A study of differences in ERP under meaningful of meaningless noise by multivariate analysis

Takahiro Tamesue[1]

[1] Yamaguchi University, Center for Information Infrastructure, Ube, Japan (corresponding author)

Corresponding author's e-mail address: tamesue@yamaguchi-u.ac.jp

ABSTRACT

The presence of noise during the performance of cognitive tasks involving such as memory, commonly causes a subjective experience of annoyance, which can lead to a decline in performance. This tendency is stronger in response to meaningful noise, such as music and conversation, than for meaningless noise, such as the sound of traffic, and heating ventilating and air-conditioning noise. In designing a comfortable sound environment, it is important to understand the relationship between not only the measurable aspects of noise, such as the sound pressure level, but also the qualitative aspects, such as the degree of meaningfulness of the noise, and the subjective experience of annoyance. On the other hand, it is well known that the Event-Related Potential (ERP) in the brain wave elicited by internal or external stimuli are related to the operation of selective attention. The present experiment was designed to determine the effects of meaningfulness of the external noise on selective attention. In order to examine differences in the ERP components during the odd-ball paradigms under the meaningful noise or meaningless noise, the multivariate analysis such as Principal Component Analysis (PCA) was adopted to define a set of components on P300 under various external noise condition.

INTRODUCTION

To create a comfortable sound environment in which cognitive tasks are performed, it is important to understand the relationships between the acoustic characteristics of external noise and psychophysiological evaluation of the noise. When carrying out intellectual activities involving memory or arithmetic tasks, it is common for external noise to increase levels of subjective annoyance, which can lead to a decline in performance. This tendency is stronger in response to meaningful noise, such as music and conversation, than for meaningless noise, such as the sound of traffic, and heating, ventilating and air-conditioning noise. Hence, in designing a comfortable sound environment, it is important to understand the relationship between not only the measurable aspects of external noise, such as the sound pressure level, but also the qualitative aspects, such as the degree of meaningfulness of the external noise, and the subjective experience of annoyance. On the other hand, it is well known that the transient event-related potentials (ERPs) elicited by internal or external stimuli in the brain wave are related to the operation of selective attention [1]. In this study, the effects of meaningfulness of the external noise on selective attention during mental task were considered by psychophysiological experiment. In order to examine differences in the ERP components during the odd-ball paradigms under the meaningful noise or meaningless noise, the multivariate analysis such as Principal Component Analysis (PCA) [2] was adopted to define a set of components on P300 under various external noise condition.

OUTLINE OF EXPERIMENT

Psychophysiological experiments were conducted to determine the effects of the meaningfulness of external noise on selective attention to auditory stimuli by examining differences in brain ERPs during the completion of the repetitive odd-ball paradigm. The outline of the experiments was as follows.

Participants

A total of 8 students with normal hearing participated in the experiment.

Odd-ball paradigm

The odd-ball paradigm is typically used to examine selective attention and information processing ca-pacity [1]. In this task, subjects detect and respond to rare target events embedded in a series of repeti-tive events. Thus, to complete the odd-ball task it is necessary to regulate attention to a stimulus. In the auditory odd-ball paradigm, the common non-target stimulus (“frequent”) was a 1,000 [Hz] tone burst. The target stimulus was 2,000 [Hz] tone burst (“rare”) with an occurrence probability of 20 [%]. Both stimuli were presented binaurally at 60 [dB], and 120 [ms] duration (includng 10 [ms] rise-fall time and 100 [ms] plateau). The frequent-rare sequence was randomly presented with an inter-stimulus interval of 2 [s]. The subjects task was only to count the “rare” stimuli for approximately 10 [min].

External noise

The following external noises with different degree of meaningfulness, were employed as examples of typical indoor noises.

(a) Meaningless noise

Pseudo voice-noise from a CD that was originally produced for the evaluation and fitting of hearing aids (TY-89) [3] was used as meaningless noise.

