韓國感性科學會誌
Korean Journal of The Science of Emotion & Sensibility
1999. Vol.2. No.1. 137-145

Electroencephalographic Manifestations of Transient Stress Responses While Performing a Memory Task With Background White Noise*

Jin-Hun Sohn**, Estate Sokhadze, Kyung-Hwa Lee, Sangsup Choi, Imgap Yi

Abstract The relative power spectrum of EEG was analyzed in 12 subjects during rest, exposure to white noise, attending to mental task and performance of test with noise background. The EEG was recorded monopolarly from frontal, temporal, and occipital areas. Obtained results demonstrated that exposure to white noise alone or task presentation with intense noise background elicited similar electrocortical responses with increased delta power, alpha blocking, and fast beta power increase. Performance on test of word recognition with noise background, a condition subjectively evaluated as stressful, resulted in the same charges of EEG but with a significantly higher profile of response magnitudes. Data are interpreted in a conceptual framework focused on distinctions among physiological reactions during passive exposure to a stressor with manifestations typical of perception of information, or an "intake" situation (during white noise or attending to task) versus "rejections" i.e., active coping with stressful situation. The employed model of laboratory stress evoked only short-term, acute stress responses, since most EEG parameters recovered in the post-stress period. This suggests that more long-lasting recurrent stressors might be more effective at producing tonic electrocortical arousal.

Introduction

Modern psychophysiological concepts of stress argue against simplistic approaches of indexing general activation using only a few indices of elctrocortical arousal, because different cortical and peripheral mechanisms might be involved in the mediation of the effects of exposure to laboratory stressors in different situational contexts. This notion is especially important when several stressors are used simultaneously (e.g., mental task and noise) or when environmental demands vary from necessity to attend external stimuli towards focus on an internal processing of information and active coping efforts

* This research was supported by MOST G-7 project. (No. 17-02-01-A-06)
** Corresponding author:
Department of Psychology, Chungnam National University
#220 Kung-Dong, Yusung-Ku, Taejon 305-764, Korea
Tel: +82-42-821-6369
Fax: +82-42-823-5106
E-mail: jhsohn@hanbat.chungnam.ac.kr

(Bongard, 1995; Dujardin et al., 1993; Jennings, 1986; Harmony et al., 1996; Poulton, 1979; Pribram, McGuiness, 1975; Van Dijk et al., 1992).

Spectral analysis of the electroencephalogram (EEG) is traditionally used to investigate regulation of cortical arousal. Among the most sensitive EEG parameters in stress research are power spectrum data, namely, the relative power of EEG bands (delta, theta, alpha, beta). They reflect aspects of brain activation, furthermore some specific electrocortical indicators are quite sensitive in terms of differentiation of the type of endured strain (mental, somatic or emotional) during multivariate psychophysiological analysis of stress-related processes (Boucsein, Trum, 1996; Sokhadze et al., 1998).

Types of attentional tasks are referred to as "intake" and "rejection" according to J. Lacey (1967). Intake tasks (e.g., listening to words) demand the observation of environmental stimuli, thus requiring attention to the external environment. During rejection tasks (e.g., word recognition test) the subject should ignore external input influences that might interfere with optimal performance of the test (Dujardin et al., 1993; Harmony et al., 1996; Jennings, 1986; Lacey, 1967; McCarthy et al., 1995). The environmental rejection tasks have been associated with different alpha and beta activity as compared to the intake tasks (Kakizaki, 1985; McCarthy et al., 1995; Ray, Cole, 1985). Thus, an attending task should evoke a phasic response to perceptual stimuli, whereas test performance needs both tonic activation that maintains readiness for the appropriate action and inhibition of inappropriate ones (Pribram, McGuiness, 1975). Some authors suggested that increased delta and theta activity might be related to an increase in the subjects' attention to internal processing during rejection tasks and could represent Vogel's "Class II inhibition" (Harmony et al., 1996; Kakizaki, 1985; Sokhadze et al., 1998; Tucker et al., 1985; Vogel et al., 1968).

