the histograms. Statistical analysis was performed by SPSS package using one-way ANOVA, Student's t-test for paired samples, and correlation analysis for data with normal distribution of variables (Pearson's coefficients of correlation - r.).

## Results

*Heart rate.* HR responses in all emotional categories were featured by deceleration . HR decelerations were statistically significant in first 30 s in all emotional states, but remained significant for the whole 60 s period only in happy and surprise states (Fig. 1). Histograms of HR changes during stimulation exhibited a normal distribution for each presented emotion category. Comparative analysis of the magnitudes of cardiac responses showed that disgusting pictures evoked the least HR deceleration (Mean=-1.44 beats per minute, bpm) while surprise and sad a larger HR deceleration response (-2.75 and -2.61 bpm respectively in 30 s). However paired-sample t-test did not revealed a significant differences in HR changes between any of two emotional states when the data were averaged for 60 s (Fig 2). Disgust and happy pictures evoked equivalent HR deceleration, smaller than that of surprise, sad or exciting pictures, but difference was not significant statistically. HR changes showed significant correlations among distinct emotions: prompted positive correlation between surprise and disgust (r=0.41, p=0.011), and happy and exciting conditions (r=0.36, p=0.03). No correlation of HR and RSR was observed in any emotional categories. With happiness inducing stimulation there was a modest correlation between HR and SCR rising time (r=0.42, p=0.03). Correlation in HR responses between the first and second presentations of pictures of the same emotion category was significant only in happy state (r=0.37, p=0.026, 30 s base). But on other hand, there were not found no statistically significant differences of HR change when responses were compared for repeated presentation of pictures of same emotion category, as analyzed for 60 s long exposure, suggesting that 30 s data of HR responses may be better for the differentiation of emotions.

***Respiration.*** RSR changes showed an unimodal normal distribution on histograms in all emotional categories except anger and fear, but RSR decrease was rather slight (Fig 3), being significant only in surprise condition (mean =-0.97 breaths per minute, p=0.04, for 30 s only) and sad (-0.86 bpm, p=0.05, for 30 s: -0.91, p=0.037 for 60 s). Difference of the RSR between emotions was not significant (Fig.4 ). Some degree of positive correlation was detected only between disgust and surprise (r=0.35, p=0.03). No significant correlation was observed between respiration and SCR parameters. Comparison of the first and second presentations of the same category stimulation did not reveal correlation of RSR changes, but no significant differences of responses was observed either.

***Skin conductance response.*** SCR to stimulation was observed in most subjects. However, data for 5 subjects did not meet the preset 0.025 μS criteria for SCR amplitude and these data were not included. Mean changes of

SCR amplitude were significant in all emotional stimulation conditions (Fig. 5). SCR expressed a significant correlation but magnitude also varied over emotions. for instance, exciting erotic stimuli had significantly higher SCR amplitude (M= 0.69 $\mu$S) than did disgust stimuli (M= 0.46 $\mu$S, paired t=-2.85, p<0.001). SCR amplitudes in surprise (M= 0.61 $\mu$S), sad (M= 0.64 $\mu$S) and happy (M= 0.57 $\mu$S) were comparable and expressed correlation in surprise vs. happy (r=0.60, p<0.01) conditions. SCR amplitude variaton in exciting state correlated significantly with disgust (r=0.53) and surprise (r=0.59). SCR response amplitude rising time in disgust correlated with happy state (r=0.72, p<0.001), while SCR rising time in exciting stimulation correlated with happy (r=0.46, p<0.05), sad (r=0.56, p<0.01) and surprise (r=0.48, p<0.05). Tendencies of a negative correlation between SCR amplitude and rising time were observed in all pairs of parameters, the highest in surprise (r=-0.25), but none of these coefficients reached significance level. SCR amplitude in the first and second presentations of disgust eliciting pictures was significantly different (t=2.47, p=0.019), but there were not any correlation, while SCR amplitude rising time correlated between repeated presentation of exciting pictures, but t-test did not show any differences of SCR rising time when the same conditions were compared. Baseline skin conductance level (SCL) in all conditions correlated significantly and was not different except anger and fear conditions (t=3.11, p=0.04 for anger and t=2.17, p=0.037 for fear) and that was another consideration why fear and anger data were excluded.

