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Analysis of the Ocular Movements during the Onset of Sleep

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There have been many investigations of ocular movements (OM) during the REM phase of sleep, whereas ocular motor activity during the onset of sleep has rarely been studied. Aserinski and Kleitman [1] noted the lack of vertical movements during the onset of sleep phase in contrast to the REM phase, during which the movements are vertical and horizontal. Kuhlo and Lehmann [4] described combined, slow horizontal OM. These movements appeared with a modification of the EEG (decrease of frequency and amplitude) and disappeared with a return of a-rhythm or with deepening of sleep (appearance of spindles). We report here the results of our recent reinvestigation of this problem.

Gabersek Analysis of Ocular Movements during Onset of Sleep 377

Technique

The following parameters were recorded: EEG, EKG, respiration, EMG of the chin muscles, body motility and electrodermogram.

To record eye movements, 8 electrodes were fixed with collodium to the upper and lower orbital edges. This arrangement gives 8 monocular and binocular derivations (fig. 1). To record relatively slow ocular movements, a time constant of 0.3 sec was used. The present study was done on 16 subjects.

Fig. 1. From top to bottom: actogram (Acto.), electromyogram (EMG), electrodermogram (EDG), respiration (Resp.), electrocardiogram (EKG: the R waves underlined represent the inspiration). Electrooculograms: vertical monoculars left (1) and right (2); lower horizontal: monoculars left (3) and right (4); upper horizontal monoculars left (5) and right (6); horizontal (7) and vertical (8) binoculars. EEG: frontomedian-right mastoid; vertex-right mastoid. Vertex derivation: integration (v. int.).

State of evident awakening but, after only three short body movements, relapse to sleep. The waking-up was gradual: after every body movement the ocular movements accelerate and from horizontal become predominantly vertical. The arrows indicate the appearance of different ocular movement types. Stage 1 b, then short awakening and another stage 1b, horizontal eye movements during stage 1b; vertical movements (between arrows) during awakening. Ct = time constant, HB = up, down, DG = right, left, FM, MDr. = Fronto médian, mastoid right, V. MDr. = vertex, mastoid right, V. int. = vertex integration.

Free Communications: E. Phenomenology of Sleep in Man 378

Results

Our study of the OM was restricted to stages 1a and 1b; a number of peculiarities manifested by speed and direction of displacement and (binocular) synergy as revealed through the multi-channel analysis of the EOG characterize the OM at the beginning of sleep.

1. During the stage immediately preceding the onset of sleep characterized by a spindle-like α -activity, the numerous OM are mainly vertical, rapid, and biphasic (up and down). They coincide with the fluttering of the eyelids. At this stage the subject can immediately answer a question without any body movement. The OM are not affected by the verbal reaction.

2. During stage 1a, the EEG activity flattens, the eyes remain closed, the OM described previously slow down and the interval between the

two phases of vertical movements is prolonged. In addition rapid nystagmic jerks can be noticed. The OM described under heading paragraph 1 reappear after spontaneous bodily movements or when the subject is asked a question.

3. A lack of rapid ocular movements is typical of the second sequence of sleep onset. The ocular asynergy appears and may affect (a) the amplitude: this is what occurs most frequently; the maximum asynergy of amplitude is found when the ocular movements affect only one eye; (b) the direction: one eye moves right, the other one left, and (c) the appearance: one eye moves right and, after a very short latency (10-30 msec), an identical movement is performed by the other eye.

Oblique and rotatory ocular movements are frequent. When the subject is asked a question, the response occurs with a reappearance of rapid and synergic ocular movements.

4. During the Ib phase, with the appearance of the 0-rhythm, the vertical OM disappear; there are often oblique and rotatory OM. However, horizontal very slow and occasionally asynergic OM are frequent. With a body movement, the subject can revert to rapid and synergic ocular movements.

Whatever the moment of onset of sleep may be, the appearance of ocular movements may sometimes be stereotyped. They then appear in a cyclic manner presenting, thus, identical sets of constant period (about 20 sec).

Gabersek Analysis of Ocular Movements during Onset of Sleep 379

Discussion

The ocular movements during the onset of sleep can be compared to those observed in subjects at different levels of vigilance and in subjects suffering from vestibular disease.

In a normal subject in the waking state the ocular movements slow down when the eyes are closed. This may be due to friction between the bulbi and the eyelids. During the onset of sleep, this action could be of greater importance because of the increased state of contraction of the two orbicular muscles. The predominance of vertical movements may be linked to the fact that during the onset of sleep, the eyeballs turn upwards (Bell's phenomenon). In this position the fluttering of the eyelids increases. The asynergy of OM may be due to the different starting position of each eye; the lack of visual fixation no longer calls for alignment of the two eyes. A certain degree of asynergy is also observed in the waking

state when the eyes are closed and the subject concentrates on an object not related to the outside world.

During the onset of sleep phase, hypnagogical effects can be observed, such as swinging sensations, floating, etc. Besides, these same slow horizontal asynergic movements are to be found in waking subjects suffering from vestibular disturbances. The slow horizontal movements observed during the onset of sleep could, thus, be related to ocular reflexes of vestibular origin. Rotatory ocular movements do not exist in a normal waking subject but, again, they are observed when the subject is afflicted by bulbar or pontine injury, that is to say when he suffers from a vestibular impairment.

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