The aims of the study included analysis of EEG manifestations of stress response during acute stress modeled by white noise, mental tasks presented with a background of intense noise, and a word recognition test performed with the same noise and time pressure conditions. The main purposes of the research were to identify the sensitivity of EEG rhythms to stress-eliciting experimental manipulations and to interpret possible psychophysiological processes involved in electrocortical reactivity to stressors.

Method

Fifteen college students (19-23 years old) participated in the study for a moderate fee. However, data on 3 subjects happened to be recorded with some artifacts at the F4 site due to equipment failure, thus limiting successful number of subjects to 12. Frontal, temporal, and occipital EEG were recorded by BIOPAC, Grass Neurodata System and Acqknowledge III (v.3.2) software. The following cortical variables were measured for each condition: relative power (RP, in percents) values of delta (0.5-3.9 Hz); theta (4.0-7.9 Hz); slow (8.0-9.9 Hz) and fast (10.0-12.9 Hz) alpha; slow (13.0-19.9 Hz) and fast (20.0-30.0 Hz) beta rhythms in the EEG spectrum (monopolar recording on F3, F4, T3, T4, O1, O2 sites). After preliminary data processing and screening of left-right and anterior-posterior differences, the main analysis was focused on data collected from the left hemisphere (F3, T3 and O1).

The experimental procedure consisted of

an adaptation period (5 min), initial resting baseline recording (1 min), white noise (85 dB, 40 s, WN), the first word - recognition task presentation with white noise background (40 s, TASK I - 10 English words for later recognition), the recognition test I also with noise background (20 s, TEST I), the second word - recognition task with white noise background (40 s, TASK II - 10 Korean words), word recognition test II with the same noise background (20 s, TEST II), post-test resting baseline (1 min, POST), music (3 min) for debriefing, and post-music baseline (1 min). Word recognition task was presented to subjects through smaller loudspeakers from pre-recorded tapes, while 85dBA WN was generated via another set of speakers located more remotely. (Details about memory task contents are available from authors upon request.) The instructions given to subjects before task presentation mentioned 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 the 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 software using T-test for paired samples.

Results

Electrocortical responses to WN, TASK, and TEST conditions. Exposure to white noise only (WN) evoked a slight increase of delta wave activity (e.g., RP of T3 delta tended to increase vs. the baseline, but $p>0.05$), no theta changes, significant alpha blocking (both slow and fast alpha bands, slow alpha reduced more), and moderate increase of fast beta activity. Changes of the RPs of EEG bands during all conditions are presented in Table 1. During task presentation with white noise conditions (both TASK I and TASK II) effects were similar: for instance, no significant differences were found between WN and TASK I conditions at any recording site (Table 2). However, most effects were significant as compared to the baseline in TASK, but not in WN vs. the baseline (e.g., frontal delta increased significantly in TASK I vs. baseline, while in WN it failed to reach the significance level, but WN and TASK I values do not differ significantly). TEST I and TEST II performance with white noise background conditions showed the most dramatic and statistically significant changes as compared to the baseline (both TASKs and/or WN only conditions). Qualitative comparisons of differences between TEST, TASK and WN conditions are summarized in Table 2. It should be noted that the initial values of all EEG bands restored in full in the POST resting period. Only the occipital and frontal slow alpha bands showed a tendency to reduced alpha power (e.g., T3 slow alpha in POST vs. the baseline decreased at -1.41, $p=0.052$). Absolute values of relative powers of specific EEG bands in experimental conditions are displayed in Figure 1-4.

Asymmetry and other topographic differences. No significant frontal asymmetry for slow and fast alpha bands was found. The temporal area demonstrated only fast alpha and fast beta asymmetry during both TEST conditions, namely lower fast alpha and fast beta at F4. Among other topographic specifics, higher values and more dynamics of slow bands (delta and theta) in the frontal area, a higher value of fast beta in the temporal area, and enhanced dynamics of slow alpha in the occipital area should be mentioned.