## Discussion

The obtained results show that despite some differences observed between discrete emotional stimulation conditions, overall response patterns of monitored parameters exhibits similar profiles with few variations , suggesting that affective visual stimulation elicits more or less stereotypical transient phasic responses in the given experimental setting, however magnitude of responses may vary over time course and across discrete stimuli. For example, in a case of disgust, HR and RSR endured the least deceleration, and both SCR amplitude and its rising time were lower as compared to other emotions.

The analysis of the physiological measures of ANS activity revealed that IAPS-based affective stimulation evoked idiosyncratic response pattern featured by HR deceleration, scorable SCR and slight decrease of respiration frequency. However, specific emotions (sad, disgust, happiness, surprise and excitation) exhibited certain differences in the magnitude of autonomic responses, in significance of changes vs. baselines and it the time course of the manifestation of the most profound effects. Namely disgust prompted the least decreased HR, a moderate and short-term amplitude increase of SCR, while the sadness pattern obtained showed relatively more reduced HR, more persistent and higher SCR. The highest amplitude of SCR was recorded in exciting stimulation with nude pictures. Meanwhile respiration rate decrease happened to be valid only in surprise and sadness. Furthermore, SCR responses among positive emotions were not uniform; SCR magnitude was greater for erotic than for happiness evoking pleasant valence pictures. Negative emotions comparison showed the most significant differences in disgust-sad and disgust-surprise pairs. Observed changes are not sufficient to prove ability of selected parameters to differentiate emotional states, but supports the assumption that affective visual stimulation evokes specific autonomic response pattern featured by HR deceleration and SCR in the given experimental situation. Integrity of HR inotropic reaction and accompanied SCR is important for understanding of underlying psychophysiological mechanisms. SCR reflects activation dimension (arousal tracer), but physiological arousal only is insufficient to capture the occurence of emotion (Ohman et al., 1993), and in this term HR reactions are more affected by valence dimension (Lang, 1995) of the affective stimuli (valence tracer).

Anyhow, situation, cognitive, perceptual and motor demands should be considered either. Viewing the IAPS pictures is a passive task that is not probably able to evoke strong defensive responses (Lang et al., 1993), which was the main consideration why fear and anger emotions were excluded from further analysis. Used stimuli, even traumatic mutilative slides are rarely evoking reliable defense reactions among subjects. Only a few subjects demonstrated reliable HR acceleration response in our study, which suggests that motionless, restrained vigilance task might not be suitable to compare anger and fear with other emotions in the given situational context.

Nevertheless, the results showed that IAPS pictures are eliciting profound orienting activity and attention, as well as congruent emotional subjective responses, especially such negative emotions (disgust, sadness) that are associated with relatively lower motor demands and typically with the passive avoidance reactions (Obrist, 1982). Attending and orienting processes may have a crucial role in initiation of emotion, since novel eliciting stimuli should capture focal attention first and furthermore evoke orienting response, thus suggesting that orienting, attention and emotion are sometimes overlapping processes, and separation of these effects is complicated task especially in our experimental context (Ohman et al., 1993; Jennings, 1986). Direction of the elicited cardiac changes is a rather important issue in an interpretation of the results of emotion provoking stimulation, because cardiac inotropic response characteristics are providing the possibility to describe type of reaction in behavioral terms and understand its potential central and peripheral neurophysiological mediation. The dynamics of HR changes is another characteristic that reflects autonomic balance in regulation of phasic and tonic cardiac reactions. Peaks of HR responses, their development in time and habituation of reactions are providing valuable information. HR deceleration might be a specific indicator of the onset of attention in orienting (Jennings, 1986), and amplitude of deceleratory change positively correlates with intensity of stimulation. Bradycardia may occur in defense immobilization as well, since picture viewing is a typical orienting task with motor inhibition, tuning of perceptual channels and reduced cardiac efforts (Lang, 1995).

