EFFECTS OF IRREGULAR VERSUS REGULAR SLEEP SCHEDULES ON PERFORMANCE, MOOD AND BODY TEMPERATURE *

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Twelve male college students slept for 38 consecutive nights in the sleep laboratory under strict control of bedtime and wake-up time. Sleep logs, body temperature and performance on an experimenter-paced auditory vigilance and subject-paced addition test were assessed before sleeping in the laboratory, following 38 consecutive nights, and one month afterward to examine the effects of rigidly controlling retiring and awakening times. While large changes in the regularity of sleep occurred during sleep in the laboratory as compared to the normal irregular schedules, no significant changes in EEG sleep stage, performance, or mood were found. Body temperature was found to be higher and, perhaps, more flattened in the initial irregular condition as compared to the regular sleep schedule condition. It was concluded, however, that careful control of sleep and waking times in relatively irregular sleeping college students had little influence on sleep or performance. This finding implies that previous differences reported between groups of regular and irregular sleepers may have been based on personality differences rather than sleep scheduling factors.

1. Introduction

The importance of adequate sleep for optimal behavioral efficiency has been the focus of much investigation. When sleep has been displaced because of shifting work schedules or travel across time zones, impaired performance, physiological desynchronization, and health, emotional and behavioral problems have been observed (Winget, Hughes and LaDou, 1978; Klein, Wegmann and Bruner, 1968). The studies have led to the suggestion that adherence to a sleep-wakefulness schedule within strict temporal confines may be important to peak waking efficiency (Taub and Berger, 1973, 1974, 1976b).

In a series of studies in which sleep was reduced or extended in length or
shifted by 2 to 4 hours in regular sleepers, the impairments resulting from
cranges in the temporal placement of sleep were generally equivalent to those
resulting from sleep loss (Taub and Berger, 1976b). Performance decrements
following acute temporal alterations in accustomed sleep schedules, however,
do not necessarily imply similar consequences would occur after phase shifts
among individuals whose sleep is chronically irregular. Nor are these findings
predictive of outcomes on waking functions if individuals who followed regular
sleep routines were exposed to a chronically irregular schedule of retiring
and/or awakening.

More recently, irregular sleepers were found to have longer auditory reac-
tion times, to have lower body temperature and pulse rate, and to feel more
deactivated than a control group which habitually slept from 24.00 to 08.00
(Taub, 1978; Taub and Hawkins, 1979). In addition, regular sleepers scored
significantly higher than irregular sleepers on the California Personality Inven-
tory scales of dominance, sociability, self acceptance, self control, achievement
in conformance and intellectual efficiency, and lower on the flexibility scale.
From these two experimental findings it is not possible to know whether the
reported performance impairments reflected differences in sleep schedules or
personality/lifestyle differences between irregular and regular sleepers.

Much evidence indicates that there are inter-relationships between sleep
patterns, waking behavior and individual differences. For example, morning
and evening types have been found to differ in body temperature distribution
(Horne and Östberg, 1976, 1977), introversion/extroversion (Blake and
Corcoran, 1972), subjective adequacy of sleep (Webb and Bonnet, 1978) and
variability in sleep length and wake-up time (Webb and Bonnet, 1978).
Further, Johns, Dudley and Masterton (1976) found significant correlations
between time of awakening, quality of sleep (negative), and academic per-
formance (negative).

It is not known whether individual differences in personality underlie sleep
scheduling and performance, or whether sleep scheduling underlies personality
and performance (Friedmann, Globus, Huntley, Mullaney, Naitoh, and John-
son, 1977). For this reason, the present study sought to examine the effects of
sleep schedule regularity/irregularity on performance with the personality
dimension held constant by use of a within subjects design. It was hypothe-
sized that if the performance differences between regular and irregular sleepers
described by Taub were based on sleep scheduling, then a within-subject
reduction in sleep schedule variability should result in performance improve-
ment. Conversely, if the differences described by Taub were based on group
personality differences, then no improvement in performance would be ex-
pected as a result of a within subject sleep variability shift. Such a shift is most
easily accomplished in the real world by selecting college students, who
frequently adhere to irregular sleep schedules (White, 1976) and having them
sleep within rigid time constraints for an extended period of time.
2. Method

Twelve young adult males between the ages of 19 and 28 were chosen from a university population. Subjects were screened with a questionnaire and selected for further study if they indicated no significant medical problems, disturbed nocturnal sleep, or alcohol/drug abuse.

