Psychomotor Performance Deficits and Their Relation to Prior Nights’ Sleep Among Individuals with Primary Insomnia

Jack D. Edinger, PhD1; Melanie K. Means, PhD1; Colleen E. Carney, PhD2; Andrew D. Krystal, MD2

1VA Medical Center, Durham, NC; 2Duke University Medical Center, Durham, NC

Objective: To examine psychomotor (reaction time) performance deficits and their relation to subjective and objective sleep measures among individuals with primary insomnia (PI).

Design and Setting: This study was conducted at affiliated VA and academic medical centers using a matched-groups, cross-sectional research design.

Participants: Seventy-nine (43 women) individuals with PI (M_age = 50.0 ± 17.1 y) and 84 (41 women) well-screened normal sleepers (M_age = 48.6 ± 16.8 y).

Methods and Measures: Participants underwent 3 nights of polysomnography (PSG) followed by daytime testing with a 4-trial multiple sleep latency test (MSLT). Before each MSLT nap, they rated their sleepiness and completed a performance battery that included simple reaction time (SRT), continuous performance (CPT), and 4 switching attention (SAT) tests. Performance measures included the mean response latency and the standard deviation of each subject’s within-test response latencies.

Results: PI sufferers reported greater (P = 0.001) daytime sleepiness, but were significantly (P = 0.02), more alert than normal sleepers on the MSLT. Multivariate analyses showed the PI group had significantly longer response latencies and greater response variability across many of the subtests than did the controls. Regression analyses showed that both PSG- and diary-based sleep measures contributed to the prediction of daytime performance indices, although objective wake time after sleep onset appeared the best single predictor of the daytime measures.

Conclusions: Results confirm that PI sufferers do show relative psychomotor performance deficits when responding to challenging reaction time tasks, and these deficits appear related to both objective and subjective sleep deficits. Findings support PI patients’ diurnal complaints and suggest the usefulness of complex reaction time tasks for assessing them.

Keywords: Primary insomnia; psychomotor performance; polysomnographic sleep measures

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Address correspondence to: Jack D. Edinger, PhD, VA Medical Center, 508 Fulton Street (116B), Durham, NC 27705; Tel: (919) 286-0411, Ext: 7054; Fax: (919) 416-5832; E-mail: jack.edinger@duke.edu

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Evidence suggests these traits are indeed pronounced among PI sufferers, yet it is not clear that such individuals are devoid of diurnal psychomotor deficits. A review of the previous investigations of PI sufferers’ performance deficits shows these studies generally included small and/or poorly characterized samples or employed a limited range of psychomotor performance measures. As a consequence, methodological limitations (e.g., limited statistical power, mixed insomnia samples, insensitive psychomotor tests) may, at least in part, explain the mixed results in this literature. Given the above-noted long-term morbidity associated with PI, it seems likely that individuals with this condition should show measurable day-to-day impairments as well. Thus, the current study was conducted to compare the diurnal psychomotor performances of well-characterized PI sufferers and non-complaining normal sleepers in a large study sample tested with a range of simple and complex psychomotor reaction time tasks. We predicted that our PI sufferers would perform significantly worse than the normal sleepers on performance measures, and group differences would be most obvious on more complex tasks. In addition to testing this hypothesis, we examined the association between the observed daytime performance deficits and both subjective and objective sleep measures derived from nights preceding our daytime testing.

METHODS

Design

This study used a between-groups, cross-sectional research design. Independent groups of age- and gender-matched primary insomnia (PI) sufferers and non-complaining normal sleepers (NS) comprised the study sample. The participants for the current study were drawn from a series of studies conducted to compare the home and laboratory sleep patterns of young, middle-aged, and older adult insomnia sufferers and normal sleepers. All study procedures were reviewed and approved by the Institutional Review Boards of the VA Medical Center and Duke University Medical Center in Durham, NC. All participants were required to provide written informed consent prior to enrolling in the research and undergoing study-related procedures. Upon completion of their study participation, they received financial compensation for their time plus reimbursement for parking expenses incurred as a result of their study involvement.

Participants

Study participants included 3 separate adult age cohorts recruited via posted announcements at a VA and affiliated university medical centers, flyers posted in public libraries, letters mailed to persons in our university’s Center for the Study of Aging and Human Development Subject Pool, and face-to-face solicitations of patients presenting to our university sleep disorders center. The oldest cohort (ages 60–79 y) was recruited between October 1992 and July 1994; the second, middle-aged cohort (ages 40–59 y) was recruited between October 1995 and July 1997; and the final young adult cohort (ages 20–39 y) was recruited between October 1999 and October 2001. Each of the 3 cohorts was comprised of age- and gender-matched groups of primary insomnia sufferers and non-complaining normal sleepers.

Prior to their acceptance into the study, all participants underwent a thorough screening that included structured psychiatric and sleep interviews, a medical exam, thyroid (TSH level) screening, and 1 to 2 nights of screening polysomnography to rule out occult primary sleep disorders. The insomnia sufferers reported sleep complaints consistent with Diagnostic and Statistical Manual for Mental Disorders (DSM) criteria for PI (e.g., ≥ 6 months of difficulty initiating or maintaining sleep or nonrestorative sleep with accompanying daytime deficits). The normal sleepers enrolled were adults who reported no sleep complaints and had no major medical or psychiatric condition that might have contributed to an unreported occult sleep disorder.