There are several theories regarding interpretation of cardiac deceleration during behavioral manipulations and conceptual suggestions regarding potential psychophysiological processes that cause decrease of HR. More influencial are Lacey's hypothesis of "sensory intake" enhancement (Lacey,Lacey, 1970; Libby et al., 1973; Sandman et al., 1977), the phasic stimulus processing and orienting reflex concept (Graham, Cliffton, 1966) and Obrist's cardio-somatic coupling hypothesis (Obrist, 1982). Taking into regard these psychophysiological concepts, observed HR and RSR deceleration and SCR might be manifestation of autonomic responses involved in modulation of attention processes and/or sensory perception enhancement, as well as entirely emotion-specific ones, and they may also interfere. Obtained changes of autonomic parameters may happen to be markers of both events, or on the other hand, may be different but overlapping in time constructs. Peripheral physiological emotion specificity concept and experimental design intended to discriminate particular autonomic responses during different emotional states depends both on adopted theory of emotion and the model of specificity as it was noted by Stemmler (1992). Physiological profiles obtained in our study had quite similar outcome for different emotions, but magnitudes of autonomic responses were not equal and showed certain discrimination between emotions. Further research are to be carried out to extend the situational context of experimental manipulation to demonstrate consistency and reproducibility of emotion-specific autonomic reactions.

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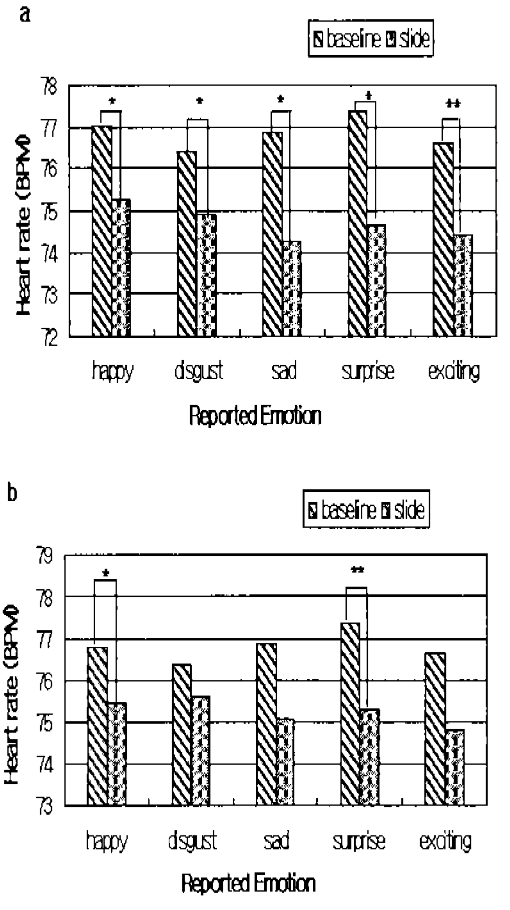

Figure 1. Mean heart rate in baseline resting state and during presentation of IAPS slides for 5 reported emotion (N=35). Fig. 1a demonstrates mean HR for first 30 s after stimulation onset, while Fig. 1b data averaged for whole 60 s period of visual stimulation. On Fig. 1a all HR deceleration responses are significant, meanwhile Fig .1b shows that only happy and surprise states exhibit significance of changes as compared to their baselines.

* - $p < 0.05$ , ** - $p < 0.01$

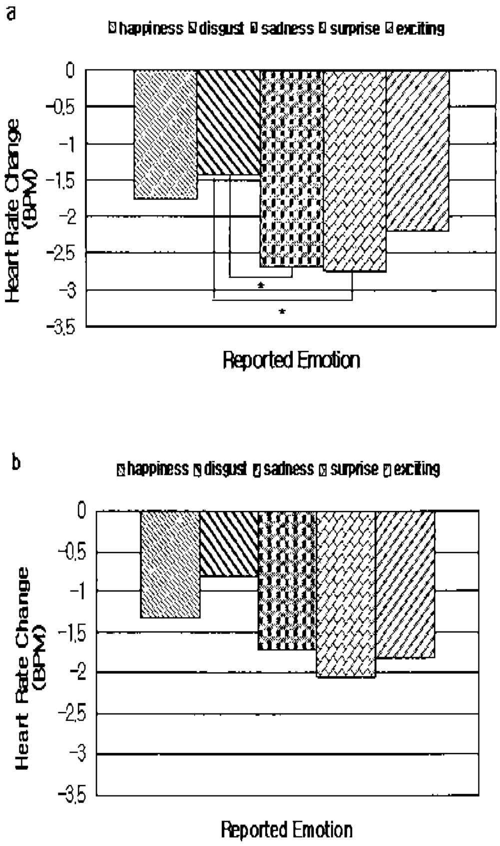

Figure 2. Heart rate changes expressed in beats per minute (bpm) calculated as mean changes compared to relevant resting baselines in first 30 s (Fig. 2a) of affective visual stimulation and whole 60 s period of exposure of slide (Fig. 2b). Differences of HR changes across emotions are significant only in disgust-sad and disgust-surprise pairs, also HR changes have larger magnitude in first 30 s period, nevertheless both figures show identical profile of changes.

