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PARAMETRIC ANALYSIS OF SACCADIC EYE MOVEMENT DEPENDING ON VIGILANCE STATES

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Abstract The purpose of this study was to investigate the relationship between characteristics of saccadic eye movement and vigilance states. We surveyed this by comparing the wave-form parameter of saccadic velocity to EEG parameter obtained from spectral power of α and β wave bands or to subjective vigilance states and sleepiness. Our results showed that the shapes of saccadic velocity changed into blunt according to a decline in the vigilance states and also to a increase in sleepiness. This indicates the possibility for estimation of vigilance states by using characteristics of saccadic eye movement.

I. INTRODUCTION

For assessing vigilance states it is common to use bioelectrical signal such as EEG or some kind of subjective rating scales. However, most of these methods have shown disadvantage so far as requiring attachment of electrodes on the body surface for signal detecting or interruption of the operation to estimate self-perceived feeling states. So it is important to propose a new effective method for estimation of vigilance states without any attachment and any interruption of operation. Therefore we studied on relationship between vigilance states and characteristics of saccadic eye movement (saccade) to examine a possibility for estimation of vigilance states by using characteristics of saccade.

II. METHODS

Experimental procedure

In order to investigate the relationships between characteristics of saccade and vigilance states changing in short-term and long-term period respectively, we conducted two different experiments, that is short-term experiment and long-term experiment. In short-term experiment, seven male subjects (mean age:22.7) participated and five of the seven subjects (mean age:22.9) participated in long-term experiment.

Short-term experiment consisted of Rest, Jump-Target session (JTS), and Non-Target session (NTS) as shown in

Fig. 1 Protocol of short-term experiment

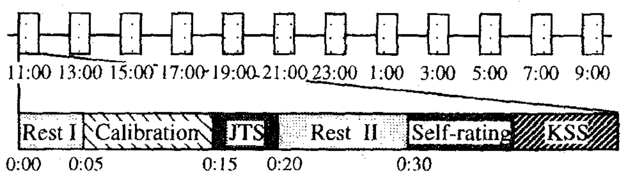

Fig. 2 Protocol of long-term experiment

Fig.1. All sessions were conducted for 3min, and movements of the dominant eye and EEG (Fz) were detected in JTS and NTS. In JTS, one visual target appeared at one of six possible locations of 2.5, 5.0, or 7.5deg on the right or left side from the center, then jumped horizontally to one of three possible locations in the other side at 2sec interval. The target jumped repeatedly until the end of the session and the subjects followed this continuously. In NTS, the subjects moved their dominant eye repeatedly to locations where they memorized just before the beginning of each measurement referring to two visual targets presented in a display symmetrically from the center.

In long-term experiment, a series of measurement performed every 2 hours from 11:00 in the morning to 9:00 in the next morning. So a experiment consisted of 12 series of measurement, and one series consisted of 6 sessions, that is Rest I, Calibration, JTS, Rest II, Self-rating, and KSS)Kwansei Gakuin Sleepiness Scale) as shown in Fig.2. JTS is all the same as in short-term experiment except for measuring time and additional detection of EEG at Cz and Pz. In Self-rating session, subjects scored self-perceived vigilance state between 0 and 10. 10 represents highest vigilance level. In KSS session, subjective sleepiness was assessed by using KSS, which is Japanese translation from Stanford Sleepiness Scale[1]. KSS ratings ranges from 0 to 7 and 7 represents sleepiest.

