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The role of background noise intensity on physiological activity during performance of mental task

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인지과제 수행시 배경 소음의 크기에 따른 생리적 반응차

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Abstract

Combination of mental stress task with noise background is a traditional tool employed in psychophysiology. However, intensity of background noise is a factor affecting both performance on test and psychophysiological responses associated with stress evoked by mental load in noisy environment. In the current study on 7 subjects we analyzed the influence of white noise (WN) intensity (55, 70, and 85 dB[A]) on psychophysiological responses during word recognition test performed on noise background. There were recorded following physiological variables: electrodermal activity (EDA) , namely, skin conductance level (SCL), skin conductance response (SCR) amplitude (SCR-A), rise time and total number of SCRs (N-SCR); cardiovascular activity, e.g., heart rate (HR), respiratory sinus arrhythmia (RSA) index, pulse transit time (PTT), finger pulse volume (PV), skin temperature (SKT) and respiratory activity, such as respiration rate (RESP-R) and inspiration wave amplitude (RESP-A) during baseline resting state and 40 s long performance on 3 similar Korean word recognition tests with different WN intensity (55, 70, and 85 dB). Electrodermal responses (SCR-A, SCL, N-SCR) demonstrated gradual increment with increased intensity of noise, and this increase of response magnitude with higher intensity of noise was typical also for r skin temperature (phasic SKT decrease) and pulse volume (phasic and tonic PV decrease). However, some cardiovascular and respiratory responses did not exhibit same tendency of gradual increase of reactivity , namely HR, as well as RESP-R and RESP-A showed decrement of response magnitudes. Important finding in terms of cardiovascular reactivity was that 55 and 70dB evoked similar profiles, while 85dB WN resulted in significantly different profile of reactions, suggesting that there exists a threshold level after which intensive auditory stimulation elicits psychophysiological responses pattern of different quality. There are discussed potential autonomic mechanism involved in mediation of observed physiological responses.

Introduction

Since the traditional laboratory stressors (i.e., mental task, intense noise, etc.) tend to induce integrated patterns of physiological reactions , it is rather important to record and analyze a sufficient number of variables indexing activity of the branches of autonomic nervous system (ANS) to identify stress response patterns and their variations [4-5,9-11,14]. Among the most sensitive autonomic parameters in stress research are those of cardiovascular, respiratory, and electrodermal activity[3,5,7,9,13-14]. The variables that may serve as indicators of general arousal or activation of particular branches of the autonomic nervous system, such as respiratory sinus arrhythmia (index of vagal influences on heart), pulse transit time (index of beta-adrenergic sympathetic activation) , and skin conductance level (index of sympathetic activation), are especially important [2,6,8,13-14]. Specific autonomic indicators are differentially sensitive in terms of identification of the type of response (phasic vs. tonic). For instance, such electrodermal parameters as SCR amplitude and rise time is more feasible measure of phasic reactions, while basic skin conductance level (SCL) is better measure for tonic sympathetic activation. In the same way, some dynamic cardiovascular variables (heart rate, pulse volume) [5] are more sensitive to detect short-term responses as compared to less reactive ones (e.g., skin temperature). These variations in sensitivity are of crucial value during stress-inducing manipulations, where contrast among stimuli are small.

The aims of the study included analysis of psychophysiological mechanisms of stress response during acute stress modeled by word recognition test performed with various intensity of white noise background . The main purpose of the research was to identify the sensitivity of selected physiological variables to stress-eliciting experimental manipulations and to interpret possible autonomic mechanisms underlying psychophysiological reactivity to noise as background component of stress during mental load.

Methods

Seven college students (19-23 years) participated in the study. Physiological signals (ECG, finger photopletysmogram/PPG/, skin conductance, finger skin temperature and pneumogram) were recorded by BIOPAC, Grass Neurodata System and Acqknowledge III software. The following autonomic variables were measured for each condition: heart rate (HR), respiratory sinus arrhythmia index (RSA calculated as difference between minimum and maximum HR in each respiration cycle), pulse transit time (PTT - time delay between R-wave of ECG and relevant maximum of pulse wave in PPG in the same cardiac cycle), finger pulse wave amplitude (PV), respiration rate (RSR) and mean amplitude of inspiration wave (A-RESP), skin temperature (SKT), skin conductance level (SCL), skin conductance response (SCR) amplitude and rise time, and the number of all SCRs . The first SCR within 2-4 s latency following stimulation onset was analyzed according to recommendations of [1].

The experimental procedure consisted of (1) an adaptation period (5 min), and following 40 s long conditions: (2) initial resting baseline recording , (3) the first word recognition task presentation, (4) baseline, (5) the recognition test I of given task with 85dB[A] noise background (TEST I, 85dB), (6) baseline, (7) the second word recognition task , (8) baseline, (9) word recognition test II with the 70 dB[A] white noise background (TEST II, 70dB) , (10) baseline , (11) the third word recognition task presentation, (12) baseline , (13) the word recognition test III with 55dB (TEST III, 55dB), (10) post-test baseline . The instructions were given to subjects before task presentation. The instructions outlined the possibility of retest if the test was performed incorrectly in pre-set time limits. Subjective stress-level rating questionnaires and check lists were used for psychological assessment. Statistical analysis for each autonomic variables was performed by SPSS using T-test for paired samples.

Results

Electrodermal activity. Basic SCL , as well as phasic SCL response demonstrated trend to gradual increase with higher intensity of background WN. The same tendency was manifested in parameters of SCR: highest amplitude and total number of SCRs was typical for 85dB noise background, while 55 and 70 dB had similar profiles of responses. In general, EDA incremented gradually with increased intensity of noise background, with only few exceptions where lower intensities of WN did not differentiate.