* - $p < 0.05$

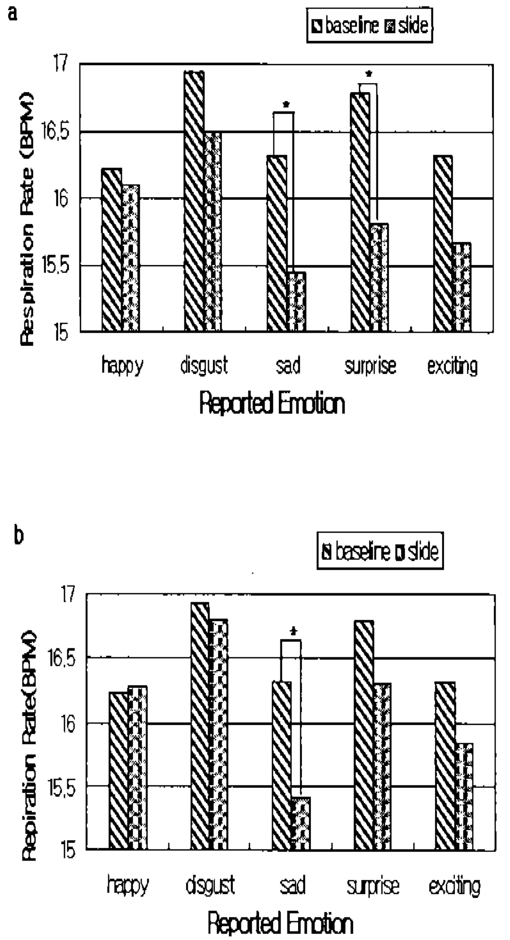

Figure 3. Mean respiration rate in baseline resting condition and during presentation of IAPS slides evoking 5 different emotions (N=35). Fig. 3a demonstrates mean RSR for first 30 s after stimulation onset, while Fig. 3b data averaged for whole 60 s period of affective visual stimulation. On Fig. 3a respiration deceleration responses are significant in sad and surprise conditions, but Fig 3b shows that only sad state exhibits significance of changes as compared to baselines. * - p( 0.05

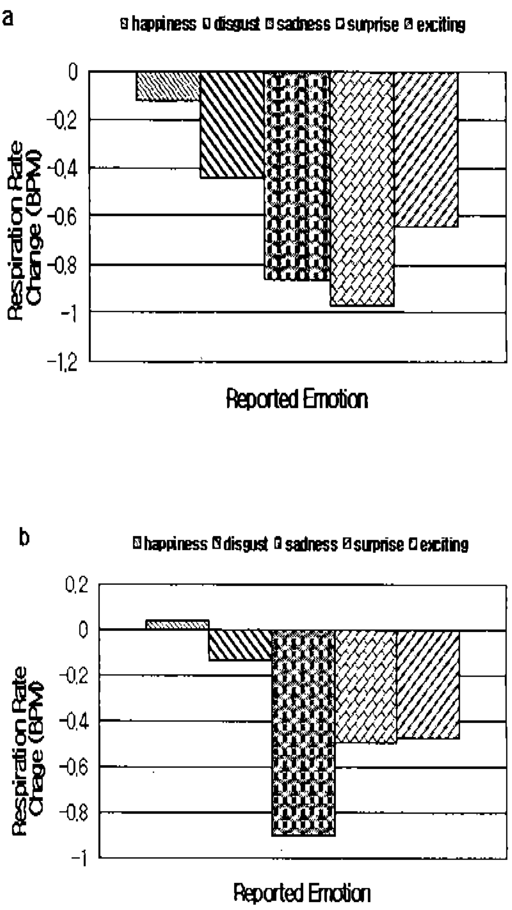

Figure 4. Respiration rate changes in breaths per minute (bpm) calculated as mean changes compared to relevant resting baselines in first 30 s (Fig. 4a) of affective visual stimulation and whole 60 s period of exposure of slide (Fig. 4b). Differences of RSR changes across emotions are not significant. Respiration slowing was persistent for 60 s only in sadness. However, general pattern of differences on both figures is almost similar.

