RELATIONSHIP BETWEEN VIGILANCE LEVELS AND CHARACTERISTICS OF SACCADIC EYE MOVEMENT

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Abstract–The purpose of this study was to investigate the possibility for evaluating vigilance levels using a parameter of saccadic eye movement. EEG was measured and analyzed by means of Fast Fourier Transform, and the spectral power of α and β wave bands were obtained so as to extract $[\beta]/[\alpha+\beta]$ which was assumed to reflect vigilance levels. Eye movement was measured so as to calculate saccadic peak velocity(SPV) and relative SPV(RSPV) which was normalized by the mean SPV at the corresponding amplitude of saccade. Relationship between $[\beta]/[\alpha+\beta]$ and RSPV was investigated and it revealed that RSPV decreased according to the decline in the vigilance level. This indicates the possibility for evaluating vigilance levels using RSPV.

I. INTRODUCTION

During VDT operation, motorcar driving and instrumentation monitoring, a decline in the vigilance level can cause a big accident, great misinterpretation, and so on. For evaluating the vigilance levels, several methods such as a method using EEG or galvanic skin reflex have been investigated. To prevent such accidental events, it is necessary to monitor the various vigilance states continuously. However, most of conventional methods has shown disadvantage such as attachment of electrodes on the body surface for detecting physical electro-signals or interruption of the operation for the measurement. We took notice of the characteristic of saccadic eye movement which provides a possibility for evaluating vigilance levels. Because measurement of eye movement using a photometric method has a possibility to recognize the vigilance levels without any attachment and any interruption of working. Saccadic eye movement consists of two different components: visually triggered saccade (VTSC) and internally guided saccade (IGSC) [1]. VTSC is elicited reflexively by a sudden presentation, while IGSC intentionally by own will. These shows different characteristics, that is, velocity of VTSC is relatively higher than that of IGSC. Relationship between vigilance levels and characteristics of both saccades remains unknown. Therefore we studied on this relationship between them as a basic research for proposing a new method to evaluate vigilance levels.

II. METHODS

A subject was seated at the distance of 1.45m from a display system consisting of two personal computers. Horizontal eye movements were detected by the infrared limbus reflection system. EEG (Fz) were detected with standard Ag/AgCl electrodes. Eye movement data and EEG data were amplified, and then sampled at 2kHz.

In order to induce VTSC and IGSC, experiments were performed under two conditions. VTSC was induced under a moving-target condition, where a target was presented at one of six possible locations ±2.5, ±5.0, ±7.5deg, and was controlled to shift the location repeatedly to the right and the left alternately at 2sec intervals. The subject were asked to follow the target presented. IGSC was induced under a non-target condition, where two targets were presented at ±2.5 or ±5.0deg symmetrically before each measurement. The subject memorized those locations, then the targets were extinguished. The subject moved their eyes to memorized locations to the right and the left alternately at any timing. All measurements were performed for 3min and repeated two times under each condition.

EEG data were used to extract $[\beta]/[\alpha+\beta]$ which may reflect vigilance levels. 2048 sample of EEG data obtained just before the beginning of saccade were analyzed by means of Fast Fourier Transform, and the spectral power of α (8∼13Hz,$[\alpha]$) and β (13∼100Hz,$[\beta]$) wave bands were obtained so as to calculate $[\beta]/[\alpha+\beta]$. The $[\beta]/[\alpha+\beta]$ decreases according to the decline in the vigilance level, since the power of α wave band ($[\alpha]$) increases and the power of β wave band ($[\beta]$) decreases.