The following led to study exclusion: (a) a sleep disruptive medical condition (e.g., rheumatoid arthritis); (b) a current major psychiatric (Axis I) condition on the basis of a Structured Clinical Interview for Psychiatric Disorders (SCID); (c) sedative hypnotic dependence and unwillingness/ability to abstain from these medications while in the study; (d) use of anxiolytics, antidepressants, or any other psychotropic medication; or (e) an apnea-hypopnea index ≥ 15 or a periodic limb movement-related arousal index ≥15 on screening PSG. In addition, we excluded insomnia sufferers who met structured interview criteria for another sleep disorder in addition to primary insomnia, and we excluded normal sleepers who met criteria for any sleep disorder.

A total of 208 volunteers were enrolled, but 45 of these were dropped from study analyses since they had insufficient nights of sleep data (see polysomnography section below) or because they failed to complete some or all of the daytime testing relevant to this report. As a result, the final sample consisted of 163 participants. Seventy-nine of these participants (43 women) met criteria for PI, whereas the remaining 84 (41 women) met the selection criteria for normal sleepers. The average age of the insomnia sufferers was 50.0 y (SD = 17.1 y), and they averaged 15.2 y (SD = 2.9 y) of formal education. Of these individuals, 60 were Caucasians, 12 were African Americans, 4 were Asians, and the remaining 3 had other diverse ethnic backgrounds. The normal sleepers had a mean age of 48.6 y (SD = 16.8 y) and an average of 15.8 y (SD = 2.8 y) of formal education. Seventy-one of the normal sleepers were Caucasians, 9 were African Americans, 3 were Asian Americans, and the remaining individual had a biracial background. The 2 samples did not differ significantly in regard to their mean ages ($F_{1,162} = 0.30, P = 0.58$), gender composition ($\chi^2(1) = 0.51, P = 0.47$) or ethnic group composition ($\chi^2(3) = 2.34, P = 0.50$).

Polysomnography

Immediately prior to daytime testing, all participants underwent 3 consecutive nights of polysomnography (PSG), conducted either in their homes or in our university medical center’s sleep laboratory. The location of PSGs (lab vs. home) was randomly determined, so that roughly one-half of the men and women in each study sample underwent lab recording (44 PI, 45 normal sleepers), and the other half completed home monitoring (43 PI, 47 normal sleepers) before their daytime testing. All PSGs were conducted using 8-channel Oxford Medilog 9000 or 9200 series ambulatory cassette recorders. The monitoring montage included 2 electroencephalogram (EEG) chan-
nels (C$_3$A$_2$, O$_2$C$_3$), bilateral electrooculogram (EOG), submental electromyogram (EMG), 2 channels of anterior tibialis EMG (right and left leg) and a nasal-oral thermistor. All PSGs were scored using standard scoring criteria for assignment of sleep stages, identification of respiratory events (e.g., apneas, hypopneas), and identification of periodic limb movements and periodic limb movement-related arousals.28-31 Per preplanned study protocols, the first night (older cohort ages 60+ y) or initial 2 (remainder of the sample) PSG nights (home or lab) were used to screen out those exceeding the above-mentioned apnea-hypopnea index or periodic limb movement arousal index cut-offs for study inclusion. Although PSG typically includes additional respiratory measures (respiratory effort, oximetry) to detect breathing abnormalities, it was thought that monitoring of nasal/oral airflow along with our thorough interview screening for apnea would be sufficient to identify most cases with an apnea-hypopnea index above the study’s exclusionary cut-off. In addition to the screening data, mean values of time in bed (TIB) total sleep time (TST), sleep onset latency (SOL), wake time after sleep onset (WASO), and sleep efficiency (SE) were derived from the 3 PSGs conducted prior to daytime testing and were used in various study analyses. However, 15 subjects produced technically unacceptable PSG recordings that could not be scored either on 2 of the 3 nights prior to daytime testing or on the night just prior to the daytime tests. Since study objectives included relating nighttime sleep measures to measures of daytime performance, these subjects were viewed as having insufficient PSG data and were among the 45 participants dropped from study analyses. The final sample of 163 participants included 152 (93.3%) who had PSG data available for all 3 nights prior daytime testing and another 11 (6.7%) who were missing data only from night 1 or night 2 in the 3-night series.

Sleep Diaries

Participants completed paper and pencil sleep diaries each morning subsequent to a night of PSG monitoring. Sleep diary items included questions about the previous night’s bedtime, rising time, sleep onset latency and wake time during the night, time of final awakening, and final rising time. These various entries were used to compute participants’ subject estimates of TIB, TST, SOL, WASO, and SE for each PSG night. Mean values of these subjective measures were computed for the study’s planned analyses.

Multiple Sleep Latency Test (MSLT)

All participants underwent a 4-trial MSLT following their initial 3 nights of lab or home PSG monitoring. Most aspects of the standard MSLT protocol were followed with the first nap commencing 2 to 3 h after the morning rising time following the third consecutive night of PSG monitoring, and each subsequent nap occurring at 2-h intervals. For each nap, participants were placed in a darkened room in the sleep laboratory and were instructed to attempt to fall