TRAIT-LIKE INTER-INDIVIDUAL DIFFERENCES IN SLEEP CYCLE DURATION

Marjolijn S. J. Blaauw, Liang-tso Tung, Maurice D. Baynard,
David F. Dinges & Hans P. A. Van Dongen
Division of Sleep and Chronobiology, Department of Psychiatry,
University of Pennsylvania School of Medicine, Philadelphia, Pennsylvania

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INTRODUCTION

Since the seminal work of Kleitman [1], the non-REM/REM sleep cycle is widely cited to be 90 minutes in duration. Some investigators (e.g., [2,3]) have noted variability in the precise duration of the sleep cycle. In children, for instance, sleep cycle duration is reported to be different than in adults [2,4]. Little is known, however, about inter-individual differences in the duration of the sleep cycle among adults. We investigated the magnitude and the stability of inter-individual differences in the average duration of the non-REM/REM sleep cycle in a group of healthy adults.

METHODS

As a part of a larger study, n=15 normal, healthy subjects (ages 23-38; 8 females) each completed two laboratory-based total sleep deprivation experiments, at intervals of 2 to 4 weeks. Prior to participation, they were screened to be healthy good sleepers (sleeping between 6.5 and 8.5 hours per day and getting up between 06:30 and 08:30 habitually). They were also screened to be free of any drugs and current medical treatment, and for having no sleep or circadian disorders or psychiatric illnesses. Upon entering the study, subjects first underwent a 29-hour adaptation session in the laboratory to get used to the sleep recording and performance testing procedures (see below). The laboratory was isolated and had fixed ambient temperature (21°C) and light (<50lux during wakefulness, <1lux during sleep).

The study protocols for the two sleep deprivation experiments were identical, and involved a 12-hour baseline sleep opportunity (from 22:00 until 10:00), a 36-hour behaviorally monitored sleep deprivation period (from 10:00 until 22:00 the next day), and a 12-hour recovery sleep opportunity (from 22:00 until 10:00). Every 2 hours during wakefulness, subjects were tested on a 1-hour neurobehavioral performance battery. They were allowed non-vigorous activities (e.g., reading, watching television) during the remaining hours of wakefulness, and they received a standardized meal every 4 hours.

On the 6 days preceding each of the two experiments, subjects were scheduled for sleep at home from 22:00 until 10:00 (12 hours time in bed) each day. Compliance was verified by means of actigraphy and a diary, and subjects called in their bedtimes. During the 6 days preceding each experiment, as well as during the laboratory-based experiments proper, subjects were not allowed to use any alcohol, caffeine, tobacco or drugs; and they were not allowed to take any naps.

Baseline and recovery sleep periods were recorded polysomnographically (Vitaport III recorder, TEMEC Instruments) for each of the two experiments in which each subject participated. Recordings for 4 baseline nights and 2 recovery nights were lost due to equipment failure. The remaining 54 records were scored (in 30-second epochs) by a trained scorer, blind to subject and night, using conventional criteria [5]. The average duration of the non-REM/REM sleep cycle for each night was computed by dividing the total sleep time by the number of sleep cycles. Total sleep time was corrected for any incomplete non-REM/REM cycles at the beginning or the end of the night, and for any long-duration (>60 minutes) intermittent wakefulness.

The intra-class correlation (ICC) was used as the primary statistic to describe the sleep cycle duration data. The ICC is defined as the between-subjects variance divided by the total variance (between-subjects plus within-subjects variance) in the data. Thus, the ICC is 0% when there are no consistent differences among individuals (i.e., all the variance is within subjects), while it can be up to 100% when systematic differences exist among individuals across the two replications of the experiment. The ICC was computed for the two baseline nights, as well as for the two recovery nights. In addition, the correlation (Pearson’s r) between the subjects’ mean values for the two baseline nights with the subjects’ mean values for the two recovery nights was computed to further characterize the consistency of inter-individual differences. Finally, the correlation was computed between the mean sleep cycle duration for the two baseline nights and subjects’ age, and also between the mean sleep cycle duration for the two recovery nights and subjects’ age.

