Effects of Sleep Duration, Sleep Quality, and Time of Day on Executive Function Performance in Children

Judy T. Klaus

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Effects of Sleep Duration, Sleep Quality, and Time of Day on Executive Function Performance in Children

by

Judy T. Klaus

A Thesis
Submitted to the
University of North Dakota
Honors Program Committee
In Partial Fulfillment of the Requirements
For Graduation
With Senior Department Honors
Grand Forks, North Dakota
July 1, 2002
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I would like to especially thank my husband, Chris and my children, Mitchell and Amelia for supporting me and allowing me to be gone on weekends and evenings to complete this thesis. Your devotion to my success is amazing and I know I am truly blessed. Most of all I need to thank the Lord, for His direction and guidance throughout my four years of college and especially with my Senior Honors Thesis.
ABSTRACT

Executive functions are the cognitive abilities that include self-regulation, inhibition of responding, planning, and mental flexibility. Previous studies on executive functions have focused on people with ADHD and other impairments. Studies on sleep and cognitive function abilities have focused on the effects of lack of sleep and the ability to perform executive function tasks. This study examined the cognitive abilities of children with no impairment in relationship to Time of Day, Sleep Duration and Sleep Quality.

Thirty children ranging from age 7 to age 12 were recruited from the area. A self-report questionnaire on typical Sleep Duration and Sleep Quality, and the Child Behavior Checklist were sent one week in advance to be completed before the time of testing. The children were tested at either 9AM or 3PM on five executive function tasks. The executive function tasks included the Connors Continuous Performance Test, Digit Span, Tower of London, Controlled Oral Word Association Test and the Wisconsin Card Sorting Task.

This study showed that when the participants perceived themselves to be well rested, (sleep duration and sleep quality self-reports) cognitive performance in some executive function tasks was more proficient, and this effect varied as a function of Time of Day of testing.
INTRODUCTION

Previous research of the impact of time of day on memory performance with school age children concluded that children have better memory before noon. For example, Folkard, Monk, Bradbury, & Rosenthal, (1977), tested one-hundred thirty, 12-13 year-old students with comparable reading comprehension. The between-subject design had six groups of 18-24 students, in which all the students listened to the same pre-recorded, 2000 word story. All the students were told they would be asked questions about the story but were not told when the questions would be presented.

Three of the groups heard the recorded story at 9 AM and the other three groups at 3 PM. One group from each time slot was given a questionnaire of twenty multi-choice questions immediately after hearing the story. One week later two of the remaining four groups were given the same questionnaire at the exact same time of the original presentation. The remaining two groups were given the questionnaire at opposite times of original presentation.

The results of the study were based on number of correctly answered questions. In the immediate recall, the 9 AM group scored higher than the 3 PM group. In the four delayed recall groups the 3 PM groups scored higher then the 9 AM groups regardless of the original time of presentation. Folkard concluded from these results that arousal of body temperature impaired immediate memory recall but facilitated delayed memory recall. Previous work has argued that arousal is related to performance and people start the day at a lower level and reach their highest level of arousal in mid-afternoon.
Folkard (1980) reanalyzed the data from his 1977 study. The earlier study results were based on the correct number of answers on a questionnaire of 20 questions pertaining to the story. Folkard had six undergraduate students listen to the story and then rate each question as to the importance of understanding the story. The results indicated that the decline in recall from 9AM to 3PM was for the less important information from the story while no effect of time of day was found for the most important information in the story.

Petros, Beckwith and Anderson (1990) examined the impact of morningness/eveningness of participants and time of day of testing on prose recall. The subjects were seventy-nine female undergraduate psychology students who had previously completed the Horne and Ostberg (1976) questionnaire that determined whether they were morning type or evening type individuals. Subjects met in small groups (1 to 4) at either 9.00, 14.00, or 20.00. Upon arrival each subject’s temperature was taken orally and recorded. Participants listened to a tape recording of four narrative stories (270-315 words at 160 wpm.) Two passages were at the 5th-6th grade easy level and two were at 9th-10th grade difficult level. The narrative stories were about sequential actions and events that happen to a main character. Subjects were directed to remember as much detail as they could, as immediately after they would be given seven minutes to write their recall using their own words. The passages had been divided into idea units and had been rated for their importance to the story. These ratings resulted in idea units of high, medium and low importance to the theme of the passage. The results indicated that the recall of morning types decreased across time of day, while recall of evening type participants increased non-significantly across time of day.
One factor that may explain circadian effect on memory performance is fatigue. One method of manipulating fatigue is sleep deprivation. Angus and Heslegrave (1985) examined the effects of sleep deprivation on performance of cognitive skills over a period of 54 hours. The participants were 12 college students, who performed nine identical 6-hour performance blocks. The 6-hour blocks consisted of 4 work sessions that focused on the executive function tasks of serial reaction time, encoding/decoding, short-term memory auditory signal detection, digit span, logical reasoning, and subtraction. Participants were given short breaks between each work session. Participants also answered self-report scales every hour, which focused on fatigue, sleepiness and their mood. Results of the study supported the decrease in performance as a function of sleep loss on executive function tasks.

