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# Individual Differences in Cognitive Performance Relating to Non-Pathological Sleep Parameters in the Presence of a Stressor

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Running Head: INDIVIDUAL DIFFERENCES IN COGNITIVE PERFORMANCE

# Individual Differences in Cognitive Performance Relating to Non-Pathological Sleep Parameters in the Presence of a Stressor

by

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# CERTIFICATE OF APPROVAL

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## Abstract

Non-pathological sleep parameters in relation to cognition among individuals who do not qualify as having sleep disorders or who are not subjected to extended periods of total sleep deprivation have not been adequately investigated in previous studies. The current study investigates the influence of circadian typology (morning-type vs. evening-type individuals), time of session (AM vs. PM), habitual sleep practices (sleep hygiene), sleep quality, life stress, and the presence of an acute stressor on sustained attention, memory, and mental rotation performance. Several main effects emerged for individual variables above; however, the data failed to reveal significant interactions among these variables. The evidence in this study of non-pathological sleep parameters affecting cognitive performance presents a need for further investigation.

# Individual Differences in Cognitive Performance Relating to Non-Pathological Sleep Parameters in the Presence of a Stressor

As cited by the National Commission on Sleep Disorders Research (1993), a range of sleep disorders and disturbances affect as many as one-third of all American adults. A 1991 national survey conducted by the Gallup Organization documents the association of sleep disturbances with self-reported problems such as diminished ability to concentrate, memory impairment, failure to accomplish daily tasks, and interpersonal difficulties. The amount of past and current sleep research does not adequately meet the need for answers as evidenced by the continuing impact sleep disturbance has on day-to-day life.

Sleep disorders and their consequential behavioral, social, and psychological effects are founded fundamentally on sleep deprivation. In fact Kreuger (1989) concluded in a review of the literature on sleep deprivation that it results in increased reaction times, less vigilance, an increase in perceptual and cognitive distortions, and changes in affect. Indeed, a consensus that sleep deprivation has a detrimental effect on multiple aspects of normal day-to-day functioning is practically indisputable.

In a meta-analysis of 19 articles on current sleep deprivation studies, Pilcher and Huffcutt (1996) suggest that overall sleep deprivation strongly impairs human functioning. More importantly, however, the results found evidence that partial sleep deprivation (a sleep period of less than 5 hours in a 24-hour period) has a more profound effect on functioning than either long-term or short-term total sleep deprivation. This has much ecological value since, intuitively, partial sleep deprivation is common among many individuals who do not qualify as having a sleep disorder per se.

In turn, some researchers believe those human circadian rhythms that "dictate" sleep and wakefulness are the sole bases for the most detrimental effects of insufficient sleep. Relatively early findings by Blake (1971) support the hypothesis that the factors underlying the performance fluctuations related to daily biological rhythms are the same as those underlying performance after sleep deprivation. In other words, these circadian rhythms "dictate" cognitive performance in relation to morning-type and evening-type individuals (i.e., circadian typology, as defined by an individual's daily peak performance periods). More recently, there has been evidence of an interaction between daily biological rhythms and normal functioning and that "the urge to sleep depends on time of day, not just on how recently you've slept" (Kalat, 1995).

In another study, Buela-Casal, Caballo, and Cueto (1990) investigated the effect of circadian typology on cognitive performance and found a "notable difference" between the arousal rhythms of morning types and evening types. Furthermore, they concluded that an individual's arousal rhythm significantly affects reaction time and concentration level.

Other studies that have investigated memory performance (short-term, long-term, and prose), cognitive accuracy, narrative comprehension, and subjective mood state have shown evidence that desynchrony of circadian typology and time of session/testing has a detrimental effect on all of the above outcome variables (Anderson, Petros, Beckwith, Mitchell, & Fritz, 1991; Kerkhof, 1998; Lenne, Triggs, & Redman, 1998; May, Hasher, & Stoltzfus, 1993; Monk & Leng, 1982; Natale & Lorenzetti, 1997; Petros, Beckwith, & Anderson, 1990; Tankova, Adan, & Buela-Casal, 1994). May et al. (1993) stated the effects succinctly in their conclusion that "the effects of time of day vary as a function of the synchrony between individual optimal performance periods and the time at which testing occurs." Indeed, the evidence is overwhelming regarding the effect of circadian typology and time of testing on cognitive performance. Furthermore, there appears to be evidence that circadian typology, sleep deprivation, and time of session interact in affecting cognition (Cassagrande, Violani, Curcio, & Bertini, 1997; Lenne, Triggs, & Redman, 1997).

One would think that with this overwhelming evidence, there would be a plethora of further research that has already been conducted aimed at finding a correlation between sleep hygiene, sleep quality, circadian typology, and time of day in relation to cognitive performance; however, the literature is lacking for such investigations. In fact, the Report of the National Commission on Sleep Disorders Research (1993) states, "sleep research is actually shrinking." Indeed, even less research has been done within the realm of "normal" sleep patterns (i.e., those not considered to be disordered sleep, but may nonetheless affect normal daily functioning). With this in mind, it is no surprise that the aforementioned link has not been adequately documented, especially in the realm of "real world" situations.

