PHYSIOLOGICAL INDICATORS OF EMOTION AND ATTENTION PROCESSES DURING AFFECTIVE AND ORIENTING AUDITORY STIMULATION

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청각자극에 의해 유발된 정서 및 주의반응의 생리적 지표

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Abstract

In the experiment carried out on 20 college students, recorded were frontal, temporal and occipital EEG, skin conductance response, skin conductance level, heart rate and respiration rate during listening to two music fragments with different affective valences and white noise administered immediately after negative visual stimulation. Analysis of physiological patterns observed during the experiment suggests that affective auditory stimulation with music is able to selectively modulate autonomic and cortical activity evoked by preceding aversive visual stimulation and to restore initial baseline levels. On other hand, physiological responses to white noise, which does not possess emotion-eliciting capabilities, evokes response typical for orienting reaction after the onset of a stimulus and is rapidly followed by habituation. Observed responses to white noise were similar to those specific to attention only and had no evidence for any emotion-related processes. Interpretation of the obtained data is considered in terms of the role of emotional and orienting significance of stimuli, dependence of effects on the background physiological activation level and time courses of attention and emotion processes. Physiological parameters are summarized with regard to their potential utility in differentiation of psychological processes induced by auditory stimuli.

Introduction

There are surprisingly few studies that address the issue of differentiation of autonomic and cortical responses specific to emotion and attention processes during auditory stimulation. Our previous studies supported the idea that effects of auditory stimulation are often manifested in the pattern of physiological responses where attentional and emotional components were mixed up and defied clear differentiation [13, 14]. Survey of the relevant references indicated that auditory affective stimulation is able to evoke emotional reactions accompanied by the autonomic and electrocortical responses [2,3,10,11,12]. It was also demonstrated that some physiological responses (EEG, facial EMG, cardiovascular activity, respiration) distinguish among the basic emotions elicited by different laboratory manipulations such as imagery, facial expressions etc. [1,3,10,12]. Physiological responses during orienting reflex and focused attention to external cues are also well established and described [6,9, 11,15,16].

There are also only few studies regarding systematic investigation of relationship between music and electrocortical activity [4]. One of the findings was that music evoked both calming and stimulating effects depending on ongoing general cortical activation level of subjects. Arousal-modulatory effects of different affective music on EEG activity and effects of repetitive exposure of music on subjective and physiological responses were reported by Iwaki et al. (1997), and functional relation between music and brain activation discussed. The authors emphasized that two processes occur during presentation of music. One process is orienting response and habituation, the other process involved attention to music accompanied by changes in feelings, I. e., emotion [4]. At the same time individual differences in responses add further complications in understanding of the patterns specific to emotion and attention and makes a task of concretization of the above processes even more challenging.

The aim of present study of physiological responses to affective auditory stimuli (music) was to compare with reaction to orienting reflex evoking stimulus (white noise) in order to identify patterns of activity specific to attending and entire experience of emotion.

Method

Twenty female college students (20-24 years old) participated in the study. They were placed in a recliner-chair in the room with dim light and were left for 10 min for an adaptation and baseline recording.

Experimental procedure consisted in 3 sessions of stimulation with following regime: pre-stimulation resting baseline recording (1 min), visual stimulation with International Affective Picture System (IAPS) [8] pictures (3 slides with mutilated bodies, 20 sec exposure of each) followed by 2 min long auditory stimulation, post-stimulation resting baseline (1 min). In the 1st session there were exposed 3 IAPS pictures followed by auditory stimulation with subjectively "pleasant" (1/f) music ("Spring song", Victor Musical Industries), in the 2nd session by "sad" (according to subjective reports) music ("Canon", Music Therapy, Erato, Inc.), while in the 3rd by white noise (20Hz - 20 KHz, 35 dB), which was evaluated as non-emotional, but alerting. "Pleasant", "sad" music and white noise will be further in the text referred to respectively as P-music, S-music and WN.

