# AUTONOMIC MECHANISMS OF AN ACUTE STRESS RESPONSE DURING WORD RECOGNITION TASK PERFORMANCE WITH INTENSE NOISE BACKGROUND

Sangsup Choi, Kyung-Hwa Lee, Yoon-Ki Min, Estate Sokhadze, Jin-Hun Sohn
Department of Psychology, Chungnam National University
#220 Kung-Dong, Yusung-ku, Taejon, Korea
Email: jhsohn@hanbat.chungnam.ac.kr

# 백색소음하의 단어재인검사 수행에 따른 자율신경계 스트레스 반응

최상섭, 이경화, 민윤기, Estate Sokhadze, 손진훈
충남대학교 심리학과
대전시 유성구 궁동 220번지

## Abstract

Cardiovascular, respiratory and electrodermal responses to acute stress episodes modeled by combined presentation of intense white noise and performance of word recognition task with noise background were studied in 15 college students. Experimental procedure consisted in sessions with white noise, word recognition task presentation with noise background and test with noise background. Recorded physiological variables were analyzed in terms of their sensitivity to detect activation of sympathetic and parasympathetic branches of autonomic nervous system and thus reflect autonomic arousal level during short-term stress-inducing experimental manipulations. It was shown that performance of effortful mental task with noise background elicited significant physiological responses typical for active coping behavior, namely electrodermal arousal and increased cardiovascular activity. This response profile was more profound as compared to white noise only or attending task in noise background. However, all physiological responses were mostly phasic, without long-term tonic changes, since almost all variables recovered to their initial baseline levels, suggesting that dominant autonomic mechanisms in transient acute stress episodes were of parasympathetic nature (withdrawal in stress with subsequent activation in restoration period), while sympathetic contribution was not long-lasting. Nevertheless, increased number of stressors and their longer exposure may result in higher profile of tonic sympathetic arousal and reduced functional role of vagal mechanisms in autonomic balance regulation.

## Introduction

Experimental studies on stress in humans are often limited to acute stress episodes and are intended to elicit short-term stimulus or situation dependent psychophysiological responses. 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 select a sufficient number of variables reflecting activity of the different branches of autonomic nervous system (ANS) to allow the transient stress response patterns and their variations to be detected and identified. Contemporary psychophysiological concepts of stress state that different cortical and peripheral mechanisms might be involved in the mediation of phasic and tonic effects of exposure to stressors [4]. On other hand, situational context characteristics, such as availability of effortful stress coping strategies, are also capable to affect the pathways of realization of stress response and concomitant physiological manifestations. Several studies emphasize differences, for instance, in cardiovascular response profiles during passive and active coping efforts [2, 9].

Usually named as the most sensitive autonomic parameters in stress research are those of cardiovascular, respiratory, and electrodermal activity. 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 [1,5,9]. Specific autonomic indicators are differentially sensitive in terms of identification of the type of response (phasic vs. tonic) during multivariate psychophysiological analysis of stress-related processes [3, 4]. For example, such electrodermal parameters as skin conductance response (SCR) magnitude 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) [1,5,12] 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 when stress-inducing manipulations operate with stimuli or situations where startle, orienting or defense responses are expected.

The aims of the study included analysis of psychophysiological mechanisms of stress response during acute stress modeled by white noise, mental tasks presented with a background of intense noise, and word recognition test performed with noise and time pressure conditions. 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 stressors and involved in post-stress recovery process.

## Methods

Fifteen college students ( 19-23 years old) participated in the study for moderate fees. 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), respiration rate (RSR), skin temperature (SKT), skin conductance level (SCL), mean skin conductance response (SCR) amplitude and rise time, and the number of all SCRs for estimation of SCR magnitude (mean SCR amplitude × rise time × number of SCRs /2 ). The first SCR , occurring within 1-4 s latency following stimulation onset, was analyzed separately to estimate orienting significance of stimuli.