Indeed, Pilcher and Huffcutt (1996) express the need for more research investigating the effect of partial sleep deprivation on subjective mood and cognitive performance. Intuitively, this research would have to investigate non-pathological sleep parameters among individuals without a diagnosis of any sleep disorder. As one can imagine, research of this nature has intrinsic ecological validity. Plus, when coupled with circadian typology and time of testing, this research has the potential of uncovering possible interactions among morningness-eveningness, sleep hygiene, and sleep quality in affecting cognitive performance and subjective mood state.

Another point to consider is subjective ratings of sleepiness after chronic sleep loss. Kuo, Carlin, Powell, and Dinges (1998) have found that as sleep restriction progressed beyond one week, subjective ratings "failed to reflect the continued linear changes in behavioral dysfunction evident in performance" as measured by a battery of cognitive tasks and subjective scales. In other words, subjective ratings of sleepiness may not accurately reflect the impact poor sleep practices (marked by chronic sleep loss) has on cognitive performance and mood state; therefore, it may not be adequate to look at subjective sleep quality in the absence of other sleep parameters. That is to say, an investigation of sleep quality necessitates addressing other factors in concert with it.

All in all, the studies reviewed thus far have been done primarily to investigate cognition in laboratory-controlled sleep deprivation studies and in chronic sleep disruption studies using individuals with sleep disorders. These studies are in want of the ecological validity intrinsically found among sleep patterns outside the parameters of disordered sleep, which have not been adequately studied with respect to cognition. Likewise, despite the overwhelming evidence of the effect circadian typology has on cognitive performance and mood state, studies cited thus far have not investigated circadian typology along measures of non-pathological sleep parameters (i.e., hygiene and quality) in uncovering possible interactions affecting cognitive performance and mood state.

As alluded to in the title of this investigation, stress can very well have an effect in the sleep-cognition equation. In fact, Hall, Baum, Buysse, Prigerson, Kupfer, and

Reynolds (1998) have found evidence of sleep being a mediator in the stress-immune relationship. The evidence of a relationship between stress and sleep prompts the investigation of stress as a moderating variable in the sleep-cognition equation. Indeed, intuition dictates a cyclical relationship between stress and sleep; stress relates to poor sleep, which leads to more stress, eliciting even poorer sleep, etc. The implication of this relationship's possible effects on cognition should not be ignored. Precedents for such an investigation, however, do not exist.

This study, therefore, investigates the effects non-pathological sleep parameters have on cognitive performance. In turn, these parameters are studied individually as well as in conjunction with circadian typology and stress. Furthermore, due to the explicit characteristics of different cognitive performance measures, the utilization of multiple cognitive tasks is warranted. For this reason, the investigators chose measures of sustained attention, memory, and visual-spatial working memory to compose a battery of tasks used for assessing cognitive performance.

Four main hypotheses emerge from the current problem under investigation. First, cognitive performance degrades as sleep hygiene (habitual behaviors that affect sleep) worsens. Second, cognitive performance degrades as sleep quality deteriorates. Third, being tested in a state of asynchrony (circadian typology by time of session) exacerbates the above effects. Finally, stress is expected to act as a mediator in affecting cognitive outcomes for each of the above variables (i.e., interactions of stress x sleep hygiene, stress x sleep quality, and stress x state of synchrony/asynchrony).

# Method

## Participants

Undergraduate students enrolled in introductory level psychology classes at a mid-sized university in north Florida participated in this study (N=121). Participants were offered points toward fulfillment of respective course requirements or extra credit. A total of seven participants were excluded from the analyses: four due to previous diagnoses of attention deficit disorder, two due to current antihistamine (i.e., Benadryl) intake that affected variable outcomes, and one due to an inability to comply with instructions for the cognitive tasks. As a result, data from 114 participants were included in the final analyses. Ages ranged from 18 to 50 years with a mean of 24.08 ($\pm$ 7.11) years and a median of 21.5 years. Gender distributions were as follows: 78.1% female ($n = 89$), 21.9% male ($n = 25$). A total of 54 participants were randomly assigned to the stressor condition (i.e., administration of a mental arithmetic task); the remaining 60 participants did not receive the stressor. Twenty-one morning-types, 34 evening-types, and 59 intermediate-types emerged from the data. From this, 32 participants were assessed as synchronous (i.e., circadian typology by time of session), and 23 participants were assessed as asynchronous. No incidences of diagnosed sleeping disorders were reported.

## Materials

**Demographics.** Typical demographic information (e.g., age, sex, educational status, employment status) were acquired as well as information with regard to daily caffeine intake, current medications, and any medical diagnoses that may affect cognitive functioning (i.e., sleep disorders and attention deficit disorder).