Physiological signals were acquired by BIOPAC MP100 hardware with AcqKnowledge III (v.3.2) software. Constant voltage technique was employed to measure skin conductance level (SCL) and skin conductance response (SCR). ECG and pneumogram signals were processed and mean heart rate (HR), respiration rate (RSR), as well as SCR amplitude were calculated and averaged in 60 s windows. There was scored also mean number of SCR during each stimulation condition. Monopolar EEG was recorded from frontal, temporal and occipital sites (F3, F4, T3, T4, O1, O2 by 10/20 system, referent electrodes on ipsilateral earlobes). EEG power values were calculated using FFT for following bands: delta 0.5-3.9 Hz, theta 4.0-7.9 Hz, alpha 8.0-12.9 Hz (slow alpha 8.0-9.9 Hz; fast alpha 10.0-12.9 Hz); beta 13.0-30 Hz (slow beta 13.0-19.9 Hz; fast beta 20.0-30.0 Hz). Statistical analysis was performed by SPSS package using Student's T-test for paired samples, one-way ANOVA and Post-hoc Tukey test.

Results

ANS responses. Effects of affective visual stimulation resulted in consistent HR deceleration in all 3 sessions. P-music evoked further deceleration of HR (-1.64 bpm as compared to IAPS condition) at 1st minute of stimulation and at less extent at 2nd minute (-0.36 bpm), with full recovery of pre-baseline HR after stimulation. S-music led to HR acceleration during whole period of stimulation (mean 2.59 bpm, $p < 0.01$). Comparison of effects of P-music and S-music revealed significance of HR differences both at 1st and 2nd minute of stimulation. HR during listening S-music was also significantly higher than during WN(1.76 bpm higher in S-music, $p < 0.05$). WN resulted in further HR decrease as compared to IAPS stimulation and baseline conditions at 1st min, habituation of HR response at 2nd minute followed by total restoration in post-stimulation.

Visual stimulation evoked slight decrease of respiration rate. Effects of both conditions with music stimulation were similar and can be described as RSR increase, nevertheless, RSR acceleration was significant as compared to visual stimulation and resting state only while listening to S-music. Comparison of RSR responses across auditory stimulation showed that RSR in WN was significantly lower (at 1st minute of stimulation, WN vs. S-music was -1.68 bpm, $p < 0.01$; WN vs.

Table 1. Visual stimulation effects

Affective visual stimulation (IAPS) evoked changes compared to baseline							
	ANS Variables				EEG Relative Power		
Session	HR	RSR	SCL	SCR amplitude	O2 Delta	O2, F3, F4 Slow alpha	T3 Theta
1st	↓	↓	↑*	1=2=3	↑*	↓*	↓
2nd	↓*	=	↑*	1=2=3	↑*	↓*	↓
3rd	↓*	↓	↑	1=2=3	↑*	↓*	↓
Summary	↓*	↓	↑*	1=2=3	↑*	↓*	↓

= no changes, ↓ decrease to baseline, ↑ increase to baseline, * - $p<0.05$,
1=2=3 : SCR amplitude did not differ significantly across 3 sessions

Table 2. Auditory stimulation effects

2-1. Affective music and white noise evoked changes compared to IAPS-level (1st and 2nd min. of stimulation)								
	HR	RSR	SCL	SCR amplitude	O2 Delta	O2 Slow alpha	F4 Slow alpha	T3 Theta
P-music(PM)	↓ ↓	↑ ↑	↓* ↓	PM1<SM1<WN1* PM2=WN2<SM2 PM1<PM2	↓* ↓*	↑* ↑*	↑* ↑*	↑* ↑
S-music(SM)	↑* ↑*	↑* ↑*	↓ ↓*	PM1<SM1<WN1* SM2>PM2<WN2 SM1<SM2	↓* ↓*	↑* ↑	↑* ↑*	↑ =
WN	↓ =	↓ ↓	= ↓	WN1<SM1<PM1* WN2=PM2<SM2 WN1<WN2*	↓* ↓*	↑* ↑	↑ ↑	= ↑

First arrow corresponds to changes at 1st min., while second to 2nd min.
SCR are compared for each minute. * - $p<0.05$

2-2. Post-stimulation level compared to relevant session pre-stimulation baseline							
	HR	RSR	SCL	O2 Delta	O2 Slow alpha	F4 Slow alpha	F3 Slow alpha
P-music	=	=	=	↓	=	↑	↑
S-music	=	↑	=	↓*	↑*	↑*	↑*
WN	↓	↓	=	↑	↓*	↓	↓

* - $p<0.05$

P-music was -1.94 bpm, $p<0.001$). White noise stimulation decreased RSR as compared to session pre-stimulation level at -1.26 bpm ($p<0.05$).