RESULTS

Figure 1 shows the average duration of the non-REM/REM cycle for baseline nights 1 and 2 (left-hand panel) and for recovery nights 1 and 2 (right-hand panel) for all individual subjects. The mean duration of the sleep cycle across the two baseline nights, among all subjects, was 94.5 minutes (s.d. over subjects 12.1 minutes). The mean duration of the sleep cycle across the two recovery nights, among all subjects, also was 94.5 minutes (s.d. over subjects 11.3 minutes).

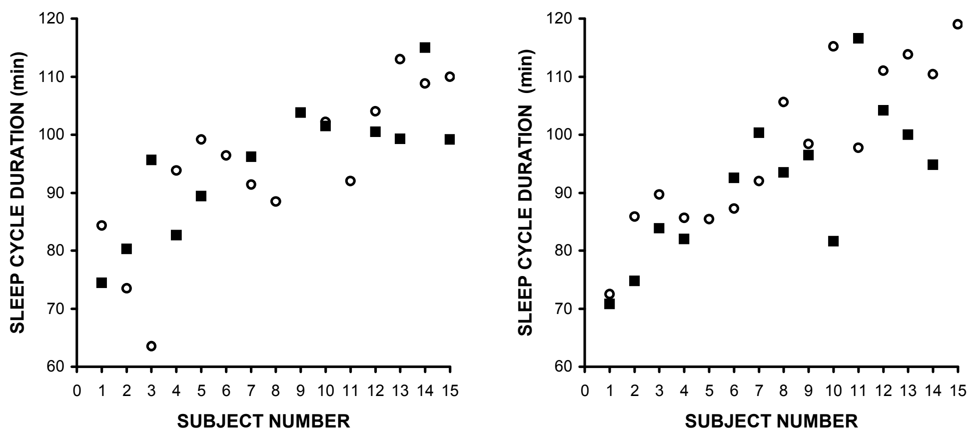

Figure 1: The left-hand panel shows the average duration of the non-REM/REM cycle for baseline night 1 (open circles) and baseline night 2 (black squares). The right-hand panel shows the sleep cycle duration for recovery night 1 (open circles) and recovery night 2 (black squares). Subjects were ranked by their mean sleep cycle duration across all four nights, and were then assigned subject numbers, according to which they are ordered on the abscissas.

The intra-class correlation (ICC) for the average duration of the non-REM/REM cycle across subjects was computed for the two baseline nights, as well as for the two recovery nights. Complete data for both baseline nights were available for n=11 subjects; complete data for both recovery nights were available for n=13 subjects. The ICC for baseline nights 1 and 2 was 55.6%, which was significantly greater than zero ($F[10,10]=3.29$, $P=0.037$). The ICC for recovery nights 1 and 2 was 48.3%, which was also significantly different from zero ($F[12,12]=3.09$, $P=0.031$).

The correlation across subjects between the mean sleep cycle duration for the baseline nights and the mean sleep cycle duration for the recovery nights was 0.75, which was statistically significant ($P=0.001$). The correlation of the mean sleep cycle duration for the two baseline nights with age was 0.32, and the correlation of the mean sleep cycle duration for the two recovery nights with age was 0.11. Neither of the correlations with age was significant ($P=0.34$ and $P=0.71$, respectively).

DISCUSSION

Substantial inter-individual differences were found for the average duration of the non-REM/REM sleep cycle. While the grand mean sleep cycle duration in this study was 94.5 minutes, the duration varied from 63.5 to 119.0 minutes across subjects and nights. This is a considerable range around the often cited value of 90 minutes. The inter-individual differences replicated across two baseline nights, as well as across two recovery nights after 36 hours of sleep deprivation, at 2 to 4 weeks intervals. In fact, approximately 50% of the variance in sleep cycle duration in this study reflected trait-like inter-individual variability (the ICC ranged from 48.3% to 55.6%).

The high correlation (Pearson's r=0.75) across subjects between the duration of the non-REM/REM sleep cycle in the baseline nights versus that in the recovery nights indicated that inter-individual differences in the sleep cycle duration were stable even when the drive for sleep was increased after 36 hours of total sleep deprivation. We found no evidence that, among healthy individuals in the age range 23-38, the duration of the sleep cycle was associated with age. What makes individuals consistently different from each other in terms of the sleep cycle duration, and what the biological significance of this variability may be, remains to be elucidated.

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