Discussion and conclusions

The obtained results show that white noise alone at the applied intensity of stimulation elicited electrocortical responses with increase of delta power, alpha-blocking and fast beta activity increase. This EEG pattern is typical of responses evoked by unexpected intense auditory stimulus and matches other studies (Hockey, 1970; Kaufman et al., 1992; Sokhadze et al., 1998). Subsequent presentation of a task in combination with white noise (TASK) led to smaller changes in EEG responses, thus demonstrating the same pattern with a lower profile. The word recognition test performance with noise background (TEST) resulted in a dramatic increase of slow electrocortical activity in the delta band, a further decrease of alpha power, and fast beta enhancement, practically observed were the same EEG shifts but with a much higher profile. Similar data were reported for some of above cortical parameters (Dujardin et al., 1993; Harmony et al., 1996; Kakizaki, 1985; Kaufman et al., 1992; Ray, Cole, 1985). Thus, such a stressor as intense white noise evoked EEG responses and general arousal that might be only partially modulated by attending to a task, but are facilitated by the performance of test. At the same time, non-specific arousal provoked by noise might positively affect selectivity of attention and alter task performance as has been shown by other researchers (Hockey, 1970; Poulton, 1979). Our experimental design, however, was not intended to study this point, that is,

Table 1. Comparative analysis of detected EEG changes to baseline
WN: white noise, TASKI,II: attending task with noise, TESTI,II: test performance with noise, POST: post-stress resting state. Values are presented as mean differences (N=12) between condition and initial resting baseline.

EEG Variables		Conditions					
		WN	TASK I	TASK II	TEST I	TEST II	POST
Delta	F3	2.02	2.04*	3.76**	8.53**	7.40**	-0.56
	O1	3.24*	2.65**	2.83*	3.71*	7.03*	0.67
	T3	2.86*	2.13**	2.88**	4.61**	3.57*	-0.54
Theta	F3	-0.14	-0.56	-0.22	1.39	2.45*	-0.78
	O1	0.34	0.01	0.38	-0.39	0.08	-0.56
	T3	-0.80	-0.83	-0.86	-1.22	-0.60	-1.11
S. alpha	F3	-2.49	-2.36*	-1.98	-5.51**	-5.10**	-0.23
	O1	-2.99	-2.96*	-3.13*	-6.08**	-5.87**	-1.23
	T3	-3.11*	-3.24*	-2.55*	-5.76**	-5.61**	-1.41
F. alpha	F3	-0.77	-0.56	-2.43	-6.92**	-7.09**	1.35
	O1	-3.05	-2.42	-2.98	-8.55**	-8.53**	1.28
	T3	-1.83	-1.77	-2.07	0.05	1.11	2.28
S. beta	F3	-0.03	-0.19	-0.35	-0.43	-0.08	0.25
	O1	0.55	0.89	1.85	2.29	2.80*	0.50
	T3	0.14	0.17	-0.06	1.18	1.71	0.31
F. beta	F3	1.42**	1.27	0.41	2.94**	2.33**	-0.02
	O1	1.89**	1.83*	1.23*	9.01**	8.45**	0.26
	T3	2.74*	3.54	2.41	7.84**	7.17**	2.03

Table 2. Qualitative comparative analysis of EEG bands' differences across conditions

EEG Variables		Conditions			
		WN vs. TASk I	WN vs. TEST I	TASK I vs. TEST I	TASK II vs. TEST II
Delta	F3	=	<<	<<	<<
	O1	=	=	<=	<=
	T3	=	<=	<	<=
Theta	F3	=	<=	<	<
	O1	=	=	=	=
	T3	=	=	=	=
S. alpha	F3	=	>	>>	=>
	O1	=	>>	>>	>>
	T3	=	>>	>>	>>
F. alpha	F3	=	>>	>>	>>
	O1	=	>	>>	>>
	T3	=	<=	<=	<=
S. beta	F3	=	=	=	=
	O1	=	<=	<=	<=
	T3	=	<=	<=	<=
F. beta	F3	=	<	<	<
	O1	=	<<	<<	<<
	T3	=	<<	<<	<=

