Psychiatry and Clinical Neurosciences (2002), **56**, 257–258

Human Sleep Physiology

Comparison of the event-related potentials between tonic and phasic periods of rapid eye movement sleep

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Abstract The event-related potentials (ERP) of eight young healthy volunteers were recorded during wakefulness and rapid eye movement (REM) sleep using an auditory discrimination task. REM sleep was classified into phasic and tonic periods according to the presence or absence of REM. In wakefulness, deviant stimuli elicited a P300 that was maximal over parieto-central areas. During the tonic period of REM sleep, deviant stimuli elicited a P200 and a P400. The P200 was distributed more anteriorly and the P400 was distributed more posteriorly than the P300; however, no prominent ERP components were observed during the phasic period. The study's findings suggest that the brain is less sensitive to external stimuli during the phasic period than during the tonic period of REM sleep.

Key words event-related potentials, oddball task, P200, P300, tonic and phasic periods of REM sleep.

INTRODUCTION

The similarity between information processing in rapid eye movement (REM) sleep and in wakefulness has been discussed. Event-related potentials (ERP) are often used to determine mental activity during sleep. P300 is one of the ERP components that are elicited in the so-called 'oddball' task, in which participants are asked to detect infrequently occurring 'deviant' stimuli among a train of frequently occurring 'standard' stimuli. If a participant fails to detect the target stimulus, usually no P300 is elicited.[1] During non-REM (NREM) sleep, P300 decreases in amplitude or disappears. However, during REM sleep, it has been demonstrated that a P300-like component can be elicited.[2] REM sleep is known to contain phasic and tonic periods. Phasic periods are characterized by bursts of REMs, whereas no REM occur during tonic periods, and these two periods of REM sleep have been reported to differ in terms of the processing of external stimuli.[3]

In the present study, subjects were instructed to continue the oddball task and respond to the deviant stimuli during sleep. The purpose was to compare the ERP elicited during wakefulness, and during tonic and phasic REM sleep.

METHOD

Eight university students (four men and four women; age range 20–24 years) participated in the study. The electroencephalogram (EEG) was recorded from 21 electrodes (Fp1, Fp2, F7, F8, Fz, F3, F4, T3, T4, Cz, C3, C4, T5, T6, Pz, P3, P4, O1, O2, M1, and M2, referenced to the nose tip, time constant = 3.2 s, high cut filter 60 Hz). A standard 1000 Hz tone ($P = 0.9$) and a deviant 2000 Hz tone ($P = 0.1$) were presented through inserted earphones at an intensity of 60 dB sound pressure level (duration 50 ms, interstimulus interval 1450 ms). The task was to make a finger-lift response to deviant tones. Following a 15-min wake session, participants were asked to fall asleep while continuing to respond to deviant tones. The tones were presented continuously until the end of the sleep session. Vertical and horizontal electro-oculograms (EOG) and the chin electromyogram (EMG) were also recorded. Data were digitized at 200 Hz. Sleep staging was done according to the standard criteria of 30-s intervals.[4] Stage REM was further classified into phasic (REM present) and tonic (REM absent) periods of 3-s intervals. There were three to five sleep cycles per night.

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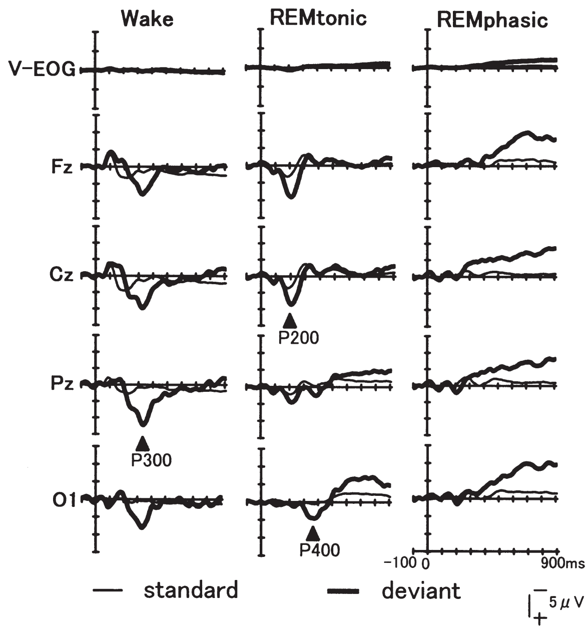

Figure 1. Grand average event-related potentials (ERP) during wakefulness and during the tonic and phasic periods of rapid eye movement sleep.

REM sleep periods were collected from all sleep cycles for ERP averaging. The ERP waveforms were calculated by averaging the interval between 100 ms before and 900 ms after the stimulus onset. At least 20 artifact-free responses were averaged for each subject in each condition.

RESULTS

Figure 1 shows the grand average ERP values. In wakefulness, deviant stimuli elicited a P300, which was maximal over parieto-central areas ($F_{4,28} = 7.91$, $P < 0.01$). During the tonic period of REM sleep, a P200 that was maximal over the fronto-central areas and a late positive component (P400) occurred in response to deviant tones. P400 was distributed more posteriorly than the P300 during wakefulness. Peak latencies of the P300 during wakefulness and the tonic REM P400 were 335.0 ± 25.63 ms (at Pz) and 356.3 ± 24.31 ms (at O1), respectively. The peak latency of the tonic REM P400 was significantly longer than that of the P300 during wakefulness ($t(7) = 1.94$, $P < 0.05$). Conversely, no ERP components were observed during the phasic period except a slow negative shift in deviant ERP waveforms.

DISCUSSION

The results confirmed that the deviant tones elicited a P300 component during wakefulness. In the tonic period of REM sleep, which contained no REM, a P200 and a late positive component (P400) were elicited by deviant tones. Because the P400 in REM sleep was distributed more posteriorly and had a more prolonged peak latency than the P300 during wakefulness, we speculated that these two components might have different source generators and different functional significance. Alternatively, the topographies of the P200 and the P400 in REM sleep were similar to those in the early NREM sleep, respectively,[5] which may show that these two components reflect auditory information processing specific to sleep. No prominent ERP components were observed during the phasic period of REM sleep, which contained bursts of REMs. This result agrees with the previous finding that the threshold of perceiving external stimuli may be higher in the phasic period than in the tonic period of REM sleep.[3] Although a late negative shift was observed in response to the deviant tones during the phasic period, what this negative shift reflects remains unclear and is a topic for further investigation.

REFERENCES

1. Hillyard SA, Squires KC, Bauer JW, Lindsay PH. Evoked potential correlates of auditory signal detection. *Science* 1971; **172**: 1357–1360.
2. Cote K, Campbell K. P300 to high intensity stimuli during REM sleep. *Clin. Neurophysiol.* 1999; **110**: 1345–1350.
3. Sallinen M, Kaartinen J, Lyytinen H. Processing of auditory stimuli during tonic and phasic periods of REM sleep as revealed by event-related brain potentials. *J. Sleep Res.* 1996; **5**: 220–228.
4. Rechtschaffen A, Kales A (eds). *A Manual of Standardized Terminology, Techniques, and Scoring System of Sleep Stages in Human Subjects.* Public Health Service, US Government Printing Office, Washington, DC, 1968.
5. Michida N, Ebata A, Tanaka H, Hayashi M, Hori T. Changes of amplitude and topographical characteristics of event-related potentials during the hypnagogic period. *Psychiatry Clin. Neurosci.* 1999; **53**: 163–165.