III. RESULTS AND DISCUSSION

Fig. 1(a) shows a relationship between amplitude and peak velocity derived from the eye movement data accompanying with a saccade. It is well known that peak

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velocity can be fitted by the following equation;

$$PV = PV_0\{1 - \exp(-A/k)\} \qquad (1)$$

where PV represents peak velocity, PV_0 the asymptotic peak velocity for very large saccade, A an amplitude and k a constant [2]. As shown in Fig. 1(a), not all experimental data are along the regression curve. This deviation of peak velocity from the regression curve is likely to attribute to some changes in the oculomotor control system during experiment. We supposed these changes were caused by the changes in vigilance level which may affect a function of oculomotor control system. However we can't use peak velocity to compare with vigilance level, because this parameter doesn't quantitatively represent the deviation from the regression curve. In order to clarify the degree of the deviation, we divided every peak velocity by the value of regression curve at each amplitude, and named it relative saccadic peak velocity (RSPV, Fig. 1(b)).

As shown in Fig. 2, RSPV of both saccades showed the similar tendency to $[\beta]/[\alpha+\beta]$, which seem to mean that RSPV reflects the changes in the vigilance level. Moreover, comparing the data between two types of saccade, we found that RSPV of VTSC is relatively higher than that of IGSC, and so was the $[\beta]/[\alpha+\beta]$. In other words, under the moving-target condition RSPV and vigilance level were relatively high, but under the non-target condition those were relatively low. In addition to these facts, Fig. 2 shows that scattering plots under two different conditions are overlapping each other and that the trends of regression lines under each condition are almost same. From these result, we could infer that difference of saccadic peak velocities under the two conditions might depends on the difference between vigilance levels under the different conditions, not on the difference in the types of saccade with different cerebrophysiological processes of VTSC and IGSC. This can be indirectly explained as follows; under the moving-target condition, differently from under the non-target condition, there exist a target to be a factor to maintain high vigilance level by giving out the light and changing locations.

To determine whether or not our assumption is applicable, we performed two additional measurements under a fixed-target condition, where two fixed targets at ±2.5 or ±5.0deg were presented continuously and the subject moved their eyes toward the targets to the right and the left alternately at any timing. $[\beta]/[\alpha+\beta]$ under this condition was in-between that of the non-target condition and that of the moving-target condition, and so was RSPV. This can be considered that the difference of three target conditions of moving target, fixed target, and no target caused the difference of vigilance levels, and then this resulted in the difference of RSPV.

IV. CONCLUSION

This study has shown that vigilance level and relative saccadic peak velocity have a positive correlation regardless of the type of saccade. This indicates a possibility for evaluating vigilance levels using saccadic parameter.

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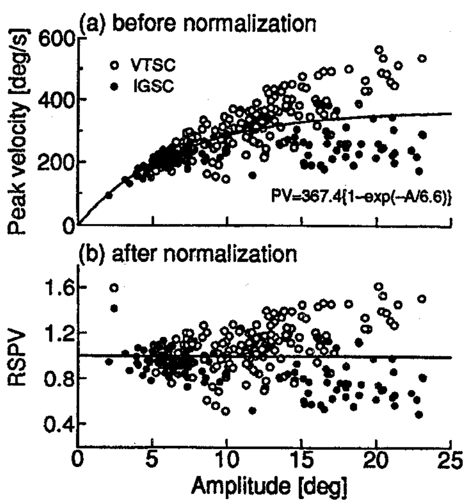

Fig. 1 Normalization of saccadic peak velocity

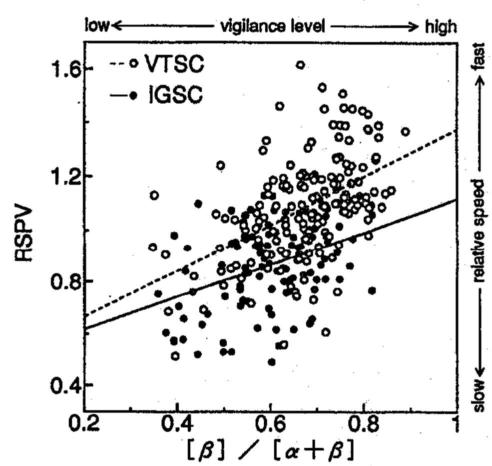

Fig. 2 Relationship between $[\beta]/[\alpha+\beta]$ and RSPV