SCL reaction to IAPS-based stimulation in all 3 sessions consisted in elevation of mean level (0.022 μS, $p<0.05$). Presentation of auditory stimuli after visual stimuli induces SCL decrease, but it was not significant when compared to pre-stimulation baselines, furthermore, in a case of WN even vs. visual stimulation SCL (-0.01 μS, $p>0.05$). Amplitude of SCRs to IAPS-based stimulation was featured by reproducibility of values in all 3 sessions (mean SCR amplitude 0.37 μS, mean number of SCRs 2.39). P-music presented after negative visual stimulation evoked significantly lower SCR amplitude (0.11 μS, $p<0.01$) at 1st minute. P-music, at the same time, elicited SCR amplitude significantly lower than that in S-music stimulation conditions (0.28 μS, mean number of SCRs 1.33/per min). White noise evoked SCR (mean N=1.34 per minute) with highest amplitude at 1st minute (mean SCR amplitude 0.61 μS, N=1.58) which habituated at 2nd minute (0.17 μS and 1.2/min) becoming significantly lower. Amplitude of SCR to WN at 1st minute is significantly higher than those in S- or P-music stimulation conditions (e.g. both the 1st and the 2nd minute of listening to music).

EEG responses. Occipital and frontal (O2, F3, F4 sites) demonstrated significant increase of delta RP values when subjects were exposed to IAPS pictures in all 3 sessions. Effects of music were exhibited in delta decrease and were quite similar. However, right occipital (O2) and right frontal (F4) sites had same delta decrease response with post-stimulation levels lower than those of relevant pre-stimulus baselines, while effect was similar but less obvious at left frontal (F3) and left temporal (T3) sites. White noise effects on delta RP values consisted in modest but significant decrease at occipital site, but only when compared to visual stimulation levels. Differences of delta responses to white noise and music were significant for WN vs. P-music (F4) and WN vs. S-music (O2) pairs, emphasizing distinction of right delta RPs in music and WN conditions.

Visual stimulation had practically no impact on theta RP values at most recording sites, however at temporal area (T3) there was a tendency to decrease. P-music stimulation evoked significant increase of theta at temporal site (T3) with respect to visual stimulation (1.49, $p<0.01$) and pre-baseline (1.42, $p<0.01$) conditions and resulted in higher value of theta in post-stimulation state (0.91, $p<0.05$). Other changes of theta band were not significant.

Significant slow alpha blocking effect as a result of aversive visual stimulation was expressed at all recording site, most profound in occipital (02) area (mean decrease of slow alpha RP for 3 sessions was -3.11 vs. baseline, $p<0.01$). P-music resulted in slow alpha enhancement and restoration of pre-stimulation level, however at most of the sites post-stimulation slow alpha RP was not significantly different from initial baselines, but significant as compared to affective visual stimulation levels at right F4 and O2 sites. On its turn, S-music evoked increase of slow alpha at all sites as compared to visual stimulation. Slow alpha exceeds baseline level during the 2nd minute of stimulation with S-music at right occipital site (1.06, $p<0.05$) and right frontal F4 site (1.09, $p<0.01$), and after S-music slow-alpha remains significantly higher during post-stimulation state when compared to pre-stimulation level at most of recording sites (3.31 higher vs. baseline at O2; 1.8 at F3 and 1.76 at F3). Other bands of occipital, frontal and temporal EEG did not yield significant information (e.g., beta rhythm) [13].

Discussion

Repetitive aversive visual stimulation with IAPS pictures in all sessions evoked reproducible physiological responses: significant HR deceleration, moderate RSR decrease, increase of SCL, relatively high amplitude SCRs, and EEG shifts in a form of increase of delta RP values in occipital, frontal and temporal areas, slight decrease of temporal theta, and significant slow alpha blocking effect in occipital and frontal areas. Such effects were reported in literature [3,6,7,9,12,16] and may be attributed to orienting reaction, motivated attention and "freezing" type behavioral response. Subjective reports acquired after this kind of visual stimulation are associated with experiencing disgust emotion. Our finding in this study was 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 involvement of subjects and active vigilant state with broad attention signs .

Phasic cardiac negative chtonotropic changes accompanied by SCRs were important to detect occurence of emotional arousal, 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. Since HR deceleration and SCR may be reflecting also orienting activity or attentional processes, this consideration argues as well for utility of simultaneous use of HR (valence sensitive), SCR (arousal sensitive), respiration rate (HR modulator) and EEG (general cortical arousal level) parameters in assessment of ANS mediated integrated CNS responses in affective stimulation mode [9,15]. Such electrocortical parameter as delta band power according to [5] could also be regarded as indicator of attention process.