(b) Meaningful noise 1

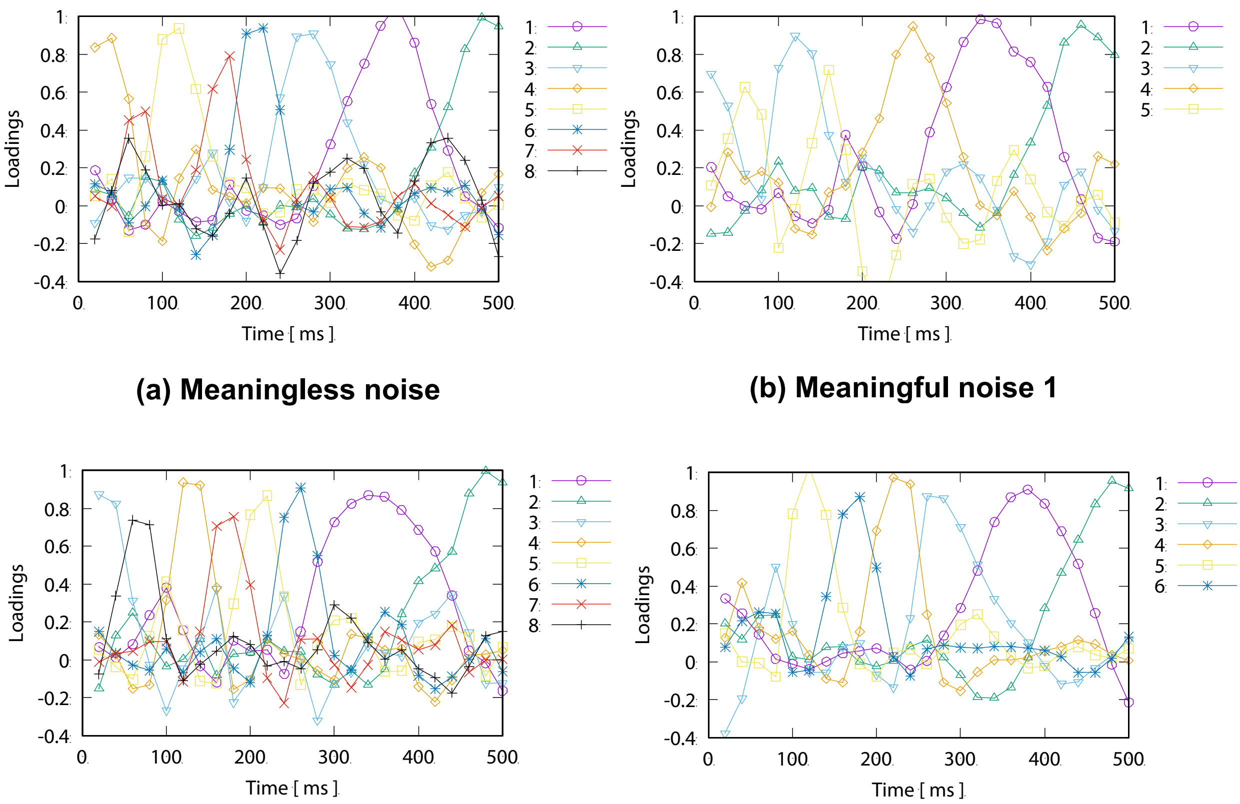
Multi-talker noise from a CD for the evaluation and fitting of hearing aids (TY-89) [3], was used as meaningful noise 1.

(c) Meaningful noise 2

Male speech, produced by deleting handclaps, sound effects, and music, etc. from commercially avail-able speech Tapes, was used as meaningful noise 2.

For practical reasons, the energy-mean value of the sound pressure level of the above external noises was adjusted to approximately 50 [dB]. In addition, the following conditions were tested.

(d) No external noise



(a) Meaningless noise

(b) Meaningful noise 1

(c) Meaningfull noise 2

(d) No external noise

Figure 1: Component loadings

Measurements

Participants were seated in a sound-attenuated electrically shielded room. The auditory signal was gen-erated by a CD player and presented through loud-speaker. Electroencephalogram (EEG) was recorded from 20 locations (Fp1, Fpz, Fp2, F7, F3, Fz, F4, F8, T3, C3, Cz, C4, T4, T5, P3, Pz, P4, T6 O1, O2) of scalp based on 10-20 system with Ag/Ag Cl electrodes of which impedance was held below 10 [kΩ]. Electrodes were referenced to linked earlobes, and the ground electrode was placed on the midfore-head electrode (Fpz). The electrooculogram (EOG)was recorded from an electrode located at the su-pra-orbital ridge of the right eye and referenced to the linked earlobes. EEG and EOG signals were amplified with a bandpass filter of 0.01 to 30 [Hz], and recorded with 16-bit quantization level at sam-pling rate of 1 [kHz], continuously. ERPs for the responses to the “rare” and “frequent” stimuli were synchronously averaged to enhance the evoked signal and suppress the background brain activity.