Subjects were studied three times within a 3-month period:
(i) a two-week baseline period during which subjects maintained habitual sleep patterns at home;
(ii) nights 32–38 of a 38 consecutive night ‘treatment period’, which involved sleeping in the laboratory while adhering to a strict regular sleep schedule; 1
(iii) following night 38, the subjects immediately resumed their habitual irregular sleep patterns at home for four weeks and were then studied for a two-week follow-up period.

During observational periods (i), (ii), and (iii), subjects were given standard sleep logs and instructed to fill them out following each night of sleep for two weeks (nights 32–38 in the regular condition). Subjects were also given thermometers and told to record oral body temperature upon awakening, at 12.00, 16.00, and 20.00 hours, and just before retiring for the night on the same days that they filled out sleep logs. Subjects were instructed to sleep as they normally would during time periods (i) and (iii). During time period (ii) (spent in the laboratory) subjects went to bed and were awakened at the same time each day. Sleep length was determined from the initial two-week sleep log. Morning wake-up time (and, necessarily, bedtime) was determined by each individual’s earliest weekly class or appointment.

At the end of each time period, performance and mood were measured. *Time of day of testing was held constant* for each subject within the confines of his schedule. This meant that four subjects were tested in the morning and eight in the afternoon. Previous work (Taub, 1978) has shown irregular/regular performance differences to exist throughout this period of time. For the Wilkinson Auditory Vigilance Task (Wilkinson, 1970), subjects spent approximately 30 min in instruction and practice, reaching a 75% hit rate before beginning the experiment. Subjects were isolated for the duration of the practice and the test. The test was 60 min with a break after 30 min to rewind the tape. Hit rate and false alarm rate were computed for each half of the test. For the Wilkinson Addition Task (Wilkinson, 1970), subjects were instructed to complete as many additions as they could, working steadily for 2 hours. The number correct and the total number of problems completed were recorded. Finally, the Thayer Deactivation Activation Adjective Check List was administered (Thayer, 1967).

1 During this time, subjects were given either a drug (WE-941, a thienodiazepine with a 3–4.5 hour half-life) or placebo 15 min before going to bed. On nights 4–31, six subjects received drug and six received placebo. On nights 1–3 and 32–38, all subjects were given placebo.
Standard EEG recordings (Rechtschaffen and Kales, 1968) were made on
nights 1, 2, and 38 in the laboratory for nine of the 12 participants. Night 1
served as adaptation to the laboratory; night 2 and 38 were designated the
irregular night and the regular night respectively.

3. Results

Data from time period (ii) from subjects who had received medication on
nights 4–31 were compared to those of the subjects who had received placebo
throughout the study for all measures using group t-tests. No consistent or
significant differences between the two groups were found. Therefore, data for
all subjects were included in further computations.

All data collected during each of the three time periods of the study were
averaged by variable and (for body temperature) by time of day so that each
subject had one data observation per variable for each of the three experimen-
tal times (and one for each time of day for body temperature). These data were
analyzed by a two factor analysis of variance with terms for regularity/irregular-
ity and subject. Where justified by significant findings from the ANOVA
(significant means p < 0.05), pairwise comparisons were made using the New-
man–Keuls test (Winer, 1971).

