soon after tetanus was indeed smaller than the values obtained before tetanus. They regarded this difference as insignificant and arrived at the above conclusion. The difference we detected ($2.29 \pm 0.12$ before tetanus and $1.76 \pm 0.09$ at 500 to 1000 msec after tetanus, $N = 7$) might have been too small to be revealed by only two observations.

Huxley (3) has concluded from his observations on the axial x-ray reflections that the return of myosin heads to their resting positions takes at least several seconds; there is a discrepancy between the fall of tension and the return of myosin heads. Our results supported this conclusion and showed that the discrepancy arises from the behavior of about 20 percent of the myosin heads that do not return promptly (Fig. 2). The nature of the prolonged stay of these myosin heads in the vicinity of the thin filaments is not clear; they might be remaining there without being attached to actin, or they might be attached to actin without producing significant contractile force. At present we cannot distinguish between these possibilities. Some mechanical experiments, such as stiffness measurements of the muscle after tetanus, might solve this problem.

N. YAGI, M. H. ITO
H. NAKAJIMA,* T. IZUMI†
I. MATSUBARA
*Department of Pharmacology,*
*Tohoku University School of Medicine,*
*Seiryo-machi, Sendai, Japan 980*

**References and Notes**

1. H. E. Huxley and W. Brown, *J. Mol. Biol.* **30**, 383 (1967).
2. J. C. Haselgrove and H. E. Huxley, *ibid.* **77**, 549 (1973).
3. H. E. Huxley, *Cold Spring Harbor Symp. Quant. Biol.* **37**, 361 (1972).
4. R. J. Podolsky, R. St. Onge, L. Yu, R. W. Lymn, *Proc. Natl. Acad. Sci. U.S.A.* **73**, 813 (1976).
5. R. Allemand and G. Thomas, *Note Technique LETL/MCTE, Grenoble, Nr. 1056* (1974).
6. The initial rapid increase in the intensity ratio can be accounted for in part by the lengthening of the sarcomeres after the end of tetanus. The sarcomere length was 2.05 $\mu$m during tetanus (see text) and 2.20 $\mu$m after the tension had fallen to resting. According to Haselgrove and Huxley (2, see their table 1), the frog sartorius muscle during tetanus gives an intensity ratio of 0.53 at the sarcomere length of 2.0 $\mu$m and 0.78 at 2.2 $\mu$m. This suggests that a part of the initial increase in the intensity ratio can be explained without postulating the return of myosin heads to the thick filaments.
7. H. E. Huxley, *J. Mol. Biol.* **37**, 507 (1968). We put the muscles into rigor by soaking them for 1 to 2 days in Ringer solution (20° to 22°C) containing 1 m*M* iodoacetate and recorded the equatorial patterns by the position-sensitive counter with an exposure time of 1 minute.
8. G. F. Elliott, J. Lowy, C. R. Worthington, *J. Mol. Biol.* **6**, 295 (1963).
9. A. F. Huxley and R. M. Simmons, *Cold Spring Harbor Symp. Quant. Biol.* **37**, 669 (1972).
10. The rapid increase in the intensity ratio upon the cessation of stimuli is likely to have been caused in part by the lengthening of the sarcomeres (6). However, the rapidity of the initial return of myosin heads shown in Fig. 2 cannot be attributed to the lengthening of the sarcomeres, since the lengthening has been taken into account in calculating the value plotted in Fig. 2 (that is, a correction has been made for the lengthening).
11. We thank Professor M. Endo for advice and encouragement. Supported by Toray Science Foundation and the Muscular Dystrophy Association of America.
* Present address: Department of Applied Physics, Faculty of Engineering, University of Tokyo, Tokyo, Japan.
† Present address: Department of Engineering Physics, Chubu Institute of Technology, Matsumoto, Kasugai, Aichi-ken, Japan.