The experimental procedure consisted of (1) an adaptation period (5 min), (2) initial resting baseline recording (1 min, BAS), (3) white noise (85 dB, 40 s, WN), (4) the first word recognition task presentation with white noise background ( 40 s, TASK I - 10 English word for further recognition), (5) the recognition test I of given task also with noise background (20s, TEST I), (6) the second word recognition task with white noise background (40 s, TASK II - 10 Korean words), (7) word recognition test II with the same noise background (20 s, TEST II) , (8) post-test resting baseline (1 min, POST), (9) music (3 min) for de-briefing and (10) post-music baseline (1 min). The instructions were given to subjects before task presentation. The instructions outlined the possibility of discontinuation of noise if the test was performed correctly in pre-set time limits. This was to encourage and challenge subjects to apply active mental efforts to avoid aversive noise background. Subjective stress-level rating questionnaires and check lists were used for psychological assessment. Filling the check-lists did not alter the physiological response patterns. Statistical analysis was performed by SPSS using T-test for paired samples.

## Results

*Cardiovascular and respiratory responses.* Cardiovascular effects of white noise (WN) were expressed by significant increase (as compared to baseline) of HR (3.53, $p< 0.05$), RESP (2.63 breath/min, $p<0.01$), decrease of RSA (-2.76 bpm, $p<0.01$) and PTT (-9.06 ms, $p<0.05$), but practically without any SKT changes. Both task presentation with noise background conditions (TASK) were featured by increase vs. baseline of RESP (e.g., TASK I 4.81 br/min to baseline, $p<0.05$) and HR (e.g., TASK I 6.06 bpm, $p<0.01$), decrease of RSA (TASK I, -2.73 bpm, $p<0.05$) , PTT (TASK I, -6.26, $p<0.05$) and slight reduction of SKT (TASK I, -1.36° F , $p<0.05$). Word recognition tests (TEST) led to significant increase of HR (TEST I, 14.66 bpm; TEST II , 14.44 bpm to baseline, ps<0.01), some RESP changes ( TEST1, II, both 1.33, $P>0.05$), decrease of PTT (TEST I, -13.66ms, $p<0.05$), RSA (TESTI,II, -2.73 and -4.28 bpm, ps<0.05) and SKT (TEST I, II, -2.05 and -2.30° F, $p<0.05$).

*Electrodermal activity.* Skin conductance effects were displayed by increase of SCL (1.81 $\mu$S, $p>0.05$) and large SCR magnitude during WN condition, while during task presentation with white noise conditions (TASK) they were characterized by somehow lower SCL drift (WN, 1.66 $\mu$S, while TASK I, 1.59 $\mu$S, $p>0.05$), modest SCR amplitude, and less frequency of SCRs. Electrodermal activity during word recognition tests (TEST I and II) was almost as high as during WN only condition in terms of SCL changes ( 3.38 and 3.59 $\mu$S vs. baseline, ps<0.05) and magnitude of SCRs. All autonomic variables fully recovered in post-test period except skin temperature, nevertheless, since only SKT drop was statistically significant in post-stress rest period ( POST vs. baseline, -2.01 F, $p<0.05$). Absolute values of ANS variables in experimental conditions are presented on Table 1. Differences of ANS parameters across conditions are displayed on Table 2.

## Discussion and conclusions

Analysis of obtained results might lead to following interpretation of processes evoked by experimental

