Mechanisms of the Autonomic Nervous System to Stress Produced by Mental Task in a Noisy Environment

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소음상황에서 인지적 과제에 의해 유발된 스트레스에 대한 자율신경반응의 기제

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Abstract

A mental task combined with noise background is an effective model of laboratory stress for study of psychophysiology of the autonomic nervous system (ANS). The intensity of the background noise significantly affects both a subjective evaluation of experienced stress level during test and the physiological responses associated with mental load in noisy environments. Providing tests of similar difficulties we manipulated the background noise intensity as a main factor influencing a psychophysiological outcome and the analyzed reactivity along withe the noise intensity dimension. The goal of this study was to identify the patterns of ANS responses and the relevant subjective stress scores during performance of word recognition tasks on the background of white noise (WN) of the different intensities (55, 70 and 85 dB). Subjects were 27 college students (19-24 years old) . BIOPAC, Grass Neurodata System and AcqKnowlwdge 3.5 software were used to record ECG, PPG, SCL, skin temperature, and respiration. Experimental manipulations were effective in producing subjective and physiological responses usually associated with stress. The results suggested that the following potential autonomic mechanisms might be involved in the mediation of the observed physiological responses: A sympathetic activation with parasympathetic withdrawal during mild 55 and 70dB noise (featured by similar profiles) and simultaneous activation of sympathetic and parasympathetic systems during intense 85dB WN. The parasympathetic activation in this case might be a compensatory effect directed to prevent sympathetic domination and to maintain optimal arousal state for the successful performance on mental stress task. It should be mentioned that obtained results partially support Gellhorn's (1960; 1970) "tuning phenomeno n" as a possible mechanism underlying stress response.

Introduction

Autonomic balance (of sympathetic & parasympathetic inputs) plays a crucial role in maintaining equilibrium and effective coping during exposure to stressor [1]. Understanding the entire autonomic mechanisms mediating physiological responses in experimental manipulations intended to evoke acute stress become possible if used parameters specifically sensitive to the activation of branches of ANS, such as Respiratory sinus arrhythmia (RSA), or high frequency component of heart rate variability (HF of HRV) - indices of parasympathetic activity [1, 6, 9, 11], along with vascular parameters (pulse volume, pulse transit time etc.) and electrodermal variables as indices of sympathetic activity [9,10,12]. Such approach is especially useful, since according to some theoretical frameworks [4,5,7] during certain extreme behavioral states (e.g., stress), normal autonomic reciprocity may break down, and one autonomic branch becomes "tuned" at the expense of another affecting balance of sympathetic or parasympathetic dominance. Furthermore, Gellhorn (1970) proposed that "alterations in autonomic balance are not merely reflections of changes in overall behavior including stress, but are causally related to them" .

Mental stress task performance under the noise background is widely employed in autonomic psychophysiology research [2,3,8]. However, the intensity of background noise is significantly affecting both the subjective evaluation of experienced stress level during test and the physiological responses associated with mental load in noisy environment. Providing tests of similar difficulties it is possible to use the background noise as a main factor influencing psychophysiological outcome and analyze autonomic reactivity along the noise intensity dimension.

The purpose of this study was to analyze patterns of ANS responses and the relevant subjective stress scores during performance of word recognition tasks under the background of noise with different intensities to assess autonomic reactivity to stressful environment and potential autonomic mechanisms mediating specific psychophysiological responses profiles under the stress.

Methods

Subjects in this study were 27 college students (19-24 years old). Physiological signals (ECG, PPG, skin temperature, and respiration) were acquired by BIOPAC MP100WS, Grass Neurodata System and AcqKnowlwdge 3.5 software. There were recorded following physiological variables: electrodermal activity (EDA), e.g., skin conductance level (SCL), skin conductance response magnitude (SCR-M, i.e., sum of all SCR amplitudes), SCR number (N-SCR); cardiovascular activity, namely, heart rate (HR), HF (0.15-0.4 Hz) and LF (0.04-0.15 Hz) components and HF/LF ratio of heart rate (i.e., inter-beat period) variability (HRV) [1], respiratory sinus arrhythmia index (RSA) measured by a peak-to-valley method in each respiration cycle [6] and averaged within condition, pulse transit time (PTT), calculated as interval from R-wave to PPG ascending slope (10% of maximal PPG amplitude) [12], finger pulse volume (PV), skin temperature (TEMP); and respiratory activity, such as respiration rate (RESP) and inspiration wave amplitude (IA) 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). The selection of autonomic variables was primarily determined by their indicator values as indices of activation of specific branches of ANS. A subjective rating of experienced stress level (0-100 scale) during test was assessed after each session. Data were analyzed by SPSS statistical package using paired samples t-test and Pearsons correlation.