27 December 1976; revised 18 March 1977

## Appetitive and Replacement Naps: EEG and Behavior

Abstract. *Consistent subjective, behavioral, and electroencephalographic sleep-stage differences were found between afternoon naps of 11 habitual appetitive nappers (who nap lightly for psychological reasons apparently unrelated to reported sleep needs) and 10 replacement nappers (who apparently nap regularly in response to temporary sleep deficits). Both types of naps were compared with naps of 12 confirmed non-nappers.*

Although the need for sleep is universal, extensive research has yet to clarify the functions of sleep, the efficiency with which it is obtained, and the mechanisms underlying the recovery from fatigue. Sleep is not a unitary phenomenon, and broad individual differences in the amount of sleep and its different stages are obtained. In addition, not all of an individual's sleep is obtained during nighttime hours; some individuals nap during the day. The functions served by daytime napping may differ widely among individuals. Like sleep in general, daytime napping is apt to serve functions other than physiological, restorative, and homeostatic ones. For many people a brief nap is reported to have restorative value far exceeding the length of time involved. In contrast, for some other individuals, the aftermath of napping seems to be sufficiently unpleasant that it is actively avoided.

To determine the frequency of napping in a young adult population and to evaluate whether there were differences among subjective experiences of napping, 430 college students were surveyed and patterns of napping and their attitudes toward napping were evaluated. Sixty percent of the students indicated they sometimes, usually, or always took catnaps during the day; only 40 percent answered they rarely or never napped. This finding is consistent with the frequency described in the literature (1) among a similar age group.

On the basis of criteria developed from pilot surveys, at least two different kinds of nappers could be identified from an analysis of these questionnaire descriptions of naps. (i) Replacement nappers nap to make up for previously (or soon to be) lost night sleep, and (ii) appetitive nappers nap primarily for reasons other than sleep need and apparently derive psychological benefits from the nap not directly related to the physiology of sleep. Specifically, a replacement napper was defined as a subject who had answered "no" to the criterion question "Do you nap even when you do not feel very tired?" and an appetitive napper was one who had responded either "definitely yes" or "possibly yes" to this question. A number of other questionnaire responses consistent with this distinction significantly differentiated between appetitive and replacement nappers. About 22 percent of the 261 nappers were classified as appetitive nappers, and 78 percent napped primarily for replacement reasons (2).

Subgroups of 11 appetitive and 10 replacement nappers (each of whom typically napped in the afternoon at least once a week), as well as 12 consistent non-nappers (who reported they rarely or never napped because napping had unpleasant mental and physical aftereffects) were asked to take a nap in a standard sleep laboratory. Subjects were included in the study only if an interviewer, who was unaware of the subjects' questionnaire responses, made the same classification as the questionnaire assignment. Thus, subgroup assignments were made by the independent classifications of both the questionnaire responses and a blind interviewer. Any subjects (particularly the non-nappers) who expressed doubts about being able to sleep in the laboratory were assured that the physiological data would be valuable even if they only rested quietly.

Standard electroencephalographic (EEG) and electrooculographic (EOG) recording electrodes were applied by an experimenter who was blind as to the subjects' napping classification. Subjects were provided with a comfortable bed in which to take a nap. Although the length of the nap was not discussed, subjects were aroused by a loud telephone buzzer 60 minutes after they were asked to begin their nap. Arousal reaction time, defined as the time taken to pick up the telephone, as well as alpha-onset arousal latency was recorded. A number of rating scales were administered to evaluate tiredness, recovery from fatigue, and satisfaction with the nap. Subjects were scheduled in such a way that no naps began before noon nor later than 5:30 p.m. The physiological records of the nap period were scored blind with regard to nap classification in 30-second epochs, according to the conventional method of scoring EEG sleep stages described by Rechtschaffen and Kales (*3*).

Of the 12 habitual non-nappers, nine were indeed able to fall asleep in the laboratory. Some of the variables of the nap for the three subgroups are presented in Table 1.

Sleep onset latency is significantly shorter for both napper groups than the non-nappers (*4*). This result is consistent with other questionnaire data, which indicate that an important characteristic of nappers is their voluntary control over sleep; they can fall asleep easily in a wide variety of circumstances, whenever they choose to do so.

As expected, virtually no rapid eye movement (REM) sleep appears in the afternoon naps (*5*). The amount of sleep stages 2 and 3 and total time asleep are similar for the three subgroups.

