한국감성과학회2000추계
학술대회발표논문집

Dynamics of Facial Subcutaneous Blood Flow Recovery in Post-stress Period

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Abstract

The aim of the study was to compare effects of music and white noise on the recovery of facial blood flow parameters after stressful visual stimulation. Twenty-nine subjects participated in the experiment. Three visual stimulation sessions with aversive slides (the IAPS, disgust category) were followed by subjectively "pleasant" (in the first session), "sad" music (in the second), and white noise (in the third). Order of sessions was counterbalanced. Blood flow parameters (peak blood flow, blood flow velocity, blood volume) were recorded by Laser Doppler single-crystal system (LASERFLO BPM 403A) interfaced through BIOPAC 100WS with AcqKnowledge software (v.3.5) and analyzed in off-line mode. Aversive visual stimulation itself decreased blood flow and velocity in all 3 sessions. Both "pleasant" and "sad" music led to the restoration of baseline levels in all blood flow parameters, while noise did not enhance recovery process. Music on post-stress recovery had significant change in peak blood flow and blood flow velocity, but not in blood volume measures. Pleasant music had bigger effects on post-stress recovery in peak blood flow and flow velocity than white noise. It reveals that music exerted positive modulatory effects on facial vascular activity measures during recovery from negative emotional state elicited by stressful slides. Results partially support the undoing hypothesis of Levenson (1994), which states that positive emotions may facilitate process of recovery from negative emotions.

1. Introduction

It has been frequently shown that both auditory and visual stimulation has the property to elicit emotions that can be detected by means of autonomic (ANS) nervous systems measures. In our previous studies [10] we demonstrated that affective visual stimulation in a passive viewing mode evoked a transient ANS response pattern featured by heart rate (HR) deceleration, skin conductance increase, slight decrease of respiration frequency. However, ANS responses varied across discrete emotions. For example, heart period variability (HPV) and respiration rate showed the least deceleration, but higher non-specific SCR frequency in disgust as compared to other emotions. We did not used any measures of vascular activity nor skin temperature in that study.

However, an important component of the pattern of physiological responses associated with emotional responses is such hemodynamic response as a blood flow redistribution controlled by α-adrenergic-mediated constriction of blood vessels supplying skin and other organs and β-adrenergic-mediated dilation of vessels supplying skeletal muscles[9]. An assessment of the changes in the pattern of blood flow through the peripheral vasculature could include blood flow volume, blood flow velocity, and peak of blood flow in each heart beat.[9]. These variables can be non-invasively measured by laser Doppler technique[1]. A single-crystal Doppler systems can be used to measure changes in blood flow velocity (laser light back-scattered from the moving red blood cells) within a vessels and indicate relative change in flow velocity [1,9].

It is well known that skin teperature is significantly dependent on vascular tone and peripheral blood circulation. McFarland (1985) studied effects of music on skin temperature (TEMP) and demonstrated that arousing, negative emotion music (Mars, from G.Holsts Planets) terminated TEMP increases and perpetuated TEMP decreases, whereas the calm, positive emotion music (Venus, from G.Holsts Planets) terminated TEMP decreases and perpetuated TEMP increases. However, the author emphasized that during the second music selection presented in an unbalanced repeated measurement design, results were less reproducible, and noted that the effects of music may depend upon what music has been previously heard[8]. This notion seems to be rather important, since it stressed a possible dependence of the vascular responses in music on preceding tonic levels of arousal.

The results obtained by Iwaki et al. (1995) supported the hypothesis that music exerts an influence on arousal mechanisms, and the different types of music induce both stimulatory and sedative effects on the arousal level . In that study, regardless of the musical type, subjects with high arousal were calmed, while subjects with low arousal were aroused while listening to music. Similar modulation by music was shown in the experiments where autonomic arousal levels were manipulated by cognitive tasks and rest periods before exposure to calm or arousing music[4].

Another important feature of the emotionally positive auditory stimulation such as music may be facilitating the process of recovery from physiological arousal provoked by aversive stimulation. According to the hypothesis of Levenson (1994) the functions of some positive emotional states might be to facilitate the restoration of pre-negative emotion arousal levels. One of the main arguments proposed by Levenson was that positive emotions may not be associated with behavioral activity requiring much of autonomic arousal[7] Namely, some pleasant emotions, such as contentment might not be associated with any particular behavior , or if they are, it would be behavior with little metabolic demands and thus moderate autonomic activation. Levenson (1994) also proposed that one of the primary functions of positive emotions might be associated with undoing the autonomic activation produced by the negative emotions.

This hypothesis recently found some experimental support in experiments using

fear as negative emotion and contentment as a positive one. Results indicated that cardiovascular arousal associated with fear induced by an affective film did in fact dissipate more quickly when followed by the contentment as compared to the sad or neutral films. Fredrickson et al. (1998) demonstrated that two distinct positive emotions advanced recovery from the cardiovascular aftereffects of a negative emotion. The duration of cardiovascular reactivity
(pulse volume, pulse transit time, and blood pressure) elicited by a speech task recovered faster if subjects viewed a contentment film, and slower if the film was neutral [2].