Mikulincer, Babkoff and Caspy (1989) examined the effects of sleep loss on psychological variables over a 72-hour time period. Participants were 12 college students, who answered self-report questionnaires regarding sleepiness, mood, motivation, cognitive complaints, and waking dreams, along with completing visual search tests and memory tasks. Tests were administered every two hours (36 test sessions) throughout the 72-hour study. The results indicated that participants performed most poorly between 2AM and 6AM, plus the self-report psychological complaints were most severe between 4AM and 8AM. A circadian effect was found with continued sleep deprivation, as general performance and accuracy were higher in late afternoon-evening.

These previous studies on Time of Day and Sleep Deprivation in conjunction with executive function tasks have focused on adult performance. The purpose of this study is to examine the performance of executive function tasks in children with Sleep Duration,
Quality of Sleep and Time of Day as the variables. The reason we chose these variables is to examine if the duration of sleep, quality of sleep, or a combination of the two, is a determining factor of when a child best performs executive function tasks (morning or afternoon).

Executive functions are those cognitive abilities that include self-regulation, inhibition of responding, planning and mental flexibility (Weyandt, 1994). A number of techniques were used to measure executive functions; the Wisconsin Card Sorting Test (WCST), Verbal Fluency, the Connors Continuous Performance Test (CPT) and the Tower of London test. These tasks were chosen because executive functions underlie the child’s ability to organize, schedule sequential events, memorize, build on prior knowledge and prioritize daily choices. All of these concepts are skills each child potentially will use with school assignments, household responsibilities, and extra-curricular activities.

METHOD

Participants:

Thirty participants were recruited from the community by various advertisements. Participants were children between the ages of 7 and 12 with no reported psychological impairments. The children were accompanied by a parent to a building on the campus of University of North Dakota and tested at 9AM or 3PM. Immediately after completion of the tests the children were paid a $10.00 stipend.

Materials:

The Chronic Sleep Habit Questionnaire was developed for this study by Dr. Penland from the USDA Human Nutrition Laboratory. The Chronic Sleep Habit Questionnaire is
an 18 item self-report inquiry that measured the typical duration and typical quality of the child’s sleep. The questionnaire required the parent (with help from the child) to rate the quality of their child’s sleep over a period of one week and record the nightly sleep duration of the child’s sleep over the same one week period of time.

The parents were given The Child Behavior Checklist, CBCL (Achenbach, 1991); a 118-item questionnaire in which the parent rated the child on the frequency with which they exhibited a number of behaviors. The CBCL contains 8 subscales, any of the data from any child who scored in the clinical range in any of the subscales was not included in the final data analysis.

The vocabulary sub-test from the Wechsler Intelligence Scale for Children Third Edition (Wechsler, 1991; WISC-III) was used in this study. This subtest consists of 35 words that are auditorily presented to the child, who verbally provides a definition that is recorded in writing by the examiner. Each response is scored (2, 1, or 0,) with a possible total of 60 points. The test is completed when the child fails 4 consecutive definition responses.

The Connor’s Continuous Performance Test (Connors, 1995; CPT) was also used in this study. The CPT task was completed on an IBM-compatible desktop computer. Three hundred and sixty letters, approximately 1 inch in size, appeared in the center of the computer screen, one at a time, for approximately 250ms. The 360 trials were presented in 18 consecutive blocks of 20 trials. The time between representation of successive numbers the inter-stimulus interval (ISI) was one, two or four seconds. The child responds to the screen by hitting the space bar whenever any letter appears except for the letter X. The CPT test takes approximately 14 minutes to complete. The CPT generates
multiple dependent measures including the errors of omission (not responding when you should) which measures inattention, errors of commission (responding when should not) which measures impulsivity, hit rate latency (average response time for correct responses) which measures inattention, and the variability of response latency (consistency of response time) which measures inattention.

The Digit Span subtest from the WISC-III (Wechsler, 1997) was also used in the present study. The Digit Span is a two-part memory task. In the first part of the trial the child is directed to repeat numbers in exact order as orally heard by administrator. In the second part of the Digit Span the child is directed to repeat numbers in reverse order orally heard by administrator. Each part of the task is completed when child fails two consecutive trials.

The present study used two measures of planning ability, the Tower of London task (Krikorian, 1994) and the Wisconsin Card Sorting Task (Heaton, 1981). The Tower of London is a preplanning task that asks the child to match the colored balls (red, blue, and green) to the picture in a specific number of moves. The task uses an apparatus that has three pegs of different lengths attached to a platform. The balls are placed in a starting order on three pegs of different lengths. The child observes the picture and then moves the balls from one peg to another to replicate the shown picture. The participants are given instructions that the balls may only be moved one at a time. Participants are allowed three trials on each problem and told there is no time limit to the task. The TOL is scored according to the number of attempts to complete the 12 trials correctly (3- 1st attempt, 2= 2 attempts, 1= 3 attempts, 0= unable to complete task) with a 36 point total possibility.
The Wisconsin Card Sorting Test (WCST) is a Mental Flexibility Sorting Rule Test. Four category key cards were placed in front of the child. The participants were only told that they must match another card to a category card (128 cards). The only assistance from administrator was a correct or incorrect confirmation of the placement of the card. The administrator switches the sorting rule after 10 consecutive correct responses, without telling the child. The WCST categories are color, form, and number (2 trials of each category). The test was finished when the child completed six trials of 10 consecutive correct responses or when all 128 cards were exhausted. The WCST was scored on number of trials, total correct, number or errors, and number of perseverance errors.