Cardiovascular and respiratory activity. Both tonic and phasic HR responses were showing pattern opposite to EDA, being lower during higher intensities of WN. RSA index was almost the same in 55 and 70 dB, but lower in 85dB, however, RSA phasic response exhibited reverse pattern, namely increase in 85dB, no changes in 70dB and decrease in 55dB. PTT decrease had similar profiles in 70 and 85dB, but lower in 55dB. Both tonic and phasic vascular responses expressed in PV were demonstrating gradual increment of reactivity, e.g., lower levels during higher intensity of WN. SKT had same tendency, reaching lower level with increased intensity of noise. Respiration rate and volume were lower in higher intensity of WN, profile resembling those of HR.

Some of the electrodermal and cardiovascular responses are presented in Figures 1 and 2.

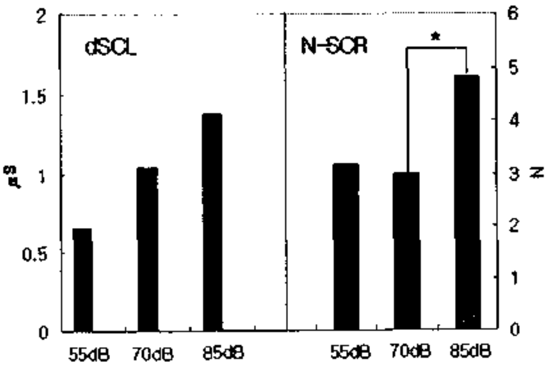

Figure 1. Electrodermal activity parameters: SCL change (left) and N-SCR during word recognition tests on noise background (55, 70 and 85dB).

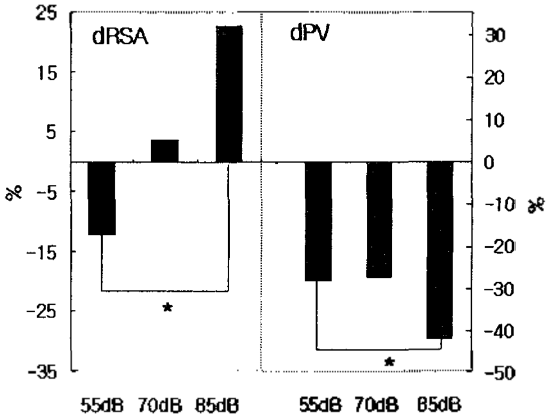

Figure 2. Cardiovascular parameters: RSA index (left) and pulse amplitude during word recognition tests on noise background (55, 70 and 85dB).

Discussion

Interpretation of processes evoked by experimental manipulations intended to induce stress response by combination of WN and performance of test with different intensity of noise environment may appear as follows.

Electrodermal and vascular responses demonstrated gradual increase of activity with increased background noise, while heart rate and respiration had reversed pattern, e.g. lower responses during higher intensity of noise. Since both skin conductance and vasomotor tone are controlled primarily by alpha-adrenergic sympathetic nervous system, we may conclude that peripheral sympathetic arousal increase was almost linear along intensity dimension. However, it should be noted that differences between 55 and 70dB effects were mostly non-significant, suggesting that only increase of noise intensity above 85dB led to differentiation of responses and marked sympathetic activation. Cardiac chronotropic responses were featured by lower activation during higher intensity of noise, and explanation for these observations should be sought in more complicated autonomic regulatory mechanisms affecting HR . Since PTT tended to decrease, presumably beta-adrenergic inputs to heart were increasing with intensity, but RSA as an index of vagal inhibitory influences on HR increased in 85dB (probably to compensate increasing sympathetic drive and low tonic parasympathetic tonus). Another possible mechanism of increase of the RSA response may be due to lower respiration rate in higher WN, but this might be secondary effect of centrally mediated simultaneous inhibition of both cardiac and respiratory responses.

We may speculate that test performance with more intense white noise background (above 80 dB) switches physiological pattern of response to those typical for an active coping [3], with synergically increased beta-adrenergic sympathetic and vagal tone (as defined by RSA)[2,6,8], accompanied by increased skin conductance and overall peripheral (alpha-adrenergic) sympathetic activation (as indexed by PTT, SKT and HR changes) [5,6,13]. During lower intensity of stress, the autonomic mechanisms mediating the phasic physiological responses were presumably primarily determined by parasympathetic withdrawal with quite moderate sympathetic activation [12], as it was shown in our previous study [7]. One of possible explanation of fractional responses of electrodermal and vascular system, on one side, and heart rate, might be in more complicated autonomic regulation of HR, which is exerted by delicate balance of parasympathetic and beta-adrenergic sympathetic influences on cardiac rhythm and contractility, whereas electrodermal and peripheral vascular activity are mostly controlled solely by sympathetic nerves. Probably, in mild stress response during mental load on the background of noise, parasympathetic system partially compensates effects of sympathetic arousal on cardiac activity, preventing by antagonism cardiovascular overreaction, however after reaching certain threshold level of intensity, sustained sympathetic activation dominates despite phasic increase of parasympathetic tonus and this may result in physiological patterns typical for acute stress response. Employed model proved to be quite effective for understanding of autonomic mechanisms potentially involved in development of stress related disorders However, employed univariate analysis is not sufficient to draw more sophisticated interpretation of autonomic regulation of physiological systems during stress, suggesting the necessity to apply multivariate approaches [5] for understanding entire mechanisms operating during stress elicited by mental load and noise background.

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