Means and standard deviations from the sleep log data are shown in table 1.
Analysis of variance and pair-wise comparisons performed on the standard
deviations for bedtimes, times of awakening, and sleep length showed that they
were significantly decreased in both irregular conditions (time periods (i) and
(iii)) as compared to the regular sleep condition. Mean bedtime and mean
wake-up time were later during both irregular conditions but only the wake-up
time shift was significant. Mean sleep length, however, remained the same in
all conditions (7.5 vs. 7.4 hours). No difference was found in subjective sleep

<table>
<thead>
<tr>
<th></th>
<th>Irregular (i)</th>
<th></th>
<th>Regular (ii)</th>
<th></th>
<th>Irregular (iii)</th>
<th></th>
<th>F2,22</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$\bar{x}$</td>
<td>s.d.</td>
<td>$\bar{x}$</td>
<td>s.d.</td>
<td>$\bar{x}$</td>
<td>s.d.</td>
<td></td>
</tr>
<tr>
<td>Bedtime</td>
<td>24.2</td>
<td>1.30 hr</td>
<td>23.8</td>
<td>0.11</td>
<td>24.4</td>
<td>1.44</td>
<td>3.25</td>
</tr>
<tr>
<td>Wake-up time</td>
<td>7.7</td>
<td>0.77</td>
<td>7.2</td>
<td>0.06</td>
<td>7.8</td>
<td>1.01</td>
<td>3.74*</td>
</tr>
<tr>
<td>Sleep length</td>
<td>7.5</td>
<td>1.16</td>
<td>7.4</td>
<td>0.02</td>
<td>7.5</td>
<td>1.33</td>
<td>0.22</td>
</tr>
<tr>
<td>(hr)</td>
<td>1.25</td>
<td>1.52</td>
<td>1.42</td>
<td>0.87</td>
<td></td>
<td></td>
<td>54.77*</td>
</tr>
<tr>
<td>Latency rating</td>
<td>0.53</td>
<td>1.20</td>
<td>0.52</td>
<td>8.36*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>awakenings</td>
<td></td>
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</tbody>
</table>

* $p < 0.05$. 

Table 1
Sleep log summary data from irregular and regular conditions
Table 2
EEG sleep data from irregular and regular conditions

<table>
<thead>
<tr>
<th></th>
<th>Irregular</th>
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<th>Regular</th>
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</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$\bar{x}$</td>
<td>s.d.</td>
<td>$\bar{x}$</td>
<td>s.d.</td>
<td></td>
</tr>
<tr>
<td>Sleep efficiency</td>
<td>0.94</td>
<td>0.04</td>
<td>0.93</td>
<td>0.04</td>
<td>-0.89</td>
</tr>
<tr>
<td># Awakenings &gt; 15 s</td>
<td>9.3</td>
<td>5.4</td>
<td>11.6</td>
<td>6.2</td>
<td>-1.43</td>
</tr>
<tr>
<td>Latency to stage 2</td>
<td>17.9</td>
<td>24.2</td>
<td>19.8</td>
<td>17.2</td>
<td>-0.54</td>
</tr>
<tr>
<td>% Awake</td>
<td>5.8</td>
<td>5.7</td>
<td>6.8</td>
<td>4.3</td>
<td>-0.66</td>
</tr>
<tr>
<td>% Stage 1</td>
<td>9.4</td>
<td>2.4</td>
<td>10.6</td>
<td>3.6</td>
<td>-1.05</td>
</tr>
<tr>
<td>% Stage 2</td>
<td>50.3</td>
<td>7.7</td>
<td>52.3</td>
<td>7.3</td>
<td>-0.47</td>
</tr>
<tr>
<td>% Stage 3</td>
<td>6.9</td>
<td>2.7</td>
<td>6.5</td>
<td>3.5</td>
<td>-0.30</td>
</tr>
<tr>
<td>% Stage 4</td>
<td>7.4</td>
<td>5.0</td>
<td>4.4</td>
<td>4.9</td>
<td>-1.64</td>
</tr>
<tr>
<td>% Rem</td>
<td>21.0</td>
<td>5.2</td>
<td>20.8</td>
<td>6.3</td>
<td>-0.10</td>
</tr>
</tbody>
</table>

latency between the two conditions, but the mean number of reported awakenings increased from the irregular conditions to the regular sleep condition.

Results obtained from the EEG sleep variables are shown in table 2. No significant differences between the regular and irregular conditions were found for any variable.

Performance data may be found in table 3. No significant differences between the regular and irregular conditions were found for any performance variable although there was a slight tendency for hit rate to increase on the vigilance task during the regular condition. Insufficient numbers of false alarms occurred during the vigilance task to allow a meaningful examination of $\beta$ (Bonnet and Webb, 1978).