Verbal fluency was measured using the Controlled Oral Word Association Test (COWAT; Benton & Hamsher, 1978). The COWAT is Timed letter and category task (verbal fluency) task. The child is asked to name as many words as possible that begin with a specific letter in a 60 second time frame (excluding proper nouns, numbers, and the same word with a different suffix). The letters used in this task were F, A, and S. The task is then repeated using the categories of animals and fruits instead of letters. The variables of interest were the number of words produced in each condition.

Procedure:

A week before the actual testing the Chronic Sleep Habit Questionnaire and the Child Behavior Checklist were sent to the parent to be completed at the start of the testing. Upon arrival the parent and child read and signed the Informed Consent and Assent forms. The parent/child and administrator then reread the Chronic Sleep habit Questionnaire together to ensure that all items were correct. The child’s age, grade in
school, gender and the time of day were all recorded.

The children were then separated from the parent and given the Vocabulary subtest from the Wechsler Intelligence Scale for Children III (Wechsler, 1991; WISC-III). The child was informed that there was no time restraint and they could take as much time as needed to answer the question. The next test given was the Connor’s CPT computer test. The children participants took the one-minute practice test before taking the 14-minute test. They were told to answer as accurately and as quickly as they could. Each child was then given the Wisconsin Card Sorting Test. They were told that the administrator could not tell them what category to place the card but if the administrator said the card was in the incorrect category they were to leave the card where it was and choose the next card. The next test was the Digit Span subtest of the Wechsler Intelligence Scale for Children. The child was given a practice trial before starting the actual test as assurance of understanding. The next test was the Tower of London. Again the child was given a practice trial to ensure understanding. The child was informed that there were no time constraints on this test and they could start over (three times) if they realized the sequence would not work. The final test was the Controlled Oral Word Assessment Test (COWAT) verbal fluency test. The average total time it took to complete the tests was approximately one-hour and thirty minutes.
RESULTS

In the first part of my analysis, the variables of Chronic Sleep Duration and Time of Day were identified. Children within each time of day group (0900 and 1500) were separated into groups of Higher Sleep Duration (HSD) and Lower Sleep Duration (LSD). Participants who reported sleeping fewer than 10 hours each night (-600 minutes) were in the LSD group. Participants who reported sleeping more than 10 hours (600 minutes +) were in the HSD group. The dividing number of 10 hours of sleep was chosen in an attempt to keep cell sizes equalized while forming these extreme groups. The number of participants (N=26) are displayed in Table 1 as a function of Sleep Duration and Time of Day of testing.

The mean age of the participants is presented in Table 2 as a function of Sleep Duration and Time of Day. A 2(Time of Day) x 2(Sleep Duration) analysis of variance revealed a significant main effect of Sleep Duration, F(1,22)=21.154, p<.05, which indicated that those children who were in the HSD group were significantly younger (mean age = 8.00) than those children in the LSD group (mean age = 10.5).

The vocabulary scores were subjected to a 2(Time of Day) x 2(Sleep Duration) analysis of variance. A significant main effect of Sleep Duration was observed F(1,22)=9.79, p<.05 which indicated that those children who were in the HSD group had significantly lower vocabulary scores (mean = 23.68) than those children in the LSD group (mean = 32.79), (see Table 3).

A 2(Time of Day) X 2(Sleep Duration) analysis of the errors of omission on the Connor's CPT indicated no significant effects (Table 4). A 2(Time of Day) X 2(Sleep
Duration) analysis of the errors of commission revealed no significant differences (see Table 5). A 2(Time of Day) x 2(Sleep Duration) analyses of response time variability scores indicated no significant differences (Table 6). The latency of correct responses was subjected to a 2(Time of Day) x 2(Sleep Duration) analysis of variance. A significant main effect of Sleep Duration $F(1,22)=8.87, p<.05$, indicated that participants in the HSD Group responded slower than those in the LSD group (429 msec vs. 366 msec), (see Table 7).

A 2(Time of Day) x 2(Sleep Duration) analysis of variance of the Tower of London scores revealed no significant effects (see Table 8).

The number of words produced during the Letter Fluency task was computed for each participant. The Letter Fluency data were examined using a 2(Time of Day) x 2(Sleep Duration) analysis of variance. The analysis revealed a significant main effect of Sleep Duration, $F(1,23)=11.21, p<.05$, which indicated that children who slept more hours performed worse (mean=21.06) than children who slept fewer hours (mean=33.40), (see Table 9). The number of words produced during the Category Fluency task was computed for each participant. The analysis of the Category Fluency test indicated no significant effect (see Table 10).

A 2(Time of Day) x 2(Sleep Duration) analysis of the Digit Span Forward data indicated no significant effects (see Table 11). A similar analysis of the Digit Span Backward data (see Table 12) indicated a significant main effect $F(1,23)=3.20, p<.05$, of Sleep Duration. The effect indicated that children who slept more performed worse than children who slept less (3.80 vs. 5.50). The dependent variables of the Wisconsin Card Sorting Test included the total number of trails (see Table 13), total number of correct
responses (see Table 14), total number of errors (see Table 15), and the total number of perseverative errors (see Table 16). Identical 2(Time of Day) x 2(Sleep Duration) analysis of variance revealed no significant effects in any of the above measures.