Inter-condition comparisions outlines following statistical significance abbreviaged as:
= : no significant differences; <= : lower but not significant;
</<< : significantly lower (p<.05/ p<.01); => : higher but not significant;
>/>> : significantly higher ((p<.05/ p<.01);

influence of noise on task performance scores.

Both white noise only and task attending with noise background in biobehavoral terms represent passive exposure to aversive stimuli without efforts of active coping. This might explain the absence of differences between WN and TASK conditions (Bongard, 1995). The physiological pattern of response to white noise is more typical of orienting responses when both cortical and autonomic parameters indicate characteristics of reaction to an intensive stimuli with subsequent habituation.

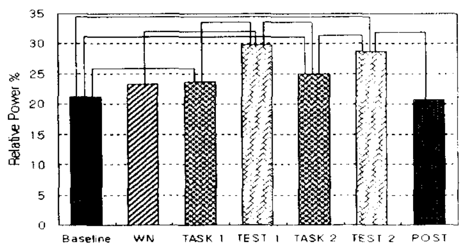

Figure 1. Relative power of left frontal delta (F3) during experimental conditions. Lines show significant differences between conditions. Delta power increase is more expressed during TEST.

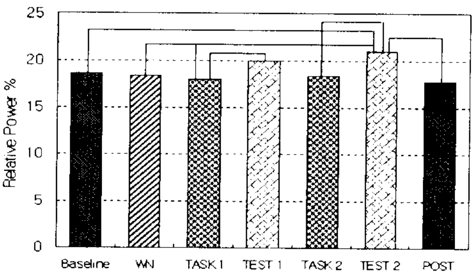

Figure 2. Left frontal theta power (F3) during experimental conditions. Theta power is augmented in TEST conditions as compared to WN, TASK, POST and baseline. Significance of differences is shown by lines

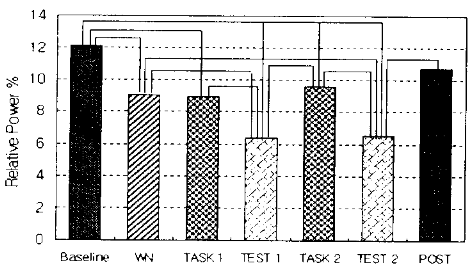

Figure 3. Left temporal slow alpha power (T3) during experimental conditions. Slow alpha is reduced during WN, TASK and TEST. Both TEST conditions demonstrate more profound alpha-blocking effect.

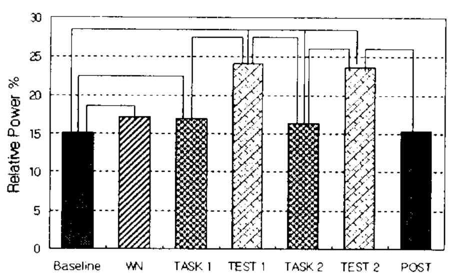

Figure 4. Left occipital fast beta power (O1) during experimental conditions. Beta power increase in TEST is significantly different from TASK, baseline and post-stress conditions. Lines show significant differences only.