**Profile of Mood States (POMS).** As cited by Moore, Stanley, and Burrows (1990), D.M. McNair tested normative samples for the POMS in 1971. The study provided evidence for the reliability of the POMS in indicating the presence of negative versus positive mood states. Since a diurnal rhythm of mood has been indicated in previous studies (Colquhoun, 1981; Kerkhof, 1998), this scale was used as an exploratory measure to investigate whether negative mood is more prevalent among those tested in a state of asynchrony as opposed to those in a state of synchrony.

**Morningness-Eveningness Scale (MEQ).** Horne and Ostberg (1976) developed a self-rating questionnaire to assess morning-type, evening-type, and intermediate-type individuals. Their investigation of this instrument revealed a significant correlation between the questionnaire and peak temperature of individuals tested; therefore, it is considered a valid measurement of circadian typology. From this questionnaire, assessments were made for synchrony/asynchrony of circadian typology and time of session.

**Pittsburgh Sleep Quality Index (PSQI).** The PSQI is a measurement used to assess subjective sleep quality (Buysse, Reynolds, & Monk, 1989). The developers of this scale have validated its use in investigating the subjective, qualitative characteristics of sleep among a population of psychiatric patients. The global score of this self-report questionnaire is considered an accurate means of assessing typical patterns of subjective sleep quality among individuals.

**Sleep Hygiene Awareness and Practice Scale.** The scale, developed by Lacks (1987), is a straightforward survey of knowledge and individual practice of sleep hygiene. Holbrook, White, and Hutt (1994) used the Sleep Hygiene Awareness and

Practice Scale to test subjects before and after training them on the effects of poor sleep hygiene. They found that this scale is an accurate indicator of individual awareness of good sleep hygiene. For this study, it was used solely to assess sleep hygiene practices of participants.

**Stanford Sleepiness Scale (SSS).** Developed by Hoddes, Zarcone, Smythe, and Dement (1973), the SSS is a one-question 7-point scale that indicates current sleepiness/alertness of an individual by referring to an integer. Each integer along the continuum refers to a qualitative statement of sleepiness/alertness with a 1 indicating "wide awake" and a 7 indicating "lost struggle to remain awake." The aforementioned research group have found this measure accurate in assessing current sleepiness for intervals as short as 15 minutes between assessments throughout a 24-hour period. For this study, the scale was used to assess the participants' current level of alertness at the beginning (i.e., initial intake) as well as at the end of the session (i.e., 45-60 minutes after initiation).

**Social Readjustment Rating Scale (SRRS).** A brief life hassles survey was included to assess amount of daily stressors. The SRRS, developed and validated by Holmes and Rahe (1967), is one of the most widely used self-report instruments to measure current life stress. The investigation at hand predicted that the amount of daily life hassles exacerbates the impact of a situational stressor (i.e., the mental arithmetic task). For this reason, the SRRS is included to assess adequately participants' current amount of daily stressors.

**Subjective Stress Rating Scale (SSRS).** This self-report questionnaire consists of visual analog scale ratings anchored by mood-related adjective pairs. Pike et al.

(1997) showed the SSRS is an accurate indicator of subjective stress in reaction to administration of a mental arithmetic task. The SSRS, therefore, was used solely as an assessment of acute psychological stress in response to the acute stressor (i.e., mental arithmetic task).

**Mental Arithmetic Task (MAT).** The MAT, usually in the form of counting down by sevens from an arbitrary 4-digit number, has been shown to raise stress levels in subjects immediately after administration as well as up to 30 minutes after completion of the task (Pike, Smith, Hauger, Nicassio, Patterson, McClintick, Costlow, & Irwin, 1997). In this study, depending on the randomly assigned condition, participants were instructed to count down by sevens from 4554. In addition to verbally counting down by sevens, participants were instructed to answer in time with each beat of a metronome set at 20 beats per minute. A list of prompts (e.g., "Pay attention to your answers"; "Try to concentrate"; "Please keep time with the metronome") were scripted and given to the participants every 30 seconds during the task. Total running time for the task was 6 minutes, gauged by a digital stopwatch.

**Attentional Vigilance Task.** An attention task that taps into concentration, vigilance, and accuracy was included as a dependent measure in this study. The task implemented in this study was the Vigil v1.2 Continuous Performance Test (CPT), which is a standardized, computer-administered test of sustained attention using visual stimuli. Participants were instructed to press the space bar on a computer keyboard every time the letter "K" appeared after the letter "A." The investigators of the current study modified the standard CPT program to make the task more challenging for college students. Background "noise" (visual white noise or monitor static) served as a backdrop for the letter stimuli; presentation duration for each stimulus was shortened from the standard; and "dummy stimuli" were introduced (i.e., letters other than "K" appeared after the letter "A"). Total errors, errors of omission, errors of comission, and average delay (reaction time) were recorded on the computer during the task.