Table 1. ANS variables (Mean + Standard. Deviation) in each of the experimental conditions (N=15). TASK and TEST conditions are presented as averaged values for TASK I,II and TEST I,II (both with white noise background). WN- white noise only. Variables: SCR-M is total magnitude of all SCRs, while SCR-A - amplitude of the first (e.g., orienting response) SCR (1-4 s from onset of noise).
Significance of differences to baseline: * p<.05, ** p <.01

| ANS | | | Experimental Coditions | | |
|---|---|---|---|---|---|
| Variables | BASELINE | WN | TASK | TEST | POST-STRESS |
| HR bpm | 72.12 (8.23) | 75.65(9.14)* | 78.85(8.89)** | 86.64(10.41)** | 70.67 (7.26) |
| RSA bpm | 8.71 (2.75) | 5.94 (3.21)** | 6.26(3.91)** | 4.25(3.28)** | 8.51 (3.93) |
| PTT ms | 193.4(16.77) | 184.3(17.12)** | 187.3(15.88)** | 179.2(17.33)** | 190.8 (12.61) |
| SKF F | 90.39 (6.34) | 90.52 (6.30) | 88.79(6.26)* | 88.20(5.97)** | 88.37 (6.50)* |
| RESP br/min | 14.2 (1.56) | 16.8 (2.28)** | 18.6(2.57)** | 15.5 (4.08) | 14.5 (3.93) |
| SCL μS | 6.59 (4.61) | 8.26 (5.15)* | 8.05(4.45)* | 10.07(4.58)** | 7.35 (3.84) |
| SCR-M μS*s | 0.18 (0.43) | 4.15 (4.11)** | 1.93(1.59)* | 4.9(5.17)** | ------- |
| SCR-A μS | 0.09 (0.03) | 2.36 (2.83)** | 1.04(0.87)** | 2.88(2.60)** | ------- |

Table 2. Across condition comparisons of the differences of ANS variables (N=15) . TASK represents mean differences for TASK I and II, while TEST for TEST I and II. The abbreviations of variables are the same as in Table. 1. Significance of variables differences between conditions : * p<.05, ** p<.01

| Variable | Compared conditions | | | | |
|---|---|---|---|---|---|
| | TASK I vs. TASK II | TEST I vs. TEST II | TASK vs. WN | TEST vs. WN | TASK vs. TEST |
| HR bpm | -1.32 | 0.21 | 3.19* | 11.01** | -7.79* |
| RSA bpm | -0.57 | -0.35 | 0.03 | -1.72* | 2.01** |
| PTT ms | -0.04 | 1.06 | 3.01 | -5.10 | 8.10* |
| SKT F | 0.45 | 0.24 | -1.73* | -2.32** | 0.59 |
| RESP b/min | 0.93 | 0.01 | 1.80* | -1.30 | 3.10** |
| SCL μS | 0.26 | -0.22 | -0.21 | 1.81* | -2.02** |
| SCR-M μS*s | 1.03* | -1.74* | -2.22* | 0.80 | -3.02* |
| SCR-A μS | 0.36 | -0.27 | -1.32* | 0.52 | -1.84* |

manipulations intended to induce stress response by combination of WN and task presentation and performance with noise environment. White noise at applied intensity of stimulation elicited physiological responses in a form of selective increase of autonomic activation expressed by enhanced cardiovascular (except SKT), respiratory and electrodermal activity. Overall picture is typical for response evoked by unexpected intense auditory stimulus and matches the results of other studies [3,6,7,10,11,12]. Subsequent presentation of task in combination with the white noise led to some further autonomic activation signs such as RESP and HR increase, RSA decrease, but fewer skin conductance responses . On other hand, test performance with noise background resulted in ANS effects manifested in RESP slowing, drastic HR increase, lowering of HR variability expressed by significantly decreased RSA, reduced SKT and PTT, increase in skin conductance level and SCR magnitude. Similar data were reported for some of above autonomic parameters in similar noise conditions [3,6,12]. Thus, such stressor as intense white noise evoked orienting responses and general arousal that might be partially modulated (namely, inhibited) by attending to task or facilitated by the performance of test . On its turn, non-specific arousal provoked by noise might positively affect selectivity of attention and alter task performance as it was shown by some authors [7,10]. It was reported either than noise even in 80-100 dB range did not induce long-lasting autonomic activation, namely tonic sympathetic arousal [8].