Results of aversive visual stimulation, expressed in a form of tendencies of changes of autonomic and EEG variables are summarized in Table 1. It should be noted that in current study selected IAPS negative visual stimulation was implied mostly as an instrument of experimental manipulation, namely to create background at which forthcoming affective and orienting auditory stimulation might lead to dissociation of responses including those with different directional orientation (increase, decrease or no change of variables).

Table 2-1 illustrates changes of monitored physiological parameters during the 1st and the 2nd minute of auditory stimulation in comparison to above IAPS-based visual stimulation level. Obtained data showed that an administration of auditory stimulation after aversive visual stimulation results in further short-term HR decrease in P-music and white noise conditions and to HR acceleration in S-music. Initial baseline HR levels nevertheless totally restored in all sessions. Meanwhile, both kind of music stimulation evokes increase of respiration rate (characteristic typical for emotion [1]), whereas WN slowed respiration frequency (classic component of orienting reflex and focused attention [15]). Post-stimulation RSR resting values did not differentiate significantly among sessions. Skin conductance activity was lower during listening to music, however, white noise evoked highest SCR amplitude after onset of stimulation followed by rapid habituation of electrodermal activity.

Electrcortical modulatory effects of music were expressed in total restoration of slow alpha in both stimulation and post-stimulation conditions. It should be mentioned that S-music happened to be more effective in term of alpha recovery, since post-stimulation alpha power increased as compared to initial pre-stimuli baseline in occipital and frontal areas. Probably it might be related to affectional significance of S-music. Influence of auditory stimulation on post-stimulation occipital delta was significant only in terms of differences between RP in music (both S- and P-music) and white noise, namely post- WN delta increased vs. baseline, while in music conditions RP of delta decreased. Comparison of post- vs. pre-stimulation level is presented in Table 2-2. Another interesting finding was that temporal theta rhythm power significantly increased both in P- and S-music stimulation and post-stimulation periods, which was higher in S-music condition, but was not affected at all by WN. It might be suggested that in this case P-music effect features characteristic of positive affect taking into account concepts about functional significance of theta rhythm and its correlation with comfort emotional states [14].

Analysis of above described physiological patterns may lead to conclusion that affective auditory stimulation with music is able to selectively modulate physiological activity evoked by preceding negative visual stimulation, even if changes elicited by later were in a form of directionally fractionated and patterned response (for example, HR decrease, SCL increase, delta increase and alpha blocking). On other hand, physiological responses of white noise, which does not posses emotion eliciting capabilities at applied intensity of stimulation, evokes response typical for orienting reaction followed by pronounced habituation. Magnitude of physiological responses as well as direction of their changes did not demonstrate significant dependence on pre-stimulation level in this case. Such pattern might be considered as characteristic of focused attention, which usually comes by without changes in general arousal level and without emotional experience [11].

Comparison of P-music and S-music effects revealed some minor differences, but general pattern of responses was quite similar. Affective significance of music stimuli might have importance in development of described effects regardless differences in emotional contents of presented music fragments. These data are partially in consistence with report [4] that frontal EEG alpha band amplitude increased during both stimulating and calming music and direction of change was rather dependent on ongoing cortical activity level. It is also understandable that more profound effects of music were observed in right cortex given the data about functional brain lateralization and dominance of right hemisphere in music processing, as well as such processes as sustained attention, vigilance maintenance [6] and emotion.

Conclusions

Affective auditory stimulation (with music) evoked physiological responses featured by short-term orienting reaction and rapid habituation masked by further development of entire emotion and sustained vigilance with such physiological manifestations as HR acceleration, RSR increase, moderate electrodermal activation, alpha and theta power increase and reduction of delta rhythm power. White noise delivered to already motivated and emotionally aroused subjects elicited physiological response pattern typical for orienting response and focused attention, with such characteristics as HR deceleration, respiration slowing, high amplitude SCR and decrease of left frontal alpha power followed by habituation. More precise indicators of attention and emotion processes should be sought for in time course of response and analysis of the overall patterns of physiological activity. Reliable and reproducible indices should reflect both central and autonomic manifestations of integrated responses typical for such processes as attention and emotion.

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