**Memory Tasks, Wechsler Memory Scale – III (WMS-III).** Two memory tasks taken from the WMS-III were administered as additional dependent measures in this study. The WMS-III is a standardized, comprehensive measure of memory functioning made up of a battery of subtests. The two tasks included in this study from the WMS-III were the wordlist and the digit span subtests. The wordlist involved immediate and delayed recall and recognition of a list of unrelated terms. Immediate recall of the wordlist served as a basis for determining percent retention (rate of change between immediate recall and delayed recall). The digit span subtest involved listening to and repeating a list of numbers in forward as well as backward order. A global, scaled score was recorded for the digit span subtest, and individual scaled scores were recorded for parameters within the wordlist subtest (e.g., immediate recall, delayed recall, delayed recognition, and percent retention). Scaled scoring of the parameters was based on normative samples used by the developers of the WMS-III and was in accordance to scoring instructions listed in the WMS-III handbook.

**Two-Dimensional Mental Rotation.** A computer-administered mental rotation task taken from the SuperLab Pro v1.04 software package (Cedrus Corporation, Phoenix, Arizona) was used to assess cognitive performance along with the attention and memory tasks discussed above. This task assessed visual-spatial working memory performance and involved determining whether the presentation of a letter of the alphabet is correct or whether it is the mirror image of the letter. In addition, the presentation of the letter stimulus (or its mirror image) involved its display in various rotated degrees. Errors and reaction times were recorded on the computer for each response during the task.

**Time of Session.** Subjects were forced to choose a test session either early in the morning (0800 h) or late in the afternoon (1700 h). The rationale behind such scheduling was to force subjects into a session that dictated either a state of synchrony or a state of asynchrony with circadian typology (given a polar score on the MEQ).

Procedure

Participants were directed to sit at a table opposite the investigator. Once written consent to participate in the study was given, the participant was instructed to fill out a packet of questionnaires. The packet included: (1) a demographics fact sheet, (2) Profile of Mood States (POMS), (3) Stanford Sleepiness Scale (SSS), (4) Morningness-Eveningness Questionnaire (MEQ), (5) Pittsburgh Sleep Quality Index (PSQI), (6) Sleep Hygiene Awareness and Practice Scale, and (7) Social Readjustment Rating Scale (SRRS) in the order listed.

Participants were randomly assigned to either a "stressor present" or a "stressor not present" condition, with the mental arithmetic task (MAT) used as the acute situational stressor. In the "stressor present" condition, participants were instructed to complete the MAT, after which the Stress Symptom Rating Scale (SSRS) immediately was administered. For those in the "stressor not present" condition, participants proceeded directly to the SSRS questionnaire without completing the MAT.

Participants then completed the battery of cognitive tasks. An initial administration of the wordlist memory task from the WMS-III was necessary to insure a delay of no less than 25 minutes before the second administration of the task. This was essential for an accurate assessment of delayed recall, delayed recognition, and percent retention (percent change between immediate and delayed recall); the initial administration served as the wordlist learning period and baseline assessment for the delayed administration. In effect, the sustained attention task (CPT), mental rotation task, and digit span subtest of the WMS-III were counterbalanced and served as intervening tasks for the wordlist. After the cognitive tasks were completed, all participants were instructed to gauge their position on the SSS one more time.

## Results

Several main effects emerged from higher order analyses of variance (ANOVAs), which were used to assess interaction effects of sleep hygiene x synchrony, sleep quality x synchrony, sleep hygiene x stress, sleep quality x stress, and synchrony x stress; however, no significant interactions were evident in these analyses. Individual bivariate correlations and one-way ANOVAs of the significant main effects indicated in the higher order ANOVAs are, therefore, reported.

### Sleep Hygiene

Pearson correlations were run for sleep hygiene in relation to the cognitive tasks. There were no significant correlations for these analyses (see Table 1).

### Sleep Quality

Pearson correlations analyzing sleep quality and the cognitive tasks revealed a significant negative relationship between sleep quality and digit span performance

($n$ = 114, $r$ = -.24, $p$ < .02). As sleep quality deteriorated, performance on the digit span memory task decreased. No other significant relationships were found with respect to mental rotation, sustained attention, and the wordlist memory task (see Table 1).

Synchrony/Asynchrony

One-way ANOVAs were performed for synchrony with regard to cognitive performance (see Table 2 for summary of means). For mental rotation errors, asynchronously tested individuals did not differ significantly from synchronously tested individuals, $F(1,54) = 0.09$, $p = .77$. Likewise, no difference was found for omission errors, $F(1,54) = 1.24$, $p = .27$, and comission errors of the sustained attention task, $F(1,54) = 0.65$, $p = .43$. Retention of the WMS-III wordlist memory subtest, however, was significantly affected by an individual's state of synchrony, $F(1,54) = 6.41$, $p < .05$; asynchronously tested participants performed better than those synchronously tested. The other subtest parameters of the WMS-III did not reveal significant results: digit span, $F(1,54) = 0.51$, $p = .48$; delayed recognition, $F(1,54) = 2.66$, $p = .11$; delayed recall, $F(1,54) = 1.12$, $p = .30$ (see Table 2 for summary of means).