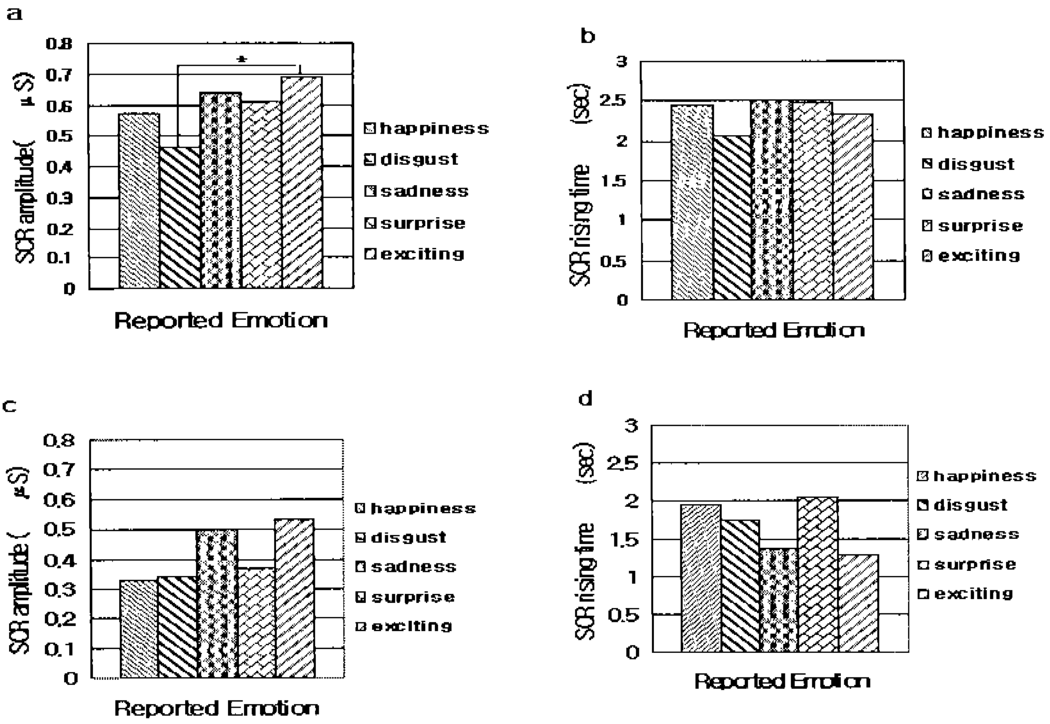

Figure5. Comparison of skin conductance response (SCR) amplitude and SCR amplitude rising time mean values for 30 s and 60 s of IAPS based stimulation (N=30). Only exciting-disgust pair (Fig. 5a) shows significance of differences of SCR amplitudes. Data averaged for 60 s stimulation period shows same covariation as mean values at first 30 s for both SCR amplitude (Fig. 5c) and SCR amplitude rising parameters (Fig. 5b, Fig. 5d).
* - $p< 0.05$

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# Patterns of Autonomic Responses to Affective Visual Stimulation: Skin Conductance Response, Heart Rate and Respiration Rate Vary Across Discrete Elicited-Emotions.

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***Abstract*** The IAPS methodology is effective for examination of ANS activity parameters in search of emotion specific physiology. The IAPS picture set is able to evoke reliable physiological responses and congruent subjective report data in similar situation context. Specific emotions elicited in affective visual stimulation mode exhibited differences of the magnitude of autonomic responses, but overall pattern evoked had similar profiles and was featured by transient phasic HR deceleration, moderate respiration slowing and stable SCR in 30 s following the onset of stimulation. Nevertheless, there were found differences in HR deceleration between surprise and disgust emotions, in SCR amplitude between disgust and exciting, and also other minor variations. Phasic HR changes accompanied by SCR were important to detect occurence of emotional arousal, given that skin conductance is assumed to be more reactive to arousal, while HR is believed to be more sensitive to valence dimension of applied affective visual stimulation. Since HR deceleration and SCR may be also reflecting orienting activity or attention processes, cross-situational experiments would be rather feasible to demonstrate reproducable and context-free emotion-specific invariant autonomic response profiles and thus provide the evidence for more generalized conclusions.