Results

Electrodermal responses (SCL, SCR-M and N_SCR) and vascular responses (PV decrease) demonstrated non-linear increment of reactivity with increased intensity of background noise and maximal response magnitudes were characteristic of the highest intensity of noise (85dB). However, some cardiac and respiratory responses did not exhibit the same tendency of reactivity increase along with the intensity dimension, namely HR, HF/LF ratio, as well as RESP showed a decrement of response magnitudes in the highest intensity of background noise. RSA index significantly increased, normalized HF/LF index decreased in a 85dB condition, whereas RSA decreased and HF/LF increased in 55 and 70dB. A subjective rating of experienced stress during test clearly differentiated conditions with different intensity noise background, but the stress scores demonstrated a significant negative correlation only with respiration rate and amplitude parameters, while failed to correlate with any other physiological variables. Comparison of some physiological responses and significance of differences during experimental conditions are shown on Figures 1-4.

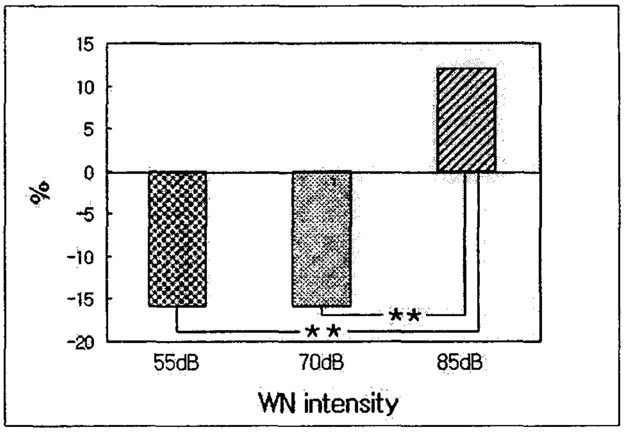

Figure 1. RSA index (indicator of parasympathetic influences on HR) during word recognition test on noise background (55, 70 and 85dB)

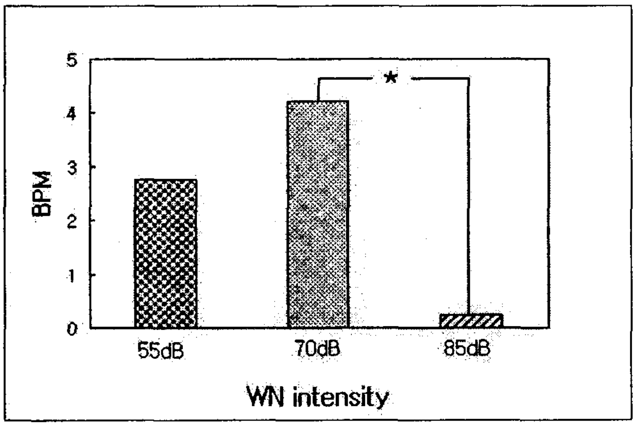

Figure 2. Phasic HR response during word recognition tests on noise background (55, 70 and 85dB)

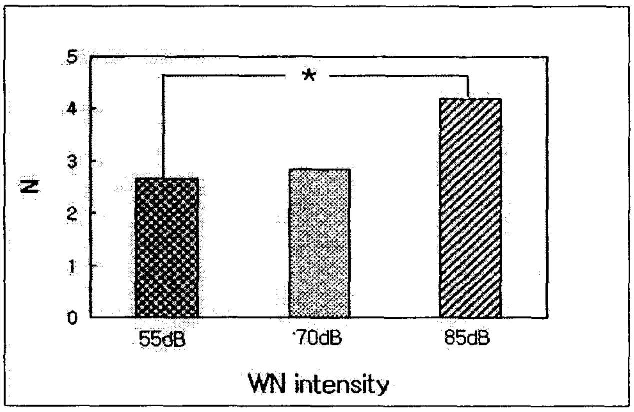

Figure 3. N-SCR (number of non-specific SCR)-indicator of tonic sympathetic activation-during word recognition tests on noise background (55, 70 and 85dB)

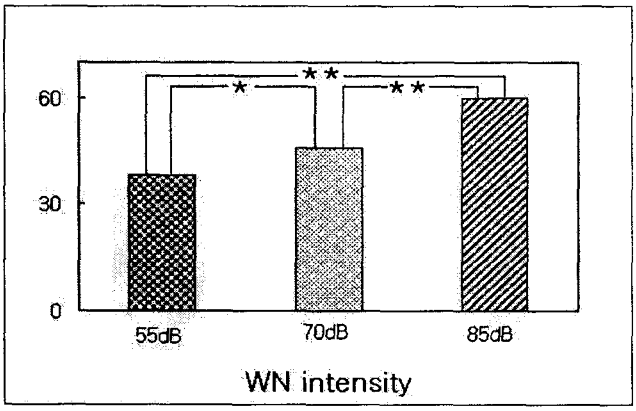

Figure 4. Subjective rating of experienced stress level during the word recognition test under the noise background (55, 70 and 85dB)

Discussion and conclusions

The experimental manipulation employed in the study was effective in producing subjective and physiological responses usually associated with stress [3, 7, 8]. However, some autonomic parameters (PTT, TEMP) did not demonstrate sufficient sensitivity to stress load, while other variables (HR, RSA, HF/LF, PV, RESP, IA, SCL, SCR-M, N-SCR) differentiated conditions, namely (55 and 70dB vs. 85dB). The important finding in terms of physiological reactivity was that 55 and 70dB evoked similar profiles, i.e., none of physiological variables differentiated these conditions, while 85dB WN resulted in significantly different profile of reactions (lower cardiorespiratory, but higher electrodermal and vascular responsiveness), thus suggesting that there exists a threshold level after which intensive auditory stimulation elicits psychophysiological responses pattern of different quality(i.e., stress response). Obtained results support the special value of respiratory variables as the indicators of stress and negative emotional states.