Table 3
Performance data from irregular and regular conditions

<table>
<thead>
<tr>
<th></th>
<th>Irregular (i)</th>
<th>Regular (ii)</th>
<th>Irregular (iii)</th>
<th>$F$</th>
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<tbody>
<tr>
<td></td>
<td>$\bar{x}$</td>
<td>$\bar{x}$</td>
<td>$\bar{x}$</td>
<td></td>
</tr>
<tr>
<td>Auditory vigilance</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>First half</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hit rate</td>
<td>0.52</td>
<td>0.63</td>
<td>0.55</td>
<td>1.50</td>
</tr>
<tr>
<td>False alarm rate</td>
<td>0.011</td>
<td>0.013</td>
<td>0.008</td>
<td>1.55</td>
</tr>
<tr>
<td>Second half</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hit rate</td>
<td>0.51</td>
<td>0.56</td>
<td>0.55</td>
<td>0.44</td>
</tr>
<tr>
<td>False alarm rate</td>
<td>0.014</td>
<td>0.012</td>
<td>0.010</td>
<td>1.02</td>
</tr>
<tr>
<td>Addition</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total problems</td>
<td>371</td>
<td>368</td>
<td>366</td>
<td>0.03</td>
</tr>
<tr>
<td>Number correct</td>
<td>335</td>
<td>343</td>
<td>330</td>
<td>0.22</td>
</tr>
</tbody>
</table>
Body temperature data based on 10 subjects (excluding two subjects with substantial missing data) may be seen in fig. 1. An average value was computed for each subject at each time point (based on 7–14 observations). These average values were then entered into an analysis of variance, which showed only significant main effects for irregular vs. regular sleep schedules ($\bar{x}_{11} = 98.25$, $\bar{x}_R = 97.95$, $\bar{x}_{12} = 98.04$, $F_{2,126} = 6.64$) and for time of day ($F_{4,126} = 25.15$). Pair-wise comparisons revealed that body temperature was significantly higher throughout the initial irregular condition as compared to both the regular condition and the final irregular condition.

No significant differences were found on any scale of the Thayer Deactivation Activation Adjective Check List at any time period.

4. Discussion

The data in table 1 suggest that the major manipulation of the study – reduction in the variability of bedtime, wake-up time and sleep length – was highly successful. The standard deviations for the measures were reduced from about 70 min during the irregular condition to about 3 min during the regular condition. This variability change was accompanied by a shift in average
bedtime and wake-up time of approximately 30 min from the irregular conditions to the regular condition. However, a 30-min shift was probably of little consequence in relation to the 70 min standard deviation and is further minimized by the fact that virtually no change in total sleep length existed.

Both the subjective increase in awakenings and the negative t-values for all of the EEG sleep stage parameters (table 2) suggest that if anything the 38 night laboratory stay resulted in slightly worse sleep on all dimensions regardless of extremely regular sleep times.

Significant improvement was not found on any mood scale or performance measure as a function of the 38 days of schedule regularity but performance did move in the direction of improvement on both performance tasks.

Significant experimental changes were found on the body temperature measure. In addition to the circadian curve, body temperatures were significantly higher during the entire day in the initial irregular condition as compared to the regular and final irregular conditions. Taub (1978) reported that his regular group of sleepers had higher body temperatures than his irregular group. However, it is not clear that making sleep times more regular should increase body temperature. Rather, one might predict that in an irregular condition the body temperature curve should be flatter than in a very regular condition. If this were the case, then the regular body temperature should have a higher peak and lower trough than the irregular. While the ANOVA interaction was far from significant in the present study ($F_{8,72} = 1.34$), it can be noted from the figure that both the rise to the peak temperature and fall from the peak temperature tended to be greater during the regular condition. The placement of the final irregular condition midway between the initial irregular and regular conditions allows one to speculate that perhaps the four weeks between the regular condition and the final irregular condition were inadequate for body temperature to shift all the way back to the original irregular values. While previous data have suggested that body temperature shifts are completed within three weeks (Klein, Wegmann and Hunt, 1972), it is possible that flattening of the body temperature curve as a result of schedule irregularity proceeds at a slower pace from that of acute schedule shifts in more regular sleepers. This would account for the intermediate placement of the final irregular body temperature curve.