With the exception of sleep onset latency, the sleep stages of the non-nappers and replacement nappers are similar and resemble periods of consolidated sleep of the kind seen early in the night. The nap of the appetitive napper, however, is quite different. Although the amount of time spent in the various stages is similar, the distribution of these stages differs from the other two subgroups. The appetitive napper has significantly more epochs (lasting 30 seconds) of stage 1 sleep and also significantly more changes in sleep stage than the other two groups. Thus, the appetitive napper's sleep record shows a marked tendency to fluctuate between drowsiness, stage 1, and stage 2 sleep. Individual sequential sleep-stage distributions illustrating some of these differences in a typical nap of a non-napper, a replacement napper, and an appetitive napper are shown in Fig. 1.

Table 1. Mean EEG sleep-stage characteristics of consistent non-nappers, habitual appetitive nappers, and regular replacement nappers who fell asleep during a 60-minute period in which subjects were asked to take an afternoon nap.

| EEG variable | Non-napper ($N$ = 9) | Napper: Appetitive ($N$ = 11) | Napper: Replacement ($N$ = 10) |
|---|---|---|---|
| *Time (minutes)* | | | |
| Sleep onset | 26* | 14 | 12 |
| Stage 1 | 3 | 8* | 4 |
| Stage 2 | 17 | 16 | 19 |
| Stages 3 and 4 | 13 | 16 | 19 |
| Stage REM | 0 | 0 | 0 |
| Total sleep | 33 | 40 | 42 |
| *Frequency* | | | |
| Stage 1 epochs | 2.7 | 7.0* | 2.6 |
| All stage changes | 4.7 | 11.1* | 5.7 |

*Mean differs significantly from remaining two means in the same row ($P < .05$, two-tailed $t$-test).

No differences in subjective depth of sleep were reported by subjects in the three subgroups. Consistent with their earlier questionnaire responses, nappers reported feeling less tired and sleepy after the nap, whereas non-nappers did not. Similarly, non-nappers were significantly less satisfied with the nap and derived less subjective benefit from it. However, the decrease in fatigue and the positive rating of nap satisfaction are not apparent in the nappers until after they have been awake for several minutes. Other pilot data have indicated performance increments within a few minutes after arousal but not immediately on arousal from short naps. Performance improvements have been recently reported in habitual nappers following ½- or 2-hour naps (*6*).

After the nap, subjects were asked to complete 15-day sleep diaries. Data concerning frequency as well as the parameters of napping and nighttime sleep support the important psychological and physiological differences found in the two kinds of nap. Day-by-day analyses of the sleep diaries show that replacement nappers report having taken naps only on those days when, for the preceding 1 or more days, they described specific sleep deficits; that is, replacement nappers had typically gone to bed later than usual and slept less than usual on nights before days on which they napped. In contrast, for the appetitive napper there are no significant differences in reported sleep onset latency, length of sleep, and quality of sleep between non-nap nights and either the nights before or after naps.

In general, there are at least two distinctive kinds of naps that not only have different subjective characteristics but also differ in EEG sleep-stage characteristics (*7*). Napping appears to serve different but important functions for different kinds of individuals. These functions are reflected in the subjective reports describing napping habits, in the physiological activity that characterizes the different kinds of naps, in the subjective changes that follow napping, as well as in detailed sleep diary patterns. Some people have the capacity to nap as needed to compensate for accumulated sleep deficits; others use the nap primarily for psychological restorative functions seemingly unrelated to sleep needs (*8*). Future work will need to clarify the functions served by these two kinds of naps and their relative significance for recovery from fatigue as well as for the ongoing psychological health of the individual.


FREDERICK J. EVANS
MARY R. COOK*
HARVEY D. COHEN*
EMILY CAROTA ORNE
MARTIN T. ORNE

*Institute of Pennsylvania Hospital and University of Pennsylvania, Philadelphia 19139*