Acute Stressor (MAT)

One-way ANOVAs were used to assess effects of the acute stressor (MAT) on the cognitive tasks (see Table 3 for summary of means). The presence of an acute stressor had a significant effect on mental rotation errors, $F(1,113) = 8.21$, $p < .006$; participants in the stressor condition made more errors than those in the no stressor condition. No significant results were found for either errors of omission, $F(1,113) = 0.97$, $p = .33$, or errors of comission, $F(1,113) = 0.80$, $p = .37$, on the sustained attention task. In terms of memory, presentation of an acute stressor negatively affected outcomes for delayed recognition of the wordlist, $F(1,113) = 4.44$, $p < .04$; however, other memory parameters were not affected: digit span, $F(1,113) = 0.12$, $p = .73$; delayed recall, $F(1,113) = 0.21$, $p = .65$; retention, $F(1,113) = 0.01$, $p = .92$.

Morningness/Eveningness

The effects of morningness-eveningness on the cognitive measures were analyzed through one-way ANOVAs (see Table 4 for summary of means). Morning-type individuals made more mental rotation errors than evening-type individuals, $F(1,54) = 5.88$, $p < .02$. Morning types also made more errors of comission on the attention task than evening-type individuals, $F(1,54) = 4.67$, $p < .04$, with no significant difference for errors of omission, $F(1,54) = 0.64$, $p = .43$. Results indicated, however, morning-type individuals performed significantly better than evening-type individuals on two measures of wordlist memory: delayed recall, $F(1,54) = 4.09$, $p < .05$, and delayed recognition, $F(1,54) = 4.30$, $p < .05$. Significant differences were not found for digit span memory, $F(1,54) = 2.51$, $p = .12$, and wordlist retention, $F(1,54) = 2.12$, $p = .15$.

Subjective Stress Rating

T-tests show an effect of the mental arithmetic task (MAT) on stress level of participants subjected to the acute stressor (see Table 5 for summary of means). Several measures on the Subjective Stress Rating Scale increased for participants exposed to the MAT: anger, $t\ (112) = -4.53$, $p < .001$; anxiety, $t(112) = -5.22$, $p < .001$; stress, $t(112) = -4.46$, $p < .001$; and attention, $t(112) = 5.17$, $p < .001$. Measures of arousal and fatigue did not differ between those presented and those not presented with the MAT, $t(112) = 1.28$, $p = .20$ and $t(112) = .60$, $p = .55$ respectively.

Mood State

Pearson correlations of sleep quality in relation to mood state (as assessed by the POMS) revealed significant associations with all POMS parameters: anger ($r = .22$, $p < .02$), confusion ($r = .38$, $p < .001$), depression ($r = .30$, $p < .002$), fatigue ($r = .38$, $p < .001$), tension ($r = .21$, $p < .03$), and vigor ($r = -.27$, $p < .005$). Poor sleep quality was significantly correlated with negative mood.

T-tests did not reveal significant differences between individuals tested in a state of synchrony and those tested in a state of asynchrony with respect to mood state (see Table 6).

Sleep Parameters and Life Stressors

Other correlational analyses were performed to investigate the relationship between sleep hygiene, sleep quality, circadian typology, and life stress (see Table 7). Significant correlations were found between sleep quality and sleep hygiene ($n = 114$, $r = -.49$, $p < .001$) as well as between sleep quality and life stress ($n = 114$, $r = .41$, $p < .001$). Poor sleep quality was associated with poor sleep hygiene as well as with a high amount of life hassles.

Stanford Sleepiness Scale

Pretest and posttest measures of the Stanford Sleepiness Scale were analyzed to investigate difference in sleepiness/alertness at the beginning of the session and at the end. A paired-samples t-test revealed no difference between pretest and posttest measures, $t(113) = -0.71$, $p = .48$.

## Discussion

In summarizing the many effects found through this investigation, it is evident that certain aspects of cognitive performance varied in relation to particular non-pathological sleep parameters. More specifically, the a priori predictors for this study (i.e., sleep quality, synchrony, and acute stress – with the exception of the sleep hygiene predictor) all elicited main effects in relation to various measures of memory. In contrast, significant results for sustained attention and mental rotation performance were sparse among the predictors. In other words, memory was affected by sleep quality, synchrony, and acute stress (all the predictors except sleep hygiene); attention was not affected by any predictors (circadian typology was not an a priori predictor variable); and mental rotation was affected by only one predictor (acute stress). Perhaps stress and normal sleep parameters affect performance of memory more than performance of either sustained attention or visual-spatial working memory (mental rotation).

With respect to acute stress, the initial test for the effectiveness of the mental arithmetic task (MAT) validated its use for this study. The analyses revealed the MAT's ability to elicit elevated states of distress as indicated by robust effects on measures of the Subjective Stress Rating Scale (SSRS). The results indicate higher incidences of negative mood in participants exposed to the acute stressor. The MAT successfully elicited reports of elevated anger, anxiety, attention, and stress. The lack of significant results with regard to arousal and fatigue also validates the desired effect of MAT. Indeed, when investigating the effects of sleep parameters on performance, heightening participants' levels of arousal or fatigue could present problems in interpreting significant findings. One would have some difficulty concluding whether effects were due to the actual sleep parameters (the a priori predictors) or due to the exacerbated levels of arousal or fatigue produced during the experimental session.