Table 1 Correlation coefficients between PV/D and $[\alpha+\beta]$ in JTS and NTS (mean of every 30sec)

Subject	$[\alpha+\beta]$	
	JTS	NTS
♯1	-0.74	-0.28
♯2	-0.35	-0.74
♯3	-0.75	-0.49
♯4	-0.04	0.69
♯5	0.22	-0.86
♯6	-0.90	-0.65
♯7	-0.79	-0.75

Table 2 Correlation coefficients between PV/D and three parameters reflecting vigilance state (mean value of every session)

Subject	$[\alpha+\beta]$	KSS	Self-rating
♯2	-0.63	-0.76	0.88
♯3	0.23	-0.50	0.55
♯4	-0.72	-0.74	0.62
♯5	-0.83	-0.81	0.86
♯6	0.32	-0.70	0.82

Data analysis

Eye movement data and EEG data were amplified and sampled at 2kHz, then analyzed by computer programs. For each primary saccade three parameters were computed : amplitude, duration and peak velocity. In addition, PV/D was calculated by dividing peak velocity by duration, which represents the sharpness of saccadic velocity wave-form.

For each primary saccade, a segment of EEG (1.028s) was selected at the period just before the beginning of saccade, and then analyzed by means of Fast Fourier Transform so that total power of α (8~13Hz) and β (13~100Hz) wave bands, which is showed as $[\alpha+\beta]$, was obtained.

III. RESULTS

Short-term experiment

As shown in Table 1 there were negative correlations between $[\alpha+\beta]$ and PV/D in both sessions. This implies that PV/D tend to go down according to the decline in the vigilance state regardless of sort of saccade, for JTS and NTS induce different sort of saccade.

Long-term experiment

Fig.3 and Fig.4 show diurnal variations in $[\alpha+\beta]$, KSS ratings, PV/D and self-ratings for vigilance state. Table 2 shows correlation coefficients of PV/D to the other three parameters above. These results show that PV/D has a positive correlation to vigilance states which are reflected to EEG data and subjective vigilance state, and has a negative correlation to sleepiness.

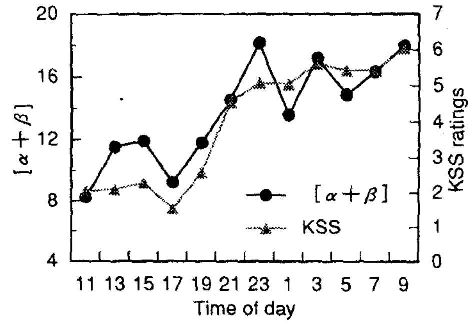

Fig. 3 Diurnal variations in $[\alpha+\beta]$ and sleepiness (Subject ♯5, mean of every series)

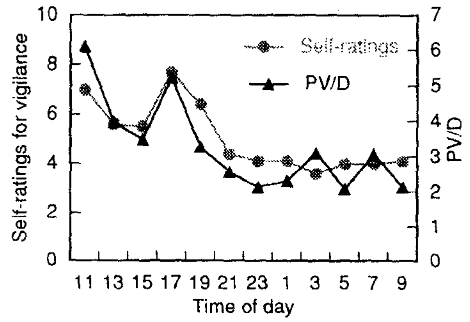

Fig. 4 Diurnal variations in subjective vigilance and PV/D (Subject ♯5, mean of every series)

IV. DISCUSSION

Results obtained from two different experiments indicate that saccadic velocity wave-form reflects both of short-term and long-term variations in vigilance states. This suggests that both of reticular controlling system and hypothalamic controlling system is concerned with control of saccade. The other hand, in case of subject ♯3 and ♯5 results showed low positive correlations between PV/D and $[\alpha+\beta]$. It is possibly due to change of EEG signal caused by sweating on the scalp, body motion, and so on. Thus it is necessary to continue careful research on this relationship.

V. CONCLUSION

This study has shown that the parameter of saccadic velocity wave-form has correlation to vigilance states which were estimated from objective EEG data and subjective vigilance and sleepiness. This indicates a possibility for assessment of vigilance states using saccadic parameter.

REFERENCES

[1] J. Herscovitch and R. Broughton : "Sensitivity of the stanford sleepiness scale to the effects of cumulative partial sleep deprivation and recovery oversleeping," *Sleep*, Vol.4, No.1, pp.83 92, 1981.