Data from a series of studies by Taub and collaborators have suggested that consistent performance loss is found in both acutely shifted sleep in regular sleepers (Taub and Berger, 1973, 1974, 1976a, 1976b) and in irregular sleepers as compared to regular sleepers (Taub, 1978). A series of potential reasons to explain why similar findings were not obtained in the present experiment must be considered:

(i) Was the study hypothesis reasonable? How did it differ from those of Taub and colleagues? The present study was based on the premise that regularity in sleep/wake scheduling is an important factor in daytime perfor-
mance. While Taub found consistent performance loss when he disrupted the schedules of extremely regular sleepers, that does not necessarily indicate that the converse hypothesis (i.e. making the schedules of extremely irregular sleepers more regular improves performance) is also true. It is possible, for example, that extremely regular sleepers are very focused on regularity in lifestyle and have preconceived notions concerning potential ill effects of violating their schedules. The subjects in the present study appeared more concerned with the social constraints imposed by rigid sleep scheduling.

(ii) Was the hypothesis of the present study operationalized correctly? The data in table 1 indicate that there indeed was a significant reduction in schedule variability in the subjects. However, one might wonder whether the subjects were variable enough for a reduction to have any effect.

Taub (1978) reported coefficients of variation of sleep length for his regular and irregular sleepers. From the coefficients, it can be estimated that the standard deviation for sleep length was about 1.7 hours for his irregular sleepers and 0.4 hours for his regular sleepers. These figures may be compared with respective standard deviations of 1.3 and 0.02 hours in the present study. As such, the actual difference between the irregular and regular conditions in the two studies was about the same although Taub’s subjects were more irregular in both conditions.

Were enough subjects studied and was the regularity condition extended over a long enough period of time? Taub and collaborators have reported numbers of subjects ranging between 10 and 18. The present number (12) falls within that range. The time required for performance shifts in normal subjects is on the order of 12 days after acute time zone shifts (Klein et al., 1972). Body temperature shifts have been reported to be complete within three weeks (Klein et al., 1972). All of these time periods are much shorter than the 5½ week period reported in the regular condition in the present study.

Finally, one might ask whether the tests used in the present study were sensitive to sleep disruption. Both the Wilkinson Vigilance and Addition tasks have been standardly used in sleep deprivation and shiftwork designs (Wilkinson, 1970; Colquhoun, Hamilton and Edwards, 1975) for many years. Further, a direct comparison of the Wilkinson Vigilance Task and a reaction time vigilance task modeled after that developed by Lisper and Kjellberg (1972) and used by Taub (1978) has been reported in the literature (Glenville, Broughton, Wing and Wilkinson, 1978). In that study, the vigilance task was more sensitive to sleep deprivation than the reaction time task.

(iii) Were there extraneous variables which could have accounted for the reported results? Two potential extraneous variables were identified. One was that half of the subjects received a short-acting thienodiazepine hypnotic (WE-941) during a part of their regularized schedule. This potential effect can be minimized by the fact that no significant or consistent differences could be found at any point during drug administration or during the placebo periods.
reported here between the six subjects receiving placebo throughout and those receiving active medication for part of the study period.

A second potential confounding variable was that subjects slept in the laboratory only during the 38 nights on their regular schedule. The performance and mood data collected during the pre- and post-experimental irregular conditions were collected after nights spent at home. It is doubtful, however, that subjects would perform more poorly simply after sleeping in the laboratory than after sleeping at home.

5. Conclusions

If it can be assumed that the experimental manipulations and measures were appropriate and that the potential extraneous variables played a negligible role in the results, then one must conclude that there is little if any effect on sleep, mood, or performance of an increase in sleep schedule regularity in healthy young adult males. Such a conclusion is further supported by the behavior of the subjects in the study. Subjects quickly returned to their irregular schedules at the conclusion of the study and this might not have occurred if significant benefits of regularity existed. Previous results may be explained in terms of underlying personality differences in regular versus irregular sleepers.

References