Both white noise only and task attending with noise background in biobehavoral terms represent passive exposure to aversive stimuli without efforts of active coping. Physiological pattern of response to white noise is more typical to orienting response, when somatic and autonomic parameters indicate characteristics of reaction to novel intensive stimuli. When white noise serves as a background for task presentation obtained pattern is of mixed type, closer to attending and sensory intake, characterized by tuning of sensory inputs for better perception. Probably, both somatic and autonomic responses were modified by external attention demands when noise was combined with the task to attend. While test performance with the white noise background switches physiological pattern of response to those typical for active coping [2, 9], with increased cardiac activity and significantly decreased vagal tone (as defined by RSA)[ 1,5], accompanied by increased skin conductance and overall sympathetic activation (as indexed by PTT, SKT and HR changes) [1,11].

Since stress conditions modeled in our study were more relevant to short-term acute stress, the autonomic mechanisms mediating these phasic physiological responses were presumably primarily determined by parasympathetic withdrawal with quite moderate sympathetic activation. This suggestion may explain fast recovery of cardiovascular and electrodermal responses, because only skin temperature (index of tonic sympathetic activation) did not recover in full. A slight tendency to have more exaggerated responses in the second test (for instance, SCR magnitude and HR in TASK II) may indicate possibility of accumulation of stress response with increased number of stressors, but this suggestion needs further experiments with recurrent stress design to be proved.

In summary, it should be stated that performance on word recognition test (i.e., mental task) with intense noise background elicited significant physiological responses typical for active coping behavior, namely autonomic responses featured by electrodermal activation and increased cardiovascular activity. This response profile was significantly more profound as compared to the white noise only conditions or as compared to attending to task with the noise background. Since employed model of inducing stress response was effective only for short-term acute episodes of mental strain, the probable autonomic mechanisms mediating response were mostly of parasympathetic nature, whereas sympathetic indices indicated less changes in our study, especially in terms of contribution to autonomic responses to the white noise. However, increased number of stressors and longer duration of experiment might lead to higher profile of general activation and more dramatic tonic sympathetic arousal, with lowered role of parasympathetic regulatory mechanisms, that usually tend to have short-lasting phasic effects.

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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: A dual-task analysis. *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]Boucsein W., Thum M. (1996) Multivariate psychophysiological analysis of stress-strain processes under different break schedules during computer work. In: J.Fahrenberg, M.Myrtek (Eds). *Ambulatory Assessment: Computer-assisted psychological and psychophysiological methods in monitoring and field studies*. (pp. 305-313), Seattle, Hogrefe & Huber.

[5] Grossman P. (1983) Respiration, stress and cardiovascular functions. *Psychophysiology*, 20, 284-300.

[6] Hanson E., Schellekens J., Veldman J., Mulder L. (1993). Psychomotor and cardiovascular consequences of mental effort and noise. *Human Movement Science*, 12, 607-626.

[7 ] Hockey G.R. (1970) Effects of loud noise on attention selectivity. *Quarterly J. of Experimental Psychology*, 22, 28-36.

[8] Jennings J.R. (1986) Bodily changes during attending. In: M.Coles, E,Donchin, S.Porges (Eds) *Psychophysiology: Systems, processes and applications* (pp. 268-289), N.Y. Guilford.

[9] Lovallo W., Wilson M., Pincomb G., Edwards G., Tompkins P., Brackett D. (1985). Activation patterns to aversive stimulation in man. *Psychophysiology*, 22, 283-291.

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

[11] Sokhadze E., Yi I., Choi S., Lee K.-H., Sohn J.-H. (1998) Physiological indicators of emotion and attention processes during affective and orienting auditory stimulation. *J. of Acoustical Society of Korea*, 17, 1s, 291-296.

[12] Vila J., Perez M., Fernandez M., Pegalajar J., Sanchez M. (1997) Attentional modulation of the cardiac defense response in humans. *Psychophysiology*, 34, 482-487.