The most productive approach to understanding processes taking place during gradual increase of background noise intensity should be sought in grouping variables with regard to their indicative qualities, i.e., RSA, HF/LF - indices of parasympathetic activation [1, 6, 11]; PV and skin conductance - indices of peripheral a-adrenergic activation [9]; HR, HRV and RESP - indices of both parasympathetic and b-adrenergic sympathetic activation [10], since it may give direct clues to the decipher components of autonomic balance during acute stress.

Taking into account the above profiles, there should be considered following potential autonomic mechanisms involved in the mediation of the observed physiological responses, namely sympathetic activation with parasympathetic withdrawal during mild 55 and 70dB noise (featured by similar profiles), and the simultaneous activation of sympathetic (as indexed for instance by SCL and SCR increase, Fig.3; and PV decrease) and parasympathetic (as indexed by RSA increase, moderate HR, Fig. 1) systems under the intense 85dB noise. The parasympathetic activation in this case might be a compensatory effect directed to prevent sympathetic domination and to maintain optimal arousal state for the successful performance on mental stress task.

However, another explanation of this phenomena as the characteristic of certain states of stress could be done in accordance with Gellhorns (1960) data, where he demonstrated that both the sympathetic and parasympathetic systems were concurrently active in the prolonged stress, and that the concurrent activation is typical for experimental neurosis and is of chronic activation generally. In some cases of stress, sympathetic signs can be masked by concurrent parasympathetic effects as suggested by [5,7] and this might be one of the reasons why we found only modest changes in some cardiac variables (e.g., HR, Fig. 2) in 85dB WN condition.

Given that 85dB noise was associated with higher subjective stress rating (Fig 4), it is suggested that sympathetic arousal be accompanied as well by PNS activation under acute stress episodes and this finding is extremely important in understanding of the potential contribution of both branches of ANS and not only traditionally recognized as sympathetic inputs to development of stress syndrome. On the other hand, results of this study propose necessity to be more cautious about selecting target parameters for stress reduction procedures. Some single variables (such as for example HR) innervated by both ANS inputs may not be sensitive enough to label actual subjective stress level, thus emphasizing the preference of the selection of several different variables or their profiles that show the activation of both sympathetic and parasympathetic branches. The same time our data outlines an important role of the parasympathetic system in autonomic balance, which was traditionally ignored in stress researches.

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References

[1] Bernston G., Cacioppo J., Quigley K. (1993) Respiratory sinus arrhythmia: Anatomic origin, physiological mechanisms and psychophysiological implications. *Psychophysiology*, 30, 183-196.

[2] Bongard S. (1995) Mental effort during active and passive coping. *Psychophysiology*, 32, 242-248.

[3] Boucsein W., Ottman W. (1996) Psychophysiological stress effects from the combination of night-shift work and noise. *Biological Psychology*, 42, 301-322.

[4] Gellhorn E. (1960) The tuning of the autonomic nervous system through the alternation of the internal environment (asphyxia). Acta Neurologica, 20, 515-540.

[5] Gellhorn E. (1970) The emotions and the ergotropic and trophotropic systems. Psycholosche Forschung, 34, 48-94.

[6]Grossman P., Svebak S. (1987). Respiratory sinus arrhythmia as an index of parasympathetic cardiac control during active coping. *Psychophysiology*, 24, 228-235.

[7] Levine P. (1986) Stress. In: *Psychophysiology: Systems, Processes, and Applications* (Eds). M.Coles, E. Donchin & S. Porges. (pp. 331-353) , New York, Guilford press.

[8] Poulton E. (1979) Composite model for human performance in continuous noise. *Psychological review,* 86, 361-375.

[9] Schneiderman N., Weiss S., Kaufman P.{Eds.} (1989) *Handbook of Research Methods in Cardiovascular Behavioral Medicine.* New York: Plenum Press.

[10] Sherwood A., Allen M.T., Obrist P.A., Langer A.W. (1986) Evaluation of beta-adrenergic influences on cardiovascular and metabolic adjustments to physical and psychological stress. *Psychophysiology*, 23, 89-104.

[11] Shulman E., Sokhadze E. (1993) Respiratory Sinus Arrhythmia: Rationale for the use as biofeedback parameter. *Biofeedback & Self-Regulation*, 18, 330-331.

[12] Sokhadze E., Shtark M. (1991) Computer analysis of hemodynamic parameters during pulse transit time biofeedback training in borderline hypertensive and normotensive subjects. *Biofeedback & Self-Regulation*, 1991, 16, 319-320.