When white noise serves as a background for task presentation, the obtained pattern is of mixed type. Basically it is closer to attending and sensory intake process, characterized by tuning of sensory inputs for better perception. Most probably, cortical responses were also slightly modified by external attention demands when noise was combined with the task to perceive. Test performance with the white noise background switches physiological patterns of response to those typical of an active coping, or in other words, psychophysiological processes of rejection of external stimulation and an intention to act (Bongard, 1995; Dujardin et al., 1993; Harmony et al., 1996; Lacey, 1967). EEG data obtained in the study support this conceptual framework, namely that increased slow wave power might reflect "Class II inhibition" (Harmony et al., 1996; Tucker et al., 1985; Vogel et al., 1968), which selectively suppresses non-relevant EEG activity during the performance of a mental task. Delta and some theta increase have been reported in different types of mental tasks (Harmony et al., 1996; Kakizaki, 1985), as well as an increase of beta and reduced alpha activity, especially when the task requires attention to internal processes and active cognitive efforts (Tucker et al., 1985). Thus our data support the functional significance of delta rhythm dynamics (based on Lacey's construct of inward vs. outward direction of attention). The data show that delta increases in conditions described as involving inward attention which includes a test on a mental task in contrast to a perceptual task only. These results add confirmation to Vogel's "Class II inhibition" posited to be involved in the active suppression of inappropriate activity. Vogel's classes of inhibition are usually applied to theta, but some studies extend them as well to delta activity (Harmony et al., 1996; Tucker et al., 1985; Vogel et al., 1968). We reported similar dynamics of delta power using noise of relatively lower intensity (Sokhadze et al., 1998).

The reduced power of alpha and low beta activity is consistent with joint decrement of alpha and beta activity during auditory stimulation and during performance of more complex tasks (Tucker et al., 1985). It is also partially in accord with the greater suppression of beta and alpha band powers in the left hemisphere during verbal cognitive tasks, as well as with reported increase in beta activity with cognitive activation (Ray & Cole, 1985). EEG desynchronization is associated with increased cognitive demands (Dujardin et al., 1993), voluntary movements, and behavioral and cortical arousal, as was the case under the TEST condition. However desynchronization, or low voltage fast activity, is considered to be due mainly to reduced synchronization and may not necessarily be associated with an increment relationship between beta activity, cortical activation, and behavioral arousal, thus outlining multiple interactions between beta activity, arousal, attention and activation in mental tasks. Our results indicate that slow beta, for instance, was not demonstrating the same typical changes as fast beta. Alpha was attenuated with alertness (Dujardin et al., 1993) and enhanced by relaxed resting states, as was expected to happen (Pribram, McGuiness, 1985), with few distinctions between slow and fast sub-bands (e.g., absence of fast alpha responses in the left temporal area).

Finally, it should be stated that performance on the word recognition task (i.e., mental task) with intense noise background elicited responses typical of active coping behavior, namely cortical responses in the form of alpha blocking, increased beta activity, and enhancement of slow wave bands (delta and frontal theta) more significant in left frontal, temporal, and occipital areas. Linguistic and word processing tasks are expressed more in the left hemisphere due to lateralization of cognitive functions. This response profile was more profound as compared to the white noise only conditions or as compared to attending to the task with the noise background. Since the employed model of inducing stress response was effective only for short-term, acute episodes of mental strain, detected responses were mostly transient and totally recovered in the post-stress resting state. This suggests that more prolonged exposure to stressors or application of recurrent stress models might be feasible in order to recognize long-lasting effects of stress on EEG patterns.

References

[1] Bongard S. (1995) Mental effort during active and passive coping: A dual-task analysis. *Psychophysiology*, 32, 242-248.

[2] 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.

[3] Dujardin K., Derambure P., Defebvre L., Bourriez J.L., Jacquesson J., Guieu J.D. (1993) Evaluation of event-related desynchronization during a recognition task: effect of attention. *Electroenceph. Clin. Neurophysiology*, 86, 353-356.

[4] Harmony T., Fernandez T., Silva J.,

Bernal J., Diaz-Comas L., Reyes A., Marosi E., Rodriguez M.A., Rodriguez M. I. (1996) EEG delta activity: an indicator of attention to internal processing during performance of mental tasks. *International Journal of Psychophysiology*. 24, 161-171.

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

〔6〕 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.