In the previous analysis reported above Time of Day and Sleep Duration revealed a confounded relationship in that children who slept longer were younger than those children who slept less. In light of this confound, we reanalyzed the data again using the variable of Sleep Quality as was reported in the Chronic Sleep Habit Questionnaire and Time of Day. Participants rated how rested they felt when waking each morning. Group division was determined by sleep quality and restful quality of waking questions. Each question used the Likert-scale which asked the participants to rate their nightly sleep quality or restfulness, as feeling better than average, normal and lower than average quality, upon waking in the morning. In each Time of Day group (0900 and 1500), the participants were grouped into High Quality Sleep (HQS) and Low Quality Sleep (LQS) as shown in Table 17. In this part of the study the emphasis is on how well you recorded sleeping not on the duration or time you actually slept. In the 2(Time of Day) X 2(Sleep Quality) analysis of variance no significant effects for age was revealed (see Table 18). In the analysis of the Vocabulary subtest of the WISC-III no significant effect was found (see Table 19). Thus it appears that our redefinition of our sleep variable eliminated the confound variable between age and sleep, and vocabulary and sleep.

The analysis of the Omission Errors on the Connor’s CPT revealed a significant main effect, $F(1,21)=4.39$, $p<.05$, of Sleep Quality indicating that High Quality Sleepers made significantly fewer errors of omission (mean=6.37) than Low Quality Sleepers (mean=12.08), (see Table 20). Analysis of Mean Commission Errors (responding when
not appropriate), showed a significant main effect, $F(1,21)=6.77, p<.05$, of Sleep Quality, indicating that High Quality Sleepers made significantly fewer errors of commission (mean=19.86) than Low Quality Sleepers (mean=26.75). In other words, HQ Sleepers did not respond by pressing the space bar when the letter X appeared as often as the LQ Sleepers (see Table 21). Analysis of CPT Mean Hit Rate Latency (response latency for correct answers), showed a significant main effect Time of Day, $F(1,21)=5.00, p<.05$, indicating that both groups of children who were tested in the morning responded significantly faster than the groups of children tested in the afternoon (367 msec vs. 417 msec) (see Table 22).

In the 2(Time of Day) x 2(Sleep Quality) analysis of variance of the Tower of London test, the scores revealed no significant effects (see Table 23).

The Letter Fluency data was examined using a 2(Time of Day) x 2(Sleep Quality) analysis of variance. The analysis revealed no significant effects (see Table 24). The analysis of the Category Fluency test indicated no significant effects (see Table 25).

A 2(Time of Day) x 2(Sleep Quality) analysis of the Digit Span Forward data indicated no significant effects (see Table 26). A similar analysis of the Digit Span Backward data (see Table 27) revealed no significant effects.

A 2(Time of Day) x 2(Sleep Quality) analysis of the Wisconsin Card Sort Test (WCST) Mean Total Trials results showed a significant interaction of Time of Day with Sleep Quality, $F(1,21)=5.43, p<.05$. This result indicated that High Quality Sleepers finished the task in fewer trials when they were tested in the Morning than in the Afternoon, while the reverse appeared to be true for Low Quality Sleepers (see Table 28).
A 2(Time of Day) x 2(Sleep Quality) analysis of variance on the WCST Mean Total Number of Errors revealed no significant effects (see Table 29).
DISCUSSION

The current research showed that when the participants perceived themselves to be well rested (sleep duration and sleep quality self-reports) cognitive performance in some executive function tasks was more proficient and this effect was modified by Time of Day. Table 29 results suggest that the quality of the child’s sleep and the time of day influenced the number of errors made in WCST, in that High Quality Sleepers (HQS) performed better in the AM, while Low Quality Sleepers (LQS) performed better in the PM. Perhaps the quality of sleep resets the participant’s circadian clock for later in the day, enabling the LQS a “second wind” to perform better in the afternoon. If a questionnaire was added that pertained to if the children perceived themselves as best performing in the morning or evening would their also be a correlation with quality and duration of sleep when considering best performance on these executive function tasks.

The implications of these findings imply that those working directly with children such as teachers, special education teachers and psychologists need to consider time of day, quality of sleep and sleep duration when testing children on executive function tasks for optimal performance to be attained.

One question raised by the present results was why differences were found on some executive function tasks and not others. Differences were found on tasks that involved time pressure (Connor’s CPT) and on those that did not involve time pressure like on the WCST. Thus the specific aspects of executive functions most influenced by Time of Day and Sleep Quality have not been clearly identified by the results of the present study.

We did not anticipate the confound variable of Age and Sleep Duration in the present results. Fortunately we were able to use Age with the independent variable of Sleep
Quality. Because of the confound variable of Sleep Duration with Age, the observed effects may have been natural age effects, in that you would expect a twelve year old to perform more proficiently than that of a seven year old on executive function tasks. Future studies could avoid this confound variable by limiting the age range of the participants.

The limitation of number of participants (N=26) in Sleep Duration and (N=25 in Sleep Quality), lead to a less than optimal statistical power (less sensitive to the effects of the independent variables). Thus future studies should aim for a more optimal number 30 to 40 participants for each cell as that will approximate a normal distribution of scores.