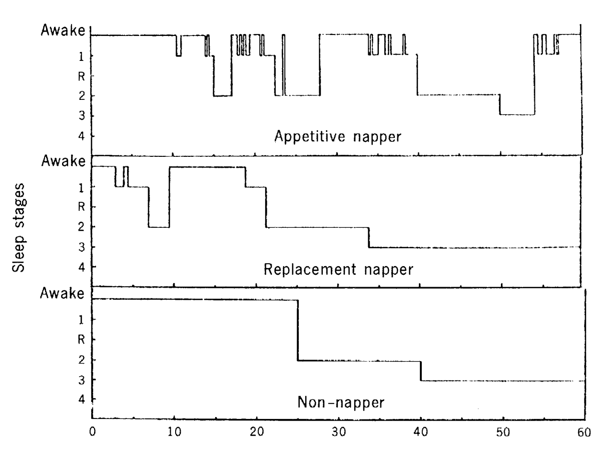


Fig. 1. Sequential sleep stages for the 60-minute afternoon naps of a typical non-napper (who shows slow sleep onset followed by sleep-stage consolidation resembling a similar period of early nighttime sleep), a replacement napper (who, after a short awakening soon after initial sleep onset, shows similar consolidated sleep staging), and an appetitive napper (who shows a large number of stage changes fluctuating through drowsiness and light-sleep stages). Stages 1, 2, 3, 4, and REM (*R*) sleep are recorded, as well as awake periods; EEG records were scored blind in 30-second epochs according to conventional criteria.

**References and Notes**


1. N. Kleitman, F. J. Mullin, N. R. Cooperman, S. Titelbaum, *Sleep Characteristics: How They Vary and React to Changing Conditions in the Group and the Individual* (Univ. of Chicago Press, Chicago, 1937); M. W. Johns, J. A. Gay, M. D. E. Goodyear, J. P. Masterton, *Br. J. Prev. Soc. Med.* **25**, 236 (1971); B. E. Lawrence,

thesis, University of Oklahoma (1971); G. S. Tune, *Br. Med. J.* **2**, 269 (1968).
2. The results of this questionnaire survey have been replicated in another sample of 489 subjects (F. J. Evans, M. R. Cook, H. D. Cohen, E. C. Orne, M. T. Orne, paper presented at the American Psychological Association, Washington, D.C., 3 to 6 September 1976).
3. A. Rechtschaffen and A. Kales, Eds., *A Manual of Standardized Terminology, Techniques and Scoring System for Sleep Stages of Human Subjects* (Public Health Service, Government Printing Office, Washington, D.C., 1968).
4. All reported differences are significant ($P < .05$, two-tailed $t$-test).
5. Studies by I. Karacan, R. L. Williams, W. W. Finley, and C. J. Hursch [*Biol. Psychiatry* **2**, 391 (1970)]; L. Maron, A. Rechtschaffen, and E. A. Wolpert [*Arch. Gen. Psychiatry* **11**, 503 (1964)]; and W. B. Webb, H. W. Agnew, and H. Sternthal [*Psychonom. Sci.* **6**, 277 (1966)] have shown that REM sleep typically occurs in naps of less than about 1½ hours only if they are taken early in the morning.
6. J. M. Taub, P. E. Tanguay, D. Clarkson, *J. Abnorm. Psychol.* **85**, 210 (1976).
7. A third type of napper who naps in response to stress-induced insomnia has been identified. Although the nap has EEG characteristics similar to those of a replacement nap, it is not satisfying and tends to interfere with the subsequent night's sleep, thereby maintaining the sleep disturbance that initially led to the nap itself.
8. Hypnagogic reverie tends to occur during these light-sleep, drowsy periods.
9. Supported in part by U.S. Army Medical Research and Development Command contract DADA17-71-C-1120 and in part by a grant from the Institute for Experimental Psychiatry. Aspects of these data were presented at the 16th Annual Meeting of the Association for the Psychophysiological Study of Sleep, Cincinnati, Ohio, 3 June 1976. We thank B. E. Lawrence, W. M. Waid, S. K. Wilson, P. A. Markowsky, and H. M. Pettinati for their helpful comments during the preparation of this report; C. Graham, who introduced subjects to the study and, where necessary, appropriately allayed subjects' anxieties about their inability to nap in a laboratory setting; and B. R. Wells and A. L. Van Campen, N. K. Bauer, J. P. DeLong, E. F. Grabiec, J. E. Hamos, M. L. Korn, A. M. Myers, L. L. Pyles, and J. Rosellini, for technical assistance. We also wish to thank H. Gleitman, who allowed his class to volunteer for the questionnaire survey.
* Present address: Midwest Research Institute, Kansas City, Missouri 64110.