〔7〕 Kakizaki T (1985) Evaluation of mental task strain based on occipital beta activity and subjective rating of task difficulty. *European Journal Physiology*. 54, 466-470.

〔8〕 Kaufman L., Curtis S., Wang J.Z., Williamson S. J. (1992) Changes in cortical activity when subjects scan memory for tones. *Electroenceph. Clin. Neurophysiology*. 82, 266-284.

〔9〕 Lacey. J. (1967) Somatic response patterning and stress: some revisions of activation theory. In: M.Appley and R.Trumbull (Eds). *Psychological Stress: Issues in research*. (pp.14-37) .Appleton, Century & Crofts.

〔10〕 McCarthy P.R., Ray W.J., Foa E. (1995) Cognitive influences on electrocortical and heart rate activity in obsessive-compulsive disorder. *International J of Psychophysiology*. 19, 215-222.

〔11〕 Poulton E. (1979) Composite model for human performance in continuous noise. *Psychological Review*. 86, 361-375.

〔12〕 Pribram K., McGuiness D. (1975) Arousal, activation, and effort in the control of attention. *Psychol. Reviews* , 82, 116-149.

〔13〕 Ray W. J., Cole H .W. (1985) EEG alpha activity reflects attentional demands and beta activity reflects emotional and cognitive processes. *Science*. 228, 750-752.

〔14〕 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.

〔15〕 Tucker D. M., Dawson S., Roth D, Penland J. (1985) Regional changes in EEG power and coherence during cognition. *Behavioral Neuroscience*. 99, 564-577

〔16〕 Van Dijk J. G., Caekebeke J. F., Jennekens-Schinkel A., Zwinderman A.H. (1992) Background EEG reactivity in auditory event-related potentials. *Electroenceph. Clin. Neurophysiology*. 83, 44-51.

〔17〕 Vogel W., Broverman D., Klaiber E. (1968)EEG and mental abilities. *Electroencheph. Clin. Neurophysiology*. 24, 166-175.

韓國感性科學會誌
rean Journal of The Science of Emotion & Sensibility
99. Vol.2. No.1. 137-145

배경 백색소음하에서 기억과제를 수행할 때 겪는 단기 스트레스의 뇌파 특성

손진훈, Estate Sokhadze, 이경화, 최상섭, 이임갑
(충남대학교 심리학과)

요약 열 두 명의 피험자가 안정상태 일때, 백색 소음에 노출되었을 때, 백색 소음 하에서 기억과제에 주의를 기울일 때, 백색 소음 하에서 기억 검사를 받을 때, 기록된 뇌파에 대해 relative power spectrum 분석을 하였다. 뇌파는 전두, 측두, 후두 영역에서 단극 유도법으로 기록되었다. 분석 결과, 백색 소음에만 노출되었을 때나, 백색 소음 하에서 기억과제에 주의를 기울일 때나 비슷한 전기피질(electrocortical) 반응이 나타났다. 즉, delta power의 증가, 알파 blocking, fast beta power의 증가. 스트레스를 일으킨다고 피험자들이 평정한 배색 소음 하에서 기억검사를 받을 때에도 동일한 뇌파 패턴이 나타났지만 그 크기가 유의하게 컸다. 정보를 지각할 때 전형적으로 나타나는 반응을 유발하는 스트레스원에 수동적으로 노출되었을 때("intake"상황)의 생리 반응과 스트레스 상황에 적극적으로 대처할 때("rejection")의 생리 반응을 구분하는 이론 틀 아래서 데이터를 해석하였다. 스트레스 후 기간에 대부분의 뇌파 변수들이 기저선 수준으로 회복된 것으로 보아 사용한 스트레스 유발 모델은 단기적 스트레스 반응만을 유발한 것으로 보인다. 이는, 더 장기적으로 지속되는 스트레스원을 사용하게 되면, tonic상태의 전기피질 반응이 나타날 것을 시사한다.