While testing the children we observed that some children used strategies such as, orally repeating the category (color, number, or form) during the WCST, or using the alphabet to assist in the COWAT. Some children looked around the room for clues in the COWAT, which seemed unproductive. Some children became frustrated and told us they were guessing at the answers. Future studies using executive function tasks may focus on teaching strategies or cues to assist in performance. A study to implement performance strategies with acute and delayed testing of the strategies when used with executive function tasks in children may determine whether Sleep Quality and Time of Day moderates these instructional interventions in immediate and delayed recall.
Table 1

Number of Participants in Sleep Duration Study Analysis as a Function of Time of Day and Sleep Duration

<table>
<thead>
<tr>
<th>Chronic Sleep Duration</th>
<th>AM</th>
<th>PM</th>
</tr>
</thead>
<tbody>
<tr>
<td>600 minutes +</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>-600 minutes</td>
<td>7</td>
<td>6</td>
</tr>
</tbody>
</table>
Table 2

Mean Age as a Function of Time of Day and Sleep Duration

<table>
<thead>
<tr>
<th>Time of Day</th>
<th>AM</th>
<th>PM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chronic Sleep Duration</td>
<td></td>
<td></td>
</tr>
<tr>
<td>600 minutes +</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>(1.55) (1.15)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-600 minutes</td>
<td>11</td>
<td>10</td>
</tr>
<tr>
<td>(.817) (1.90)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: SD are in parentheses
Table 3

WISC III Mean Vocabulary Score as a Function of Time of Day and Sleep Duration

<table>
<thead>
<tr>
<th>Chronic Sleep Duration</th>
<th>AM</th>
<th>PM</th>
</tr>
</thead>
<tbody>
<tr>
<td>600 minutes +</td>
<td>21.50</td>
<td>25.86</td>
</tr>
<tr>
<td></td>
<td>(7.34)</td>
<td>(9.86)</td>
</tr>
<tr>
<td>-600 minutes</td>
<td>33.57</td>
<td>32.00</td>
</tr>
<tr>
<td></td>
<td>(3.31)</td>
<td>(9.38)</td>
</tr>
</tbody>
</table>

Note: SD are in parentheses
Table 4

The Mean Number of Omission Errors on CPT as a Function of Time of Day and Sleep Duration

<table>
<thead>
<tr>
<th>Time of Day</th>
<th>AM</th>
<th>PM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chronic Sleep Duration</td>
<td></td>
<td></td>
</tr>
<tr>
<td>600 minutes +</td>
<td>12.83</td>
<td>8.71</td>
</tr>
<tr>
<td>(6.27)</td>
<td>(9.16)</td>
<td></td>
</tr>
<tr>
<td>-600 minutes</td>
<td>9.14</td>
<td>5.50</td>
</tr>
<tr>
<td>(6.09)</td>
<td>(6.50)</td>
<td></td>
</tr>
</tbody>
</table>

Note: SD are in parentheses
Table 5

The Mean Number of Commission Errors on CPT as a Function of Time of Day and Sleep Duration

<table>
<thead>
<tr>
<th>Chronic Sleep Duration</th>
<th>AM</th>
<th>PM</th>
</tr>
</thead>
<tbody>
<tr>
<td>600 minutes +</td>
<td>25.17</td>
<td>20.29</td>
</tr>
<tr>
<td></td>
<td>(6.08)</td>
<td>(9.39)</td>
</tr>
<tr>
<td>-600 minutes</td>
<td>25.28</td>
<td>20.83</td>
</tr>
<tr>
<td></td>
<td>(6.68)</td>
<td>(7.60)</td>
</tr>
</tbody>
</table>

Note: SD are in parentheses
Table 6

The Mean Variability of Response Latencies on CPT as a Function of Time of Day and Sleep Duration

<table>
<thead>
<tr>
<th>Time of Day</th>
<th>AM</th>
<th>PM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chronic Sleep Duration</td>
<td></td>
<td></td>
</tr>
<tr>
<td>600 minutes +</td>
<td>26.28</td>
<td>14.56</td>
</tr>
<tr>
<td></td>
<td>(17.36)</td>
<td>(9.05)</td>
</tr>
<tr>
<td>-600 minutes</td>
<td>16.53</td>
<td>14.30</td>
</tr>
<tr>
<td></td>
<td>(9.81)</td>
<td>(16.40)</td>
</tr>
</tbody>
</table>

Note: SD are in parentheses
Table 7

The Mean Response Latencies on CPT as a Function of Time of Day and Sleep Duration

<table>
<thead>
<tr>
<th>Time of Day</th>
<th>AM</th>
<th>PM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chronic Sleep Duration</td>
<td></td>
<td></td>
</tr>
<tr>
<td>600 minutes +</td>
<td>414.80</td>
<td>445.06</td>
</tr>
<tr>
<td></td>
<td>(61.76)</td>
<td>(51.25)</td>
</tr>
<tr>
<td>-600 minutes</td>
<td>341.01</td>
<td>391.37</td>
</tr>
<tr>
<td></td>
<td>(34.77)</td>
<td>(67.83)</td>
</tr>
</tbody>
</table>