EFFECT OF MEANINGFULNESS OF THE EXTERNAL NOISE

Event-related potentials

It is well established that ERPs elicited by internal or external stimuli, can be measured using EEG . A waveform of ERPs after stimulus-triggered averaging to “frequent” and “rare” stimuli,

Table 1: Cumulative Proportion

Noise condition	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7	Factor 8
(a) Meaningless noise	0.19	0.32	0.46	0.57	0.68	0.77	0.85	0.91
(b) Meaningful noise 1	0.22	0.38	0.52	0.65	0.75	-	-	-
(c) Meaningful noise 2	0.23	0.39	0.50	0.59	0.69	0.78	0.84	0.92
(d) No external noise	0.23	0.36	0.51	0.64	0.76	0.86	-	-

was individually calculated on each electrode position under each external noise condition. Furthermore, wave forms were summing and averaging across subjects. The P300 component, which is a positive peak occurring around 300 [ms] after presentation of stimulus, thought to reflect the resolution of uncertainty or the perceptual decision that an expected signal has occurred. These components are related to selective attention and working memory.

Principal component analysis for event-related potentials

Techniques such as principal component analysis (PCA) [4] use correlational structure of an ERP data set to define a set of components, may sometimes be useful for identifying latent ERP components. For each 704 wave forms of ERPs after stimulus-triggered averaging to auditory “rare” stimuli (external noise condition: 4 × electrodes: 19 × subjects: 8), voltages from 0 [ms] to 500 [ms], were averaged for 20 [ms]. 15,200 (608 × 25) data sets were employed for PCA. Based on Minimum Average Partial test (MAP) [5] for determining the number of factors to retain in PCA, at most 8 principal components were extracted for each external noise condition. The loading for each component under the meaningless noise, meaningful noise 1, meaningful noise 2 and no external noise, are shown in Figure 1 (a), (b), (c) and (d). Table 1 shows the cumulative proportion for each external noise condition. The results revealed that principal component I, which has the largest eigenvalue, was associated with P300 component.

CONCLUSION

This study focused on the effects of the meaningfulness of external noise. We examined the effects of meaningful noise and meaningless noise on physiological activity while carrying out auditory cognitive tasks. Specifically, the P300 components of the ERPs elicited by the auditory odd-ball paradigms, were measured using EEG. The principal component analysis (PCA) was adopted to define a set of components. Our results extract at most 8 principal components associated with latent component of ERPs during the completion of repetitive auditory odd-ball paradigm under the meaningful noise and meaningless noise.

ACKNOWLEDGEMENTS

This study was partially supported by the Japan Society for the Promotion of Science, Grant-in-Aid for Scientific Research (C), No. 15K00376, 18K11502.

REFERENCES

[1] S.Sutton, M.Braren, J.Zubin, and E.R.John. Evoked-potential correlates of stimulus uncertainty. Sci-ence, 150 (3700), 1187–1188, (1965).

[2] E.Donchin and E. F. Heffley. Multivariate analysis of ERP data: A tutorial review. D. A. Otto(Ed.), Multidisciplinary Perspectives in Event-Related Brain Potential Research, US Government Printing Office. 555–572, (1978).

[3] K. Yonemoto. Characteristics of cd for the evaluation of fitting condition with hearing aids (ty-89). Journal of Otolaryngology, Head and Neck Surgery, 11 (9), 1395–1401, (1995).

[4] J. T. Cacioppo, L. G. Tassinary, and G. G. Berntso. Handbook of psychophysiology, Cambridge University Press, 94–119, (2000).

[5] W. F. Velicer, Determining the number of components from the matrix of partial correlations, Psychometrika, 41 (3), 321–327, (1976).