Thus, in our understanding it should be rather challenging to test the undoing hypothesis using visual stimuli-induced disgust as an unpleasant emotion with negative valence, but with relatively low autonomic arousal, and music-induced emotion as a positive one with relatively moderate autonomic arousal, but with relatively high rating scores along pleasantness dimension. The aim of present study was to identify effects of music on the process of recovery and baseline restoration of vascular activity after aversive visual stimulation.

2. Methods

2.1 Subjects and experimental procedure

Twenty nine college students (20-24 year old Korean females) participated in the study. After a brief introduction to the 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, while auditory stimulation was presented through the stereo loudspeakers from Pioneer high fidelity CD player system.

Experimental procedure consisted in three sessions of stimulation with the following regime: pre-stimulation resting baseline recording (1 min), visual stimulation with the IAPS [5] pictures (3 IAPS-slides with mutilated bodies, 20 sec exposure of each slide), followed by 2 min long auditory stimulation, and post-stimulation resting baseline (1 min). In the 1st session there were exposed 3 IAPS pictures (IAPS #1113, #3051, #3170) followed by auditory stimulation with subjectively "pleasant" (1/f) music("Spring song", Victor Musical Industries, Ltd., Japan), in the 2nd session aversive slides (#3140, #1300, #1120) were followed by "sad" (according to subjective reports) music ("Canon", J.Pachelbel, The Music Therapy Charity, Warner Classics, UK), while in the 3rd visual stimulation (IAPS slides #3071, #1301, #3130) was followed by white noise (20*Hz* - 20 *KHz*, 55 dB), which was subjectively evaluated to as non-emotional, but alerting. The order of the sessions was counterbalanced to avoid bias. White noise (WN) was delivered through the same loudspeakers as music and had comparable intensity and loudness.

Music/noise: Pleasant music was selected from a typical relaxation CD (Spring song) featuring natural sounds (bird song, surf of ocean etc.) on a background of piano melody . Manufacturers claimed it as a 1/f frequency music, which is popular in Japan as a light relaxation music that is good for meditation exercises. Pleasant music was subjectively described in reports as soft, romantic, and cheerful, evoking relaxation . Most of the subjects liked the music. Sad music (Canon, Johann Pachelbel) was closer to traditional classic chamber music performed by Orchestre de Chambre (Jean-Francois Paillard) and was more emotional according to subjective reports. This melody was described by subjects as sad, but not annoying, melancholic etc. White noise was subjectively described as annoying, dizzy, uncomfortable, alerting, but not emotional at all .

2.2. Equipment and physiological variables

Physiological signals were acquired by Laser Doppler Blood Flow Monitor (LASERFLO) BMP403A interfaced via BIOPAC MP100WS hardware with AcqKnowledge III (v.3.5) software. Sampling rate for all signal was 512 *Hz*.

Blood flow: The LASERFLO Model BMP403A Blood Perfusion Monitor (TSI Inc., USA) was used to non-invasively measure capillary blood perfusion parameters such as blood flow, volume, and velocity(Anderson,1989). The LASERFLO device uses laser Doppler technology to measure: 1) blood flow (FLOW) in ml/min/100g of tissue; 2) blood volume (BV) expressed as the average number of Doppler shifts per photon (maximal BV is 1.60 and is proportional to concentration of red blood cells (RBCs) in tissue); 3) blood velocity (VEL) proportional to average velocity of moving RBCs in capillaries and expressed as mean Doppler shift frequency (in *KHz*). The probe was attached to forehead by adhesive material. BMP 403A device was interfaced via BIOPAC 100WS.

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 auditory stimulation condition.

All signals were processed and averaged in 60 s windows for baseline and stimulation conditions. The auditory stimulation data were measured on per minute basis and then averaged for whole 2 min long condition. Data were analyzed by SPSS (v.9.0) statistical package using paired samples t-test, one-way ANOVA and post hoc Tukey test.

3. Results

Effects of IAPS-based visual stimulation yielded rather consistent and reproducible pattern of blood flow responses. Blood flow parameters demonstrated all signs of vasoconstriction which were expressed in decreased FLOW (-0.04 ± 0.03 ml/min/100g, $t=-4.18$, $p=0.002$), decreased peak of blood flow in each cardiac cycle (PKFL, -17.51 15.94 %, $t=-3.64$, $p=0.005$), and decreased blood flow velocity (VEL, -0.14 ± 0.13 kHz, $t=-3.76$, $p=0.003$). Blood volume(BV) responses in all sessions were not significant and BV reactivity in general was quite low.