Note: SD are in parentheses
Table 8

The Mean Tower of London Score as a Function of Time of Day and Sleep Duration

<table>
<thead>
<tr>
<th>Time of Day</th>
<th>AM</th>
<th>PM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chronic Sleep Duration</td>
<td></td>
<td></td>
</tr>
<tr>
<td>600 minutes +</td>
<td>29.83</td>
<td>30.29</td>
</tr>
<tr>
<td></td>
<td>(2.64)</td>
<td>(4.15)</td>
</tr>
<tr>
<td>-600 minutes</td>
<td>31.75</td>
<td>31.17</td>
</tr>
<tr>
<td></td>
<td>(1.04)</td>
<td>(1.94)</td>
</tr>
</tbody>
</table>

Note: SD are in parentheses
Table 9

The Mean Number of Letters produced on Letter Fluency Task as a Function of Time of Day and Sleep Duration

<table>
<thead>
<tr>
<th>Time of Day</th>
<th>AM</th>
<th>PM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chronic Sleep Duration</td>
<td></td>
<td></td>
</tr>
<tr>
<td>600 minutes +</td>
<td>21.83</td>
<td>20.29</td>
</tr>
<tr>
<td></td>
<td>(7.52)</td>
<td>(6.32)</td>
</tr>
<tr>
<td>-600 minutes</td>
<td>37.13</td>
<td>29.67</td>
</tr>
<tr>
<td></td>
<td>(11.22)</td>
<td>(11.62)</td>
</tr>
</tbody>
</table>

Note: SD are in parentheses
Table 10

The Mean Number of Category Fluency words produced on Category Fluency Task as a Function of Time of Day and Sleep Duration.

<table>
<thead>
<tr>
<th>Time of Day</th>
<th>AM</th>
<th>PM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chronic Sleep Duration</td>
<td></td>
<td></td>
</tr>
<tr>
<td>600 minutes +</td>
<td>22.83</td>
<td>21.71</td>
</tr>
<tr>
<td></td>
<td>(4.83)</td>
<td>(6.40)</td>
</tr>
<tr>
<td>-600 minutes</td>
<td>27.38</td>
<td>26.33</td>
</tr>
<tr>
<td></td>
<td>(8.53)</td>
<td>(4.27)</td>
</tr>
</tbody>
</table>

Note: SD are in parentheses
Table 11

Mean Digit Span Forward Score as a Function of Time of Day and Sleep Duration

<table>
<thead>
<tr>
<th>Chronic Sleep Duration</th>
<th>Time of Day</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>600 minutes</td>
<td>8.33</td>
<td>9.57</td>
</tr>
<tr>
<td></td>
<td>+</td>
<td>(1.51)</td>
<td>(.976)</td>
</tr>
<tr>
<td></td>
<td>-600 minutes</td>
<td>10.25</td>
<td>10.17</td>
</tr>
<tr>
<td></td>
<td>-</td>
<td>(1.98)</td>
<td>(2.48)</td>
</tr>
</tbody>
</table>

Note: SD are in parentheses
Table 12

Mean Digit Span Backwards Score as a Function of Time of Day and Sleep Duration

<table>
<thead>
<tr>
<th>Chronic Sleep Duration</th>
<th>AM</th>
<th>PM</th>
</tr>
</thead>
<tbody>
<tr>
<td>600 minutes +</td>
<td>3.17</td>
<td>4.43</td>
</tr>
<tr>
<td></td>
<td>(1.72)</td>
<td>(1.40)</td>
</tr>
<tr>
<td>-600 minutes</td>
<td>5.50</td>
<td>5.50</td>
</tr>
<tr>
<td></td>
<td>(2.27)</td>
<td>(1.38)</td>
</tr>
</tbody>
</table>

Note: SD are in parentheses
Table 13

The Mean Total Number Trials on WCST as a Function of Time of Day and Sleep Duration

<table>
<thead>
<tr>
<th>Chronic Sleep Duration</th>
<th>AM</th>
<th>PM</th>
</tr>
</thead>
<tbody>
<tr>
<td>600 minutes +</td>
<td>101.00</td>
<td>108.86</td>
</tr>
<tr>
<td></td>
<td>(21.61)</td>
<td>(20.12)</td>
</tr>
<tr>
<td>-600 minutes</td>
<td>94.38</td>
<td>97.50</td>
</tr>
<tr>
<td></td>
<td>(21.88)</td>
<td>(23.31)</td>
</tr>
</tbody>
</table>

Note: SD are in parentheses
Table 14

The Mean Total Correct on WCST as a Function of Time of Day and Sleep Duration

<table>
<thead>
<tr>
<th>Time of Day</th>
<th>AM</th>
<th>PM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chronic Sleep Duration</td>
<td></td>
<td></td>
</tr>
<tr>
<td>600 minutes +</td>
<td>76.00</td>
<td>82.00</td>
</tr>
<tr>
<td></td>
<td>(7.64)</td>
<td>(12.42)</td>
</tr>
<tr>
<td>-600 minutes</td>
<td>72.25</td>
<td>78.50</td>
</tr>
<tr>
<td></td>
<td>(9.62)</td>
<td>(16.26)</td>
</tr>
</tbody>
</table>

Note: SD are in parentheses
Table 15

The Mean Number of Errors on the WCST as a Function of Time of Day and Sleep Duration