There are some caveats to consider with respect to non-significant interaction effects in the higher order ANOVAs. First, the lack of clinical cutpoints for the sleep hygiene and sleep quality variables made it difficult to assign distinct conditions (good vs. poor) for these predictors. Median splits were attempted; however, they were ultimately rejected for lack of ecological validity. A median split for the sleep hygiene variable was particularly difficult due to a large number of data points (~ 11%) with median scores; assignment of the median score to either a "good" or "poor" qualitative value would have produced a skewed data set. As for sleep quality, a median split of the variable actually elicited a skewed data set with a preponderance of the data in the "good sleep quality" condition (84%) and the remaining "poor sleep quality" data just above mid-range of the full scale. Thus, the data for sleep quality was not representative of the full range of possible scores. In effect, correlational analyses were used to preserve the continuous variables.

Another consideration with respect to the higher order analyses is the diminished sample size due to polarities on assessment of circadian typology. Half of the participants were categorized as intermediate-type individuals with respect to the Morningness-Eveningness Questionnaire (MEQ). Consequently, they were excluded in assessing synchrony/asynchrony of circadian typology and time of session since the polarities (morningness vs. eveningness) were needed for this determination. Indeed, this diminished sample size coupled with the skewed data set for sleep quality after a median split elicited an $\underline{n}$ of 1 for the "asynchrony/poor sleep quality" condition. In light of these considerations, perhaps a larger overall sample size will succeed in revealing the hypothesized interaction effects.

With regard to sleep hygiene and the cognitive tasks, perhaps the survey used to assess hygiene practice was not as sensitive a measure as needed, and, consequently, none of the outcomes were significant. Furthermore, although the survey used in this study is an accurate indicator of individual awareness of sleep hygiene (Holbrook, White, & Hutt, 1994), it has yet to be validated as an accurate indicator of sleep hygiene practice. The typical measure of sleep hygiene (a sleep diary kept daily for no less than one week prior to the experimental session) (Verbeek et al., 1999), however, was not possible for this investigation. Future investigations should take this into consideration if sleep hygiene is a variable of interest for the study.

The lack of robust results for sleep quality and measures of cognitive performance, with the exception of digit span memory, corroborate findings from Kuo, Carlin, Powell, and Dinges (1998). Their study stated that as sleep restriction progressed beyond one week, subjective ratings of sleep quality did not accurately reflect performance decrements as measured by a battery of cognitive tasks and subjective scales. The failure to find significant effects of sleep quality on cognitive performance in the current study may, in fact, be operating on the parameters alluded to in the previous investigation by Kuo et al. Indeed, for the current study, sleep quality was not intended to be viewed on its own but in conjunction with other predictors (e.g., circadian typology), which was not possible due to a diminished sample size.

As mentioned above, parameters of the MEQ cut the sample size when considering synchrony between circadian typology and time of session. With respect to the predicted effects of synchrony, a larger sample size would most likely confirm predictions for all the cognitive measures. This assertion is made in light of the fact that previous investigations have already found evidence of an interaction between circadian typology and time of session in affecting cognition (Kerkhof, 1998; Monk & Leng, 1982; Natale & Lorenzetti, 1997; Petros, Beckwith, & Anderson, 1990).

A possible explanation for the direction of the one significant difference found between synchronously tested and asynchronously tested individuals (asynchronous condition performed better than synchronous condition on wordlist retention of the WMS-III) could be based on the rate of decline. For example, the initial performance for those in the synchronous condition was such that they had a greater opportunity to decline in performance (i.e., to forget more words on the list) than those in the asynchronous condition. In other words, the asynchronous group initially remembered fewer words than the synchronous group, and they, therefore, had less of a load to retain in memory (i.e., retention was greater).

Unfortunately, synchrony was not as strong a predictor as expected for this study. Findings from this investigation do not corroborate the significant correlation between mood state and synchrony of circadian typology and time of day found in previous investigations (Kerkhof, 1998). This could be due to the nature of the measure used to assess mood (i.e., POMS). The POMS asks individuals to rate the prevalence of particular moods within the past week, whereas synchrony/asynchrony is a current, on-the-spot assessment based on an individual's prevailing circadian typology and the time of testing. Indeed, upon scrutiny of the literature cited above, one sees that Kerkhof used a one-question, 5-point scale to assess current global mood state (1 = "bad mood," 5 = "good mood"), for multiple ratings throughout the day. The various facets of negative mood, however, were of greater interest than a global assessment of mood for the present study.

Nonetheless, negative mood states were significantly correlated with poorer sleep quality. Individuals who reported poor subjective sleep quality were more likely to exhibit negative mood. The correlational analyses for sleep quality and sleep hygiene as well as for sleep quality and life stress also produced significant results. Poor sleep quality was correlated with poor sleep hygiene practice and with high amounts of daily hassles. All of these findings are previously undocumented phenomena, which reminds investigators not to overlook intuitive relationships.