To assess effects of music/noise on process of recovery after stress modeled by aversive visual stimulation, post-stress period responses were analyzed during music/noise and post-music/noise resting period (restoration). Pleasant music was characterized by increases in FLOW (

t=3.93, p=0.001), blood VEL(t=2.65, p=0.02) and peak of blood flow (t=3.16, p=0.006). PKFL increase as well marginally in sad music condition(t=2.13, p=0.048), and decreased in WN(t=-2.25, p=0.047). BV did not differentiate effects of music.

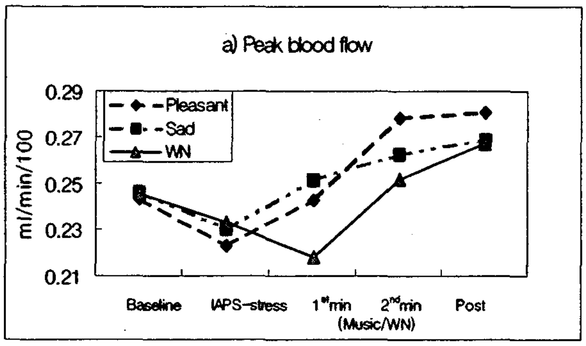

Figure 1. Dissociation of peak blood flow in music and white noise at the 1st minute of auditory stimulation. Peak blood flow which was decreased in all 3 IAPS-stress conditions continue to decrease at the 1st min of white noise , whereas increased in both music conditions. The 1st min tonic values of PKFL were significantly different for WN-sad music pair (t=-2.41, p=0.029). The 2nd min of auditory stimulation and post-stimulation period did not yield differentiation of PKFL levels. PKFL decreases at the 1st min of white noise followed by habituation of the responses on the 2nd min .

One-way ANOVA test showed differences between music (both pleasant and sad as one music group) and WN effects in FLOW (music vs. noise, F[1,48]=4.89, p=0.032) and RESP (music vs. WN, F[1,79]=4.19, p=0.044). Multiple comparisons of pleasant, sad music and WN conditions showed marginal differentiation between pleasant music and WN in FLOW(p=0.048). Blood flow parameters (FLOW, PKFL, and VEL) fully recovered and demonstrated rebound in all auditory stimulation conditions without significant differentiation of the effects of pleasant music, sad music and white noise. The dynamics of peak blood flow changes are shown on Fig. 1. Peak blood flow exceeded initial baseline levels only in the post-pleasant music condition (32.12±49.77 %, t=2.50, p=0.025). ANOVA did not show differences in pleasant, sad music and WN conditions in the restoration of the autonomic parameters.

Subjective ratings did not differentiate effects of sad, pleasant music and white noise on perceived anxiety, depression or stress elicited by aversive visual stimulation with the IAPS.

4. Discussion

The decrease of blood flow parameters during aversive visual stimulation can be assumed as vasoconstriction mediated by α-adrenergic sympathetic influences (Anderson, 1989; Papillo & Stern, 1990). Thus, the experimental model of background state on which auditory stimulation was delivered in the present study was a vasoconstriction.

Blood flow parameters, which were decreased in IAPS-stress, increased in both music conditions, whereas they decreased under white noise. However, in the post-stimulation period blood flow recovered fully, even after WN (Fig. 1). The negative valence emotion (disgust) elicited by the pre-selected affective slides (mutilated bodies, victims of accident etc.) was accompanied with such autonomic changes as vasoconstriction (decrease of blood flow parameters). The correspondent subjectively experienced emotion should be located in moderate arousal, low pleasantness position of the two dimensional map of affective space. Subsequent music exposure led to physiological response pattern characterized by increase of vascular activity (blood flow increase),

Emotional state in music should be characterized by shift in affective space to higher arousal, pleasant (pleasant music) or higher arousal, less pleasant (sadness) direction. Recorded changes were manifested not only during music condition but as well in post-music resting period. White noise did not exert any significant influences on recovery and elicited stimulus-specific changes only, such as an orienting response (further decrease of blood flow) after onset of noise with subsequent habituation on the 2nd min of WN exposure (Fig. 1). Most obvious preferential effects of music as such in restoration of initial baselines after visually elicited negative emotions were seen in comparison to white noise, whereas differentiation of the effects of different kinds of music in our study were minimal. Therefore, our results cannot be considered as directly supporting the undoing hypothesis (e.g., demonstrating effects of positive emotion on recovery from negative emotional state), but at the same time supported effectiveness of the application of music to facilitate recovery from disgust elicited by aversive visual stimulation. Modulatory effects of music were manifested in the changes of blood flow parameters in directions opposite to those induced by aversive visual stimulation. Post-stress positive facilitatory influences of music were significantly more effective than those of white noise, thus showing that they might be more depending on affective content rather than only auditory modality of stimulation.

Acknowledgments

This work was supported by KOSEF research grant to Jin-Hun Sohn.

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