<table>
<thead>
<tr>
<th>Chronic Sleep Duration</th>
<th>AM</th>
<th>PM</th>
</tr>
</thead>
<tbody>
<tr>
<td>600 minutes +</td>
<td>25.00</td>
<td>26.86</td>
</tr>
<tr>
<td></td>
<td>(15.15)</td>
<td>(12.63)</td>
</tr>
<tr>
<td>-600 minutes</td>
<td>22.13</td>
<td>19.00</td>
</tr>
<tr>
<td></td>
<td>(13.23)</td>
<td>(8.99)</td>
</tr>
</tbody>
</table>

Note: SD are in parentheses
Table 16

The Mean Number of Perseverative Errors on the WCST as a Function of Time of Day and Sleep Duration

<table>
<thead>
<tr>
<th>Chronic Sleep Duration</th>
<th>AM</th>
<th>PM</th>
<th>SD</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>600 minutes +</td>
<td>10.50</td>
<td>12.00</td>
<td>(4.14)</td>
<td>(5.29)</td>
</tr>
<tr>
<td>-600 minutes</td>
<td>11.63</td>
<td>9.80</td>
<td>(6.35)</td>
<td>(3.49)</td>
</tr>
</tbody>
</table>

Note: SD are in parentheses
Table 17

The Total Number of Participants as a Function of Time of Day and Sleep Quality

<table>
<thead>
<tr>
<th>Time of Day</th>
<th>AM</th>
<th>PM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chronic Sleep Quality</td>
<td></td>
<td></td>
</tr>
<tr>
<td>High Quality</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>Low Quality</td>
<td>6</td>
<td>6</td>
</tr>
</tbody>
</table>
Table 18

The Mean Age as a Function of Sleep Quality and Time of Day

<table>
<thead>
<tr>
<th>Time of Day</th>
<th>AM</th>
<th>PM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chronic Sleep Quality</td>
<td></td>
<td></td>
</tr>
<tr>
<td>High Quality</td>
<td>10.33</td>
<td>8.86</td>
</tr>
<tr>
<td></td>
<td>(1.75)</td>
<td>(2.04)</td>
</tr>
<tr>
<td>Low Quality</td>
<td>9.17</td>
<td>9.00</td>
</tr>
<tr>
<td></td>
<td>(2.14)</td>
<td>(1.67)</td>
</tr>
</tbody>
</table>

Note: SD are in parentheses
Table 19

The WISC-III Mean Vocabulary Score as a Function of Time of Day and Sleep Quality

<table>
<thead>
<tr>
<th>Time of Day</th>
<th>AM</th>
<th>PM</th>
</tr>
</thead>
<tbody>
<tr>
<td>AM</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PM</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chronic Sleep Quality</td>
<td></td>
<td></td>
</tr>
<tr>
<td>High Quality</td>
<td>30.67</td>
<td>28.57</td>
</tr>
<tr>
<td></td>
<td>(4.96)</td>
<td>(9.60)</td>
</tr>
<tr>
<td>Low Quality</td>
<td>28.00</td>
<td>28.83</td>
</tr>
<tr>
<td></td>
<td>(8.76)</td>
<td>(10.87)</td>
</tr>
</tbody>
</table>

Note: SD are in parentheses
Table 20

The Mean Number of Omission Errors on the CPT as a Function of Time of Day and Sleep Quality

<table>
<thead>
<tr>
<th>Time of Day</th>
<th>AM</th>
<th>PM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chronic Sleep Quality</td>
<td></td>
<td></td>
</tr>
<tr>
<td>High Quality</td>
<td>9.17</td>
<td>3.57</td>
</tr>
<tr>
<td>(6.97)</td>
<td>(3.69)</td>
<td></td>
</tr>
<tr>
<td>Low Quality</td>
<td>12.67</td>
<td>11.50</td>
</tr>
<tr>
<td>(6.06)</td>
<td>(9.63)</td>
<td></td>
</tr>
</tbody>
</table>

Note: SD are in parentheses
Table 21

The Mean Number of Commission Errors on the CPT as a Function of Time of Day and Sleep Quality

<table>
<thead>
<tr>
<th>Time of Day</th>
<th>AM</th>
<th>PM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chronic Sleep Quality</td>
<td></td>
<td></td>
</tr>
<tr>
<td>High Quality</td>
<td>23.00</td>
<td>16.71</td>
</tr>
<tr>
<td>(6.63)</td>
<td>(6.80)</td>
<td></td>
</tr>
<tr>
<td>Low Quality</td>
<td>28.50</td>
<td>25.00</td>
</tr>
<tr>
<td>(4.46)</td>
<td>(8.00)</td>
<td></td>
</tr>
</tbody>
</table>

Note: SD are in parentheses
Table 22

The Mean Response Latencies Score on the CPT as a Function of Time of Day and Sleep Quality

<table>
<thead>
<tr>
<th>Time of Day</th>
<th>AM</th>
<th>PM</th>
</tr>
</thead>
<tbody>
<tr>
<td>AM</td>
<td>368.72</td>
<td>451.94</td>
</tr>
<tr>
<td>PM</td>
<td>(64.39)</td>
<td>(51.73)</td>
</tr>
<tr>
<td>Low Quality</td>
<td>365.43</td>
<td>383.33</td>
</tr>
<tr>
<td></td>
<td>(51.35)</td>
<td>(57.98)</td>
</tr>
</tbody>
</table>

