Reproducibility of physiological patterns in disgust visual stimulation design

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Abstract

The paper is addressed to the topic of physiological response-specificity in disgust induced by visual stimulation. The purpose of this study was to evaluate reproducibility of physiological reactivity pattern during disgust elicited by the International Affective Pictures System (IAPS) in 2 experiments. Twenty-nine subjects participated in the first experiment with 3 visual stimulation sessions with disgust-eliciting slides (3 slides in each 1 min long session). In the second experiment disgust-eliciting slides from the IAPS were presented to 42 subjects in 2 sessions (one slide for 1 min). Spectral power of frontal EEG, skin conductance (SCL, SCR and NS.SCR), heart rate(HR), heart period variability(HPV) and respiration rate were recorded. Visual stimulation evoked HR deceleration, higher power of high frequency component of HPV, increased SCL and NS.SCR frequency, frontal slow alpha blocking and moderate increase in fast beta power in most of the sessions in both experiments. However, in the second experiment the EEG pattern associated with disgust showed inconsistent shifts in fast alpha and slow beta bands, but was marked by higher power of theta activity. Our data in both experiments emphasizes presence of disgust-specific profiles of autonomic and at the less extent EEG responses in visual stimulation context. Discussed are potential behavioral mechanisms leading to observed physiological manifestations in disgust elicited by visual stimulation. The results support the consideration that disgust is an withdrawal type negative valence emotion associated with relatively low autonomic arousal (low HR, low amplitude SCRs with relatively high NS.SCR frequency) and moderate EEG activation signs. Obtained data showed more consistent reproducibility of disgust-specific autonomic rather than EEG response patterns during visual stimulation design.

1. INTRODUCTION

There are only few studies combining measures of autonomic (ANS) and central (CNS) nervous system measures during experimentally induced disgust [4,16]. Davidson *et.al.*(1992) presented their subjects emotionally charged film clips and demonstrated greater right-sided frontal activation during a disgust than during a happiness condition. Other studies also showed that disgust elicited higher skin conductance level (SCL), but less respiration amplitude than happiness, less heart rate (HR) changes than sadness [13]. Cacioppo *et al.* (1993) reviewing data on disgust emphasized that the mean change scores of autonomic parameters (namely HR) for disgust were quite moderate, and discussed possible reasons for HR not changing much during such strong emotion as disgust.

As it was outlined by Levenson (1994), several emotions such as disgust are associated with low arousal, or in other words low metabolic demand behaviors and produce less autonomic changes than for instance anger, which is usually associated with high arousal, that may result in high metabolic demand behaviors such as fight-or-flight type actions requiring an increased autonomic support. Therefore, a low behavioral activation tendency on the background of highly negative emotional valence makes disgust an interesting model of passive coping with stress, which shares many common features with pathological states as for instance depression. Thus, in our understanding it should be rather challenging to analyze more deeply disgust as an unpleasant emotion with negative valence, but with relatively low autonomic arousal. The International Affective Picture System (IAPS) by Lang *et al.* (1997) provides one possibility to use standardized pictorial stimuli for eliciting specific emotional states and mapping them on affective space in the dimensions of arousal and pleasantness [5,11,12].

The aim of present study was to identify reproducibility of the physiological effects of affective visual stimulation in two experimental settings with repeated presentation of disgust-eliciting pictures from the IAPS.

2. METHOD

2.1. Subjects and experimental procedure #1

Twenty nine college students (20-24 years old Korean females) participated in the study. After brief introduction to experimental situation and attachment of electrodes they were placed in a recliner-chair in the experimental room with dim light and were left for 10 min for an adaptation and baseline recording. Visual stimulation was delivered by a Kodak slide-projector. Experimental procedure consisted in 3 sessions of stimulation with following regime: pre-stimulation resting baseline recording (1 min), visual stimulation with the IAPS [12] pictures (3 IAPS-slides with mutilated bodies, 20 sec exposure of each slide) and post-stimulation resting baseline (1 min). In the 1st session there were exposed 3 IAPS pictures (IAPS #1113, #3051, #3170) , in the 2nd session - pictures #3140, #1300, #1120, while in the 3rd - slides #3071, #1301, #3130. Order of the sessions was counterbalanced to avoid bias.