The significant differences in cognition found between morning-types and evening-types tapped into different aspects of each set of cognitive tasks with effects found for mental rotation, attention, and memory. Directions for the effects, however, are split with morning-types performing better than evening-types on measures of memory and evening-types performing better than morning-types for number of errors on mental rotation and sustained attention. With this in mind, one should reconsider the use of generalized statements such as the old adage, "The early-bird gets the worm." There is evidence that evening-types surpass the "early-bird" on certain performance measures.

Finally, the paired t-test run on pretest and posttest SSS that indicated no difference between pretest and posttest levels of sleepiness allows the investigator to assume no fatigue effect was present during the experimental testing session.

From the findings of this investigation, many applications can be derived. The application of sleep research already has been seen in real-world forums that employ shiftwork, sustained nightshift (i.e., forced de-synchrony), and long-haul drivers/airline pilots (i.e., continuous performance). All of these situations fundamentally involve deprivation or insufficient sleep. The current study, however, provides evidence that sleep parameters within the range of typical daily patterns influence cognitive functioning. For example, in light of the current investigation's findings on the intuitive relationships between sleep quality and mood state, sleep hygiene, and life stress, it follows that explorations into other common situations that do not fundamentally involve deprivation or insufficient sleep are worth investigating.

The current study is similar to prior studies that have investigated sleep deprivation's influence on cognition in that some of the same dependent measures shown to be affected by sleep restriction are also influenced by normal aspects of sleep and normal behaviors related to sleep (Anderson et al., 1991; Kerkhof, 1998; Lenne et al., 1998; May et al., 1993; Monk & Leng, 1982; Natale & Lorenzetti, 1997; Petros et al., 1990; Tankova et al., 1994). A major difference, however, is the ease of the current study's application to everyday situations. Evidence herein provide bases for investigating the role of sleep (particularly non-pathological influences) in the classroom, as well as in human factors and industrial/organizational settings for the purpose of uncovering aspects that increase peak performance.

Furthermore, the heightened attention elicited through the MAT did not significantly affect sustained attention outcomes. In light of this, one must question the desired effects of caffeine and other stimulants when the need to combat fatigue arises. Activities that involve sustained attention – from long distance driving to quality control monitoring of nuclear power plants – do not necessarily benefit from an individual's heightened attention given his/her underlying level of fatigue. Occam's razor prevails in that the best way to combat fatigue is to get some rest. Exogenous influences (i.e., caffeine and other stimulants) may do little to enhance performance when fatigue is an underlying characteristic.

In light of the effects on cognitive performance, all the predictor variables stated in the hypotheses (i.e., sleep quality, synchrony of circadian typology with time of session, and presentation of an acute stressor) – with the exception of sleep hygiene – affected various outcomes on measures of memory function. From these results, it can be concluded that either memory is more affected than attention and mental rotation performance by non-pathological sleep parameters and stress level or that the tasks for attention and mental rotation were less sensitive than what was needed.

Assuming that memory indeed is affected more readily by non-pathological sleep parameters and stress than the other performance measures, some obvious implications arise from this finding. For instance, it lends some evidence for the multiple aspects and levels of cognition, reinforcing the need to investigate various aspects within cognitive functioning as opposed to searching for global assessments in its regard. Perhaps there are underlying biological, psychological, and/or social influences that can explain why aspects of memory are more readily affected by normal sleep parameters than aspects of sustained attention and mental rotation. These implications alone serve to stimulate further investigations.

Future directions are promising. If nothing else, this study serves as a stimulus for future investigations aimed at honing in on instruments and procedures that can better explain the reported findings.

Appendix A

Table 1

Effects of Sleep Hygiene and Sleep Quality on Cognitive Performance

| Performance Measure | Sleep Hygiene[a] | | Sleep Quality[b] | |
|---|---|---|---|---|
| | r | p | r | p |
| Mental Rotation Errors | -.01 | n.s. | -.03 | n.s. |
| Attention | | | | |
| Errors of Omission | .09 | n.s. | -.17 | n.s. |
| Errors of Comission | .03 | n.s. | -.14 | n.s. |
| Memory | | | | |
| Digit Span | .002 | n.s. | -.24 | .012[c] |
| Wordlist | | | | |
| Delayed Recall | .01 | n.s. | -.04 | n.s. |
| Delayed Recognition | -.08 | n.s. | .10 | n.s. |
| Percent Retention | .00 | n.s. | -.06 | n.s. |

Note. Pearson correlations were used to analyze the above variables due to the nature of predictors (continuous, quantitative data; N = 114).

[a]Higher scores on sleep hygiene measure indicate better hygiene.

[b]Higher scores on sleep quality measure indicate poorer sleep quality.

[c]Indicates poor sleep quality (high scores) related to poor digit span memory performance.