Note: SD are in parentheses
Table 23

The Mean Tower of London Score as a Function of Time of Day and Sleep Quality

<table>
<thead>
<tr>
<th>Time of Day</th>
<th>AM</th>
<th>PM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chronic Sleep Quality</td>
<td></td>
<td></td>
</tr>
<tr>
<td>High Quality</td>
<td>31.33</td>
<td>30.43</td>
</tr>
<tr>
<td></td>
<td>(1.51)</td>
<td>(3.41)</td>
</tr>
<tr>
<td>Low Quality</td>
<td>30.86</td>
<td>31.00</td>
</tr>
<tr>
<td></td>
<td>(2.54)</td>
<td>(3.29)</td>
</tr>
</tbody>
</table>

Note: SD are in parentheses
Table 24

The Mean Number of Letters produced on the Letter Fluency Task as a Function of Time of Day and Sleep Quality

<table>
<thead>
<tr>
<th>Time of Day</th>
<th>AM</th>
<th>PM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chronic Sleep Quality</td>
<td></td>
<td></td>
</tr>
<tr>
<td>High Quality</td>
<td>35.83</td>
<td>23.14</td>
</tr>
<tr>
<td></td>
<td>(9.62)</td>
<td>(8.17)</td>
</tr>
<tr>
<td>Low Quality</td>
<td>28.14</td>
<td>26.33</td>
</tr>
<tr>
<td></td>
<td>(13.43)</td>
<td>(12.37)</td>
</tr>
</tbody>
</table>

Note: SD are in parentheses
Table 25

The Mean Number of Category words produced on the Category Fluency Task as a Function of Time of Day and Sleep Quality

<table>
<thead>
<tr>
<th>Chronic Sleep Quality</th>
<th>Time of Day</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>High Quality</td>
<td>AM</td>
<td>24.50</td>
<td>(7.71)</td>
</tr>
<tr>
<td></td>
<td>PM</td>
<td>23.00</td>
<td>(6.03)</td>
</tr>
<tr>
<td>Low Quality</td>
<td>AM</td>
<td>26.71</td>
<td>(7.87)</td>
</tr>
<tr>
<td></td>
<td>PM</td>
<td>24.83</td>
<td>(5.95)</td>
</tr>
</tbody>
</table>

Note: SD are in parentheses
Table 26

The Mean Digit Span Forward Score as a Function of Time of Day and Sleep Quality

<table>
<thead>
<tr>
<th>Time of Day</th>
<th>AM</th>
<th>PM</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chronic Sleep Quality</td>
<td></td>
<td></td>
</tr>
<tr>
<td>High Quality</td>
<td>9.17</td>
<td>10.00</td>
</tr>
<tr>
<td></td>
<td>(1.17)</td>
<td>(1.29)</td>
</tr>
<tr>
<td>Low Quality</td>
<td>9.57</td>
<td>9.67</td>
</tr>
<tr>
<td></td>
<td>(2.70)</td>
<td>(2.34)</td>
</tr>
</tbody>
</table>

Note: SD are in parentheses
Table 27

The Mean Digit Span Mean Backward Score as a Function of Time of Day and Sleep Quality

<table>
<thead>
<tr>
<th>Time of Day</th>
<th>AM</th>
<th>PM</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chronic Sleep Quality</td>
<td></td>
<td></td>
</tr>
<tr>
<td>High Quality</td>
<td>4.67</td>
<td>4.57</td>
</tr>
<tr>
<td></td>
<td>(1.21)</td>
<td>(1.40)</td>
</tr>
<tr>
<td>Low Quality</td>
<td>4.43</td>
<td>5.33</td>
</tr>
<tr>
<td></td>
<td>(3.21)</td>
<td>(1.51)</td>
</tr>
</tbody>
</table>

Note: SD are in parentheses
Table 28

The WCST Mean Total Trials as a Function of Time of Day and Sleep Quality

<table>
<thead>
<tr>
<th>Chronic Sleep Quality</th>
<th>AM</th>
<th>PM</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Quality</td>
<td>88.83</td>
<td>114.71</td>
</tr>
<tr>
<td></td>
<td>(20.42)</td>
<td>(20.55)</td>
</tr>
<tr>
<td>Low Quality</td>
<td>100.00</td>
<td>90.67</td>
</tr>
<tr>
<td></td>
<td>(19.71)</td>
<td>(15.24)</td>
</tr>
</tbody>
</table>

Note: SD are in parentheses
Table 29

The WCST Mean Number of Errors as a Function of Time of Day and Sleep Quality

<table>
<thead>
<tr>
<th>Chronic Sleep Quality</th>
<th>AM</th>
<th>PM</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Quality</td>
<td>19.00</td>
<td>28.86</td>
</tr>
<tr>
<td></td>
<td>(14.03)</td>
<td>(12.63)</td>
</tr>
<tr>
<td>Low Quality</td>
<td>24.14</td>
<td>16.67</td>
</tr>
<tr>
<td></td>
<td>(12.06)</td>
<td>(4.97)</td>
</tr>
</tbody>
</table>

Note: SD are in parentheses
REFERENCES