2.2. Subjects and procedure # 2.

Forty two college students (20-26 years old) of both genders (men, N=16) participated in the study in the similar experimental setting. Fourteen slides for 7 discrete emotions were selected from the IAPS and were presented in 2 sessions (60 sec exposure). The IAPS numbers for pictures to elicit disgust were #3140, #3071 [12] and they were rated subjectively as the highest among all disgust category slides on unpleasantness scale. Order of the slides was also counterbalanced.

Affective pictures: Slides from IAPS were selected on the base of our preliminary pilot study [15] on 90 college students and were based on their subjective rating using SAM. The pictures were rated as eliciting disgust (3.910.61 on 1-7 scale of disgust). SAM data for the slides were following: arousal 4.89 (0.38), valence 2.67 (0.49), dominance 3.18 (0.39).

2.3. Equipment and physiological measures

In both experiments we used the same experimental equipment and physiological measures.

Physiological signals were acquired by Grass Neurodata System and BIOPAC MP100WS hardware with AcqKnowledge III (v.3.5) software. Sampling rate for all signal was 512 *Hz*.

Electrocortical activity: Grass Neurodata System interfaced via BIOPAC was used to record frontal (F3,F4) EEG monopolarly referred to earlobes. Skin was prepared by abrasive OMNIPREP paste and golden Grass electrodes were filled and fixed by adhesive TEN20 gel. EEG spectral power (FFT, Hanning window) was analyzed for both frontal sites (F3,F4) and relative power (RP) was calculated for following frequency bands: delta (0.5-3.99 *Hz*), theta (4.0-7.99 *Hz*), slow alpha (8.0-9.99 *Hz*), fast alpha (10.0-12.99 *Hz*), slow beta (13.0-19.99 *Hz*), fast beta (20.0-30.0 *Hz*).

Electrocardiogram (ECG), pneumogram (PNG), and electrodermal activity (EDA) were acquired by entire BIOPAC system modules and sensors. Three Ag/AgCl electrodes (EL501 with Signa creme) were attached for measurement of Lead I ECG, and thoratic PNG was recorded with strain gauge transducer (TSD101). EDA was recorded by Ag/AgCl electrodes (TSD103) filled with isotonic Unibase gel (Germany). Constant voltage (0.5 V) technique was employed to measure skin conductance level (SCL) and skin conductance response (SCR).

There were recorded following autonomic parameters:

Electrodermal activity: Skin conductance level (SCL), skin conductance response magnitude (SCR-M, i.e., sum of all SCR with amplitude more than 0.05 μS in epoch), non-specific SCR frequency (NS.SCR) was measured as number of SCRs in 1 min .

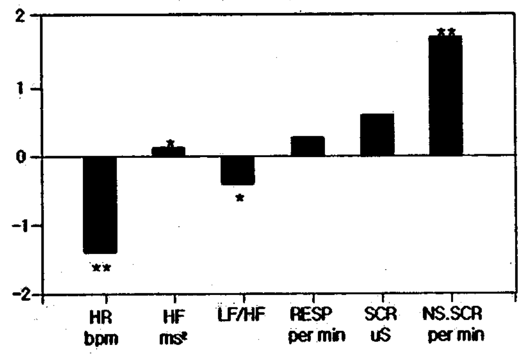
Cardiovascular activity: Heart rate (HR), high frequency and low frequency components of heart period variability (HPV) were calculated as cardiac activity measures. Inter-beat intervals of ECG were re-sampled at 10 *Hz* and analyzed with FFT to assess HPV. Integrals of spectrum in 0.039- 0.146 *Hz* (LF component of HPV) and 0.146-0.400 *Hz* (HF component of HPV) bands were measured (in ms2) [1]. The LF/HF ratio of HPV was calculated to measure ANS balance index.