20 August 1976; revised 26 January 1977

## Cerebral Lateralization of Haptic Perception: Interaction of Responses to Braille and Music Reveals a Functional Basis

Abstract. *Normally, haptic perception of the left hand surpasses that of the right. But simultaneously playing music into the left (but not the right) ear reverses this superiority. This suggests that the left cerebral hemisphere has full haptic perceptual capability, which is subject to right hemisphere interference unless the latter's attentional mechanisms are engaged by contralateral peripheral stimulation.*

Systematic investigations have shown unequivocally that haptic discrimination in dextrals, whether blind or sighted, is far more accurate for the left than for the right hand. This is true whether the measure of discrimination involves (i) linguistic encoding, as in naming palpated Braille symbols (*1*) or letters of the alphabet (*2*), (ii) making tactual-visual matches (*3, 4*), or (iii) tactual-tactual matches (*5*). Furthermore, left hand superiority is observed whether tactual stimulation is applied successively to either hand (*1, 2, 5*) or simultaneously to both (*3, 4*).

Our investigation was conducted (i) to verify the assumption made in previous reports that left hand superiority reflects greater right hemisphere efficiency in haptic form discrimination, and (ii) to determine whether the relatively poor performance of the right hand in older children and adults is due to deterioration or to suppression of the haptic discriminative ability evident in early childhood (*2, 4*).

To meet our objectives, we used a method capitalizing on sensory interaction within and across cerebral hemispheres. Incoming haptic information was pitted against music, a stimulus whose processing previously had been shown to be predominantly a function of the right hemisphere (*6*). The rationale was that, if left hand proficiency in haptic tasks results from right hemisphere dominance, then its performing a discrimination while music was being played into the left ear should stimulate competition for the same contralateral attentional mechanisms and produce diminished accuracy. Conversely, if music were fed into the right ear, intersensory rivalry for right hemisphere attentional mechanisms would be reduced, and performance with the left hand should be as good as in a control situation of no auditory input.

Observations of sensory interaction also formed a basis for determining left hemisphere capability for haptic pattern perception. We speculated that in adults the ability to discriminate form with the right hand was retained, but that its expression was thwarted by intervention from the more dominant right hemisphere. We believe that hemispheric dominance does not necessarily imply superior processing power; it may signify only a lower threshold for arousal of specific areas in a hemisphere by particular stimuli, accompanied by reciprocal inhibition of homologous parts of the opposite hemisphere (*7*). On the basis of this assumption we hypothesized that simultaneous presentation of music to the left ear, which would occupy right hemisphere attentional mechanisms, should effect its functional disengagement, permitting the left hemisphere to process uninterrupted tactual information received by the right hand. We expected, then, an improvement in right hand performance as compared to that in control conditions. We predicted that bimodal stimulation of the left hemisphere, on the other hand, would lead to a decrement in right hand performance or to no change, depending on whether the lower limit of performance had been reached under the control condition.

Twenty-four right-handed female and 24 right-handed male college students in an introductory psychology course were randomly assigned to one of six conditions: RH-RE and RH-LE, in which discrimination by the right hand was accompanied by music played into the right and left ear, respectively; RH-No, a control condition, in which right hand discrimination was carried out in the absence of any auditory input; and LH-LE, LH-RE, and LH-No, in which discrimination by the left hand was accompanied by left ear, right ear, and no auditory stimulation, respectively.

The haptic discrimination task consisted of a subject's identifying, while blindfolded, the match of a standard Braille symbol (*8*) which appeared in a comparison series of ten Braille patterns. Both the standard stimulus and the comparison stimuli were mounted in the upper left corners of two different platforms (12.5 by 10 by 3.75 cm). Subjects used their index fingers to palpate the symbols with light, small circular movements in a left to right direction. Retracing of the standard stimulus was not permitted once a comparison series was begun. Practice trials consisted of fingering serially a string of 20 randomly selected Braille patterns with the hand to be used in the experiment. The experiment itself was composed of six different matching tasks that were presented in sequence ten times. Scores were the average number of errors made on each trial and could range from 0 to 6. To maximize the probability that matches were made solely on a tactual basis, the experimenter at no time mentioned the names of the alphabet counterparts of the symbols.

The musical selections were tape recordings of classical orchestral works (*9*). Classical rather than contemporary music was chosen to minimize verbal associations or covert verbalization of lyrics. Control subjects who performed tactual discriminations without simultaneous auditory stimulation (LH-No and RH-No) donned earphones, and they were told that the earphones would muffle extraneous sounds.