Table 2

Synchrony/Asynchrony Means Summary

| | Condition | | | |
|---|---|---|---|---|
| | Synchronous ($n = 32$) | | Asynchronous ($n = 23$) | |
| Performance Measure | M | SD | M | SD |
| Mental Rotation Errors | 8.34 | 14.12 | 9.43 | 12.66 |
| Attention | | | | |
| Errors of Omission | 8.19 | 16.91 | 4.17 | 4.07 |
| Errors of Comission | 3.09 | 3.68 | 3.96 | 4.25 |
| Memory | | | | |
| Digit Span | 10.66 | 3.48 | 11.35 | 3.64 |
| Wordlist | | | | |
| Delayed Recall | 11.25 | 1.93 | 11.78 | 1.70 |
| Delayed Recognition | 11.13 | 2.12 | 10.04 | 2.80 |
| Percent Retention * | 11.06 | 1.83 | 12.30 | 1.74 |

Note. * means significantly different, $p < .05$

Table 3

Acute Stressor (MAT) Means Summary

| | Condition | | | |
|---|---|---|---|---|
| | Stressor ($\underline{n}$ = 54) | | No Stressor ($\underline{n}$ = 60) | |
| Performance Measure | M | SD | M | SD |
| Mental Rotation Errors ** | 11.94 | 15.36 | 5.42 | 8.24 |
| Attention | | | | |
| Errors of Omission | 4.20 | 5.42 | 6.07 | 12.88 |
| Errors of Comission | 2.98 | 2.71 | 3.58 | 4.21 |
| Memory | | | | |
| Digit Span | 10.76 | 3.26 | 10.97 | 3.23 |
| Wordlist | | | | |
| Delayed Recall | 11.56 | 2.05 | 11.73 | 2.09 |
| Delayed Recognition * | 10.26 | 2.78 | 11.20 | 1.96 |
| Percent Retention | 11.85 | 2.03 | 11.82 | 1.92 |

Note. ** means significantly different, $\underline{p} < .01$; * means significantly different, $\underline{p} < .05$

Table 4

Morningness/Eveningness Means Summary

| | Condition | | | |
|---|---|---|---|---|
| | Morning Type ($n = 21$) | | Evening Type ($n = 34$) | |
| Performance Measure | M | SD | M | SD |
| Mental Rotation Errors * | 14.14 | 16.44 | 5.50 | 10.07 |
| Attention | | | | |
| Errors of Omission | 8.33 | 15.89 | 5.38 | 11.40 |
| Errors of Comission * | 4.86 | 5.75 | 2.59 | 1.73 |
| Memory | | | | |
| Digit Span | 10.00 | 3.69 | 11.53 | 3.35 |
| Wordlist | | | | |
| Delayed Recall * | 12.10 | 1.64 | 11.09 | 1.88 |
| Delayed Recognition * | 11.52 | 1.50 | 10.15 | 2.80 |
| Percent Retention | 12.05 | 1.77 | 11.29 | 1.92 |

Note. * means significantly different, $p < .05$

Table 5

Acute Stressor Means Summary for Subjective Stress Rating (SSRS)

| | Condition | | | |
|---|---|---|---|---|
| | Stressor ($n$ = 54) | | No Stressor ($n$ = 60) | |
| SSRS | M | SD | M | SD |
| Anger * | 5.21 | 2.29 | 7.18 | 2.35 |
| Anxiety * | 4.49 | 2.15 | 6.62 | 2.20 |
| Stress * | 3.68 | 2.09 | 5.70 | 2.69 |
| Attention * | 5.16 | 2.02 | 3.10 | 2.20 |
| Arousal | 4.15 | 1.90 | 3.69 | 1.88 |
| Fatigue | 5.34 | 1.20 | 5.11 | 2.12 |

Note. * means significantly different, $p < .001$

Table 6

Effects of Synchrony on Negative Mood States (POMS)

| | Synchrony/Asynchrony* | |
|---|---|---|
| | t | p |
| POMS | | |
| Anger | 0.53 | n.s. |
| Confusion | -0.24 | n.s. |
| Depression | -0.04 | n.s. |
| Fatigue | 0.04 | n.s. |
| Tension | -0.48 | n.s. |
| Vigor | 0.15 | n.s. |

Note. *Synchrony/Asynchrony is in reference to circadian typology (morningness vs. eveningness) by time of session (AM vs. PM).

Table 7

Relationships Among Non-Pathological Sleep Parameters and Life Hassles

| | Sleep Hygiene[a] | Sleep Quality[b] | MEQ[c] | SRRS[d] |
|---|---|---|---|---|
| Sleep Hygiene | ------ | -.49* | .18 | -.18 |
| Sleep Quality | | ------ | -.03 | .41* |
| MEQ | | | ------ | .12 |
| SRRS | | | | ------ |

Note. *significant correlation, $p < .001$

$N = 114$

[a]Higher scores on sleep hygiene measure indicate better hygiene.

[b]Higher scores on sleep quality measure indicate poorer sleep quality.

[c]Morningness-Eveningness Questionnaire (measure of circadian typology)

[d]Social Readjustment Rating Scale (measure of life hassles)

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