Eye Movement Activity during Sleep and Intellectual Function in Mental Retardation

Abstract. *A positive relation was found between the amount of eye movement during rapid-eye-movement or paradoxical sleep and estimates of intellectual level in a group of retarded adults. This result supports the hypothesis that during sleep the brain carries out processes important for cognitive function.*

Jackson appears to have been the first to propose that during sleep the brain carries out processes vital to its plasticity. He suggested that these processes were especially important for such aspects of cognition as memory and problem-solving (*1*). More recently, Moruzzi put forward a similar hypothesis on the basis of neurophysiological considerations (*2*), and we independently proposed this view on the basis of several experimental observations (*3*). Among these observations was evidence that, within groups of both normal aged subjects and those with mental deterioration (chronic brain syndrome, CBS) certain sleep variables are correlated with independent measurements of the level of intellectual function. Thus, for 15 normal aged subjects, scores on the performance scale of the Wechsler Adult Intelligence Scale (WAIS) (*4*) were correlated ($r = +.71$, $P < .01$) with the amount of emergent stage 1 electroencephalogram (EEG), a measure of rapid-eye-movement (REM) or "paradoxical" sleep. In ten patients with CBS, the correlation coefficient (r) between these variables was +.72 at $P < .05$ (*5*).

We have now attempted to test the generality of this relation between REM sleep and intellectual level by studying patients whose intellectual deficit results from mechanisms other than those presumed to operate in normal and pathological aging. We recorded EEG and eye movement continuously during sleep in 32 mentally retarded patients. Each patient was studied for five consecutive nights with conventional (*6*) methods of recording. It was possible to obtain estimates of intellectual level, with the Wechsler Preschool and Primary Scale of Intelligence (WPPSI) (*7*), in 27 of these subjects. Included were seven mongolian, six phenylketonuric (PKU), four brain-damaged, and ten undifferentiated patients. The median age of these 27 subjects was 36.5 years (range from 17.6 to 59.8 years). Those who scored the sleep tracings had no knowledge of the WPPSI results, and this latter test was administered by consultant psychologists who were unaware of the records taken during sleep.

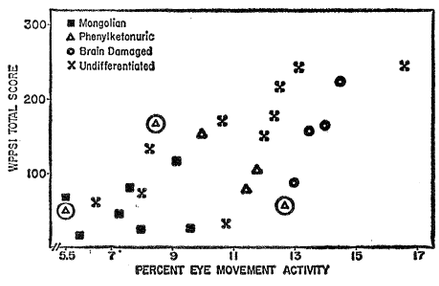

Fig. 1. Mean percentage (for nights 3 to 5 of study) of 20-second intervals of sleep with eye movement plotted against WPPSI scores. Data points for the three subjects over 50 years of age are circled.

Although the amount of emergent stage 1 electroencephalogram was significantly correlated with psychometric scores (Spearman rho $= +.44$, $P < .05$), a better relationship to intellectual function was found for another index of REM sleep, the degree of eye movement. Figure 1 plots WPPSI scores against the percentage of 20-second intervals of sleep with eye movement for the entire patient group since the number of subjects studied thus far is insufficient to permit separate analysis by diagnostic subtype. The rank-order correlation coefficient (rho) for this scattergram is $+.67$ ($P < .001$). This figure was based on eye movement scores for each subject for nights 3 to 5 of study, because the patients showed low total sleep time on the first two nights ["first-night effect" (*8*)]. However, the values for rho based on mean eye movement over five nights and for the fifth night alone (when adaptation was complete), were essentially the same (rho $= +.66$ and $+.72$, respectively).

These findings indicate that the relation between psychometric scores and eye movement did not depend on anxiety induced during adaptation to the laboratory. Neither was age a factor in producing this relation; the correlation coefficient between WPPSI scores and age was insignificant (rho $= -.18$). In addition, omission of data for the three subjects over age 50 years led to an increase rather than a decrease in the correlation coefficient between eye movement and WPPSI scores (rho $= +.76$).

These results further support the view that during sleep the brain carries out processes required for cognition, and that measurement of the electrophysiological concomitants of these processes provides an index of intellectual level, at least in individuals with varying degrees of cognitive impairment. Of course, one cannot infer causation from correlation, and the alternative possibility—that sleep pattern and intellectual level vary jointly as a function of some third factor (such as brain damage)—cannot presently be excluded. A decision between these possibilities must await knowledge of the neurophysiological mechanisms which underlie cognition; one of the virtues of the sleep-cognition hypothesis is that it suggests new directions for research into these mechanisms. Whatever theoretical view is correct, the accumulating empirical evidence indicates that the EEG of sleep is a more sensitive index of the integrity of brain function than any other physiological measure (*9*).

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References and Notes

1. J. H. Jackson, in *Selected Writings of John Hughlings Jackson* (Basic Books, New York, 1958), vol. 2, pp. 117–118.
2. G. Moruzzi, in *Brain and Conscious Experience*, J. C. Eccles, Ed. (Springer-Verlag, New York, 1966), pp. 345–388.
3. These observations also include the parallel variations of total sleep time and brain oxygen uptake across age and in chronic brain syndrome [I. Feinberg, Research Publication of *Association for Research in Nervous and Mental Disease* **45**, 211 (1967)]. We have also put forward and interpretation of the changes in sleep pattern with age which somewhat extends that of G. Moruzzi [I. Feinberg and V. R. Carlson, *Arch. Gen. Psychiat.* **18**, 239 (1968)]. Others have also recently commented on a possible relationship between sleep and cognition [R. Greenberg and P. H. Leiderman, *Comp. Psychiat.* **7**, 517 (1966); C. R. Evans and E. A. Newman, *New Sci.* **24**, 577 (1964); K. Gaarder, *Arch. Gen. Psychiat.* **14**, 253 (1966); L. Breger, *J. Abnorm. Psychol.* **72**, 1 (1967)].
4. D. Wechsler, *Manual for the Wechsler Adult Intelligence Scale* (Psychological Corp., New York, 1955).
5. I. Feinberg, R. L. Koresko, N. Heller, *J. Psychiat. Res.* **5**, 107 (1967).
6. W. Dement and N. Kleitman, *Electroencephalog. Clin. Neurophysiol.* **9**, 673 (1957).
7. D. Wechsler, *Manual for the Wechsler Preschool and Primary Scale of Intelligence* (Psychological Corp., New York, 1967).
8. A. Rechtschaffen and P. Verdone, *Percept. Mot. Skills* **19**, 947 (1964); W. C. Dement, E. Kahn, H. P. Roffwarg, *J. Nerv. Ment. Dis.* **140**, 119 (1965).
9. For example, this interpretation is supported by the findings of marked abnormalities in the sleep pattern of all of the mongolian subjects studied thus far. In contrast, this group is described as having waking EEG's which are normal [F. A. Gibbs and E. L. Gibbs, in *Medical Aspects of Mental Retardation*, C. H. Carter, Ed. (Thomas, Springfield, Ill., 1965), pp. 112–134].
10. We thank G. Jervis, Director of Research at Letchworth Village, for selecting the patients and confirming the diagnosis in each case, and J. Schneider, Hospital Superintendent, for permitting us to carry out this work. J. Gorelick and Z. Weiss administered the psychological tests with care, E. V. Shulman collected the sleep data, and M. Braun scored the tracings. Supported in part by PHS grant MH 10927.

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