Respiratory activity: Respiration rate (RESP) on per minute basis, and inspiration wave amplitude (IA) were calculated. PNG FFT analysis was used to identify Peak respiration frequency (PFRQ) as maximum of spectral curve in 0.14 - 0.50 *Hz* range. This measure was used to control HF peak related to respiratory frequencies in HPV [8].

Psychometric measures: Individual subjective ratings of perceived nervousness (anxiety), depression, and stress (7 point rating scale ranging from 1 to 7), and subjective evaluation of disgust elicited by IAPS-slides (7 point rating scale) were used. Questionnaires were given to subjects after each affective stimulation session.

All signals were processed and averaged in 60 sec windows for baseline and stimulation conditions. Data were analyzed by SPSS (v:9.0) statistical package using paired samples t-test.

Fig.1. Profiles of ANS responses in experiment #1 (N=29, 3slides x 3 sessions, means)



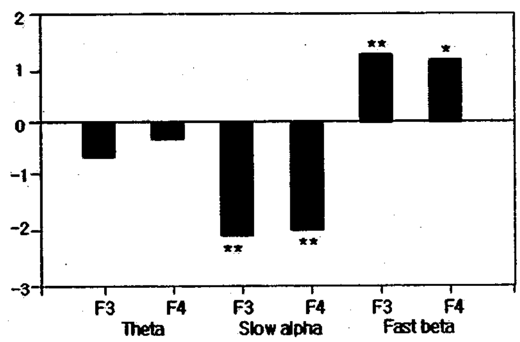
3. RESULTS

3.1. Experiment # 1

Effects of IAPS-based visual stimulation (3 slides x 3 sessions) yielded rather consistent and reproducible pattern of ANS and EEG responses. Differences in all responses between 3 sessions of visual stimulation were not significant, except theta response in the 3rd session and respiration in the 2nd session of IAPS-stress. All responses listed below are presented as the mean differences from baseline with standard deviations for 3 sessions of visual stimulation (M±SD, N=27). Two subjects were excluded from further analysis because they did not had all EEG and ANS parameters recorded.

Autonomic responses. Visual stimulation evoked HR deceleration from baseline (-1.45 ±1.44 BPM, p<0.01), increase of HF power in HPV (0.10±0.13, p<0.01), and decrease of LF/HF ratio in HPV (p<0.05). Most probable reason of HR deceleration was parasympathetic activation seen both in HF increase and shift in autonomic balance due to increase of HF component without significant changes in LF of HPV.

Fig.2. Profiles of EEG responses in experiment #1 Mean changes of RP from baseline (N=30, 3slides x 3 sessions)



Respiration rate did not change significantly (0.20±1.29 breath/min, p>0.05), as did peak respiration frequency, while inspiration amplitude only tended to increase (12.29± 23.29 % from baseline, p=0.06). Correlation of PFRQ and peak of HF in HPV was high (r=0.89, p<0.001), thus emphasizing respiratory sinus arrhythmia mediation of cardiac rhythm variability effects. SCL level increased from baseline (mean 0.09±0.16 uS, t=2.93, p<0.01). Mean SCR amplitude was 0.47±0.36 uS, and non-specific SCR frequency was 1.84±1.43 per min.

Electrocortical responses. Most typical EEG responses to aversive visual stimulation were expressed in slow alpha RP decrease at frontal sites (F3, -2.32 ± 3.17, $p<0.01$; F4, -2.19 ± 3.06, $p<0.001$). Fast alpha did not change significantly from baseline. Fast beta increased at both frontal sites (F3, 1.32 ± 1.99 $p<0.01$; F4, 1.27 ± 2.46 $p<0.05$), while slow beta only at the right side (F4, 0.72 ± 1.64 $p<0.05$). Results of disgust-eliciting visual stimulation, expressed in a form of changes of autonomic and EEG measures are summarized in the in Figures 1 and 2.

3.2. Experiment # 2

Visual stimulation (1 slide x 2 sessions) evoked similar response pattern with HR deceleration, increase of HF component and decreased balance of LF/HF in HPV, slightly decreased RESP, increased EDA (SCR, NS.SCR frequency), and electrocortical activity with frontal alpha-blocking, fast beta power increase and bilateral increase of theta. All differences between responses in both session were not significant and are reported below as mean changes from baselime (M$\pm$SD).

Autonomic responses. HR deceleration (-1.11 ± 2.27 BPM, $p<0.05$) was associated with HF component increase ($p<0.05$) and decreased LF/HF ration of HPV ($p<0.01$). Respiration rate tended to decrease (-0.36 ± 2.75 breath/min) but was not significant. PRFQ and IA were not analyzed in this experiment. Mean NS.SCR frequency was 1.79 ± 1.50 per min with mean SCR amplitude 0.51 ± 0.57 uS.

Electrocortical responses. Response pattern included frontal slow alpha blocking (F3, -1.30 ± 1.57 RP change, $p<0.01$; F4, -1.01 ± 1.70, $p<0.01$), increase of fast beta power (F3, 1.01 ± 2.46, $p<0.01$; F4, 1.44 ± 2.53, $p<0.01$) and bilateral augmentation of theta rhythm (F3, 0.98 ± 1.87, $p<0.05$; F4, 1.32 ± 2.11, $p<0.01$). Slow beta power did not change from baseline, while fast beta tended to decrease at both frontal sites. Results of experiment are summarized in Figures 3 and 4.

Fig.3. Profiles of ANS responses in experiment #2 (N=45, 1slides x 2 sessions, means)

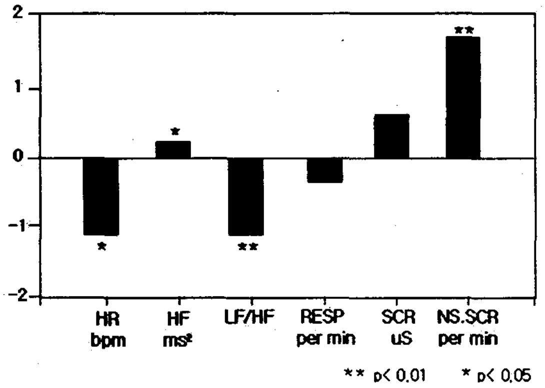
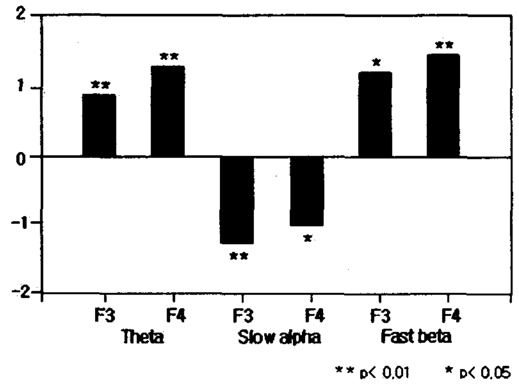


Fig.4. Profiles of EEG responses in disgust (experiment #2). Mean changes of RP from baseline (N=29, 1slides x 2 sessions).



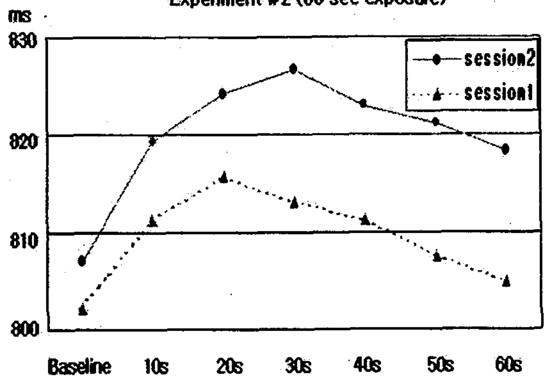
4. DISCUSSION

Repetitive aversive visual stimulation with the IAPS pictures in all sessions evoked reproducible physiological responses: significant HR deceleration, moderate LF/HF balance decrease mainly due to HF component increase, increase of SCL, relatively high NS.SCR frequency with moderate amplitude of SCR, and EEG shifts in a form of increase of fast beta RP values and significant slow alpha blocking effect in frontal areas. Responses of theta, fast alpha and slow beta bands were not reproducible.

Decrease of HR and a tendency for the respiration amplitude to increase, accompanied by increased electrodermal activity and beta power increase in the EEG during passive viewing of pictures or films of negative valence were reported in the literature [5,7,9,11,16] and may be attributed to orienting reaction, motivated attention and behavioral inhibition response [2,3]. Subjective reports acquired after this kind of visual stimulation usually are associated with experiencing disgust emotion, which is usually described as low on arousal and high on negative valence (unpleasantness) dimension scales [11]. Our finding in the present study is that above responses do not habituate over affective visual stimulation sessions, since no signs of adaptation, nor lowered reactivity were observed, thereby suggesting strong motivational and emotional engagement of our subjects during viewing disgust-eliciting IAPS slides. Figure 5 illustrates the similarity of the time course of heart period responses in both sessions during 60 sec exposure to disgust-eliciting slides in the second experiment.

The coincidence between deceleratory cardiac changes (HR decrease, gradual increases of heart period and HF component of HPV) and SCR with high NS.SCR frequency were used to determine the actual occurrence of emotion, taking into consideration 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 [11].

Fig.5. Time course of heart period changes from baseline in 2 sessions with disgust-eliciting IAPS stimulation (N=36)
Experiment #2 (60 sec exposure)



The HF peak of HPV and peak of respiration frequency demonstrated strong correlation showing that HF was actually representing respiratory sinus arrhythmia related coupling and suggested that changes in HF power could be considered as parasympathetically-mediated [1]. Thus during the IAPS-elicited disgust we find increased parasympathetic activation resulted in HR deceleration. Cardiac responses are involuntary responsive to emotional stimulation. The manifestations of cardiac responses provide objective indications of changing psychological status during priming and manifestation of emotion and HR is one of the best discriminators of emotions, especially sensitive to valence dimension of emotional response [4,5,11]. Respiration rate turned out to be less sensitive measure of affect during visual stimulation.

The obvious signs of sympathetic activation were expressed in increased electrodermal activity which is innervated solely by sympathetic system [2]. Negative valence emotion (i.e., disgust) elicited by the pre-selected affective slides (mutilated bodies, victims of accident etc.) was accompanied with such autonomic changes as HR deceleration, heart rate variability changes (HF increase and LF/HF ratio decrease) and high tonic electrodermal activation (NS.SCR increase, SCL elevation). The EEG changes were expressed in frontal slow alpha decrease and fast beta power increase. However, the EEG reactivity in theta, fast alpha and slow beta bands was not showing quite similar profiles across experimental sessions with visual stimulation.

Disgust belongs to emotions with moderate values on the arousal scale, but high scores on the negativity scale in a 2-dimensional affective space [11], and by its motivational category disgust can be considered as a typical example of withdrawal behavioral tendency [7]. Disgust is considered as a universal and primary emotion. It is associated also with stereotyped facial expressions that are understood the similar way across different cultures. Pathways mediating physiological responses in this emotion should be closer to the behavioral inhibition system and represent an interesting model of directional fractionation [10], featured in our study by relatively low cardiac and respiratory activities, but at the same time increased electrodermal and electrocortical activities. Obtained data showed more consistent reproducibility of disgust-specific autonomic rather than respiratory and EEG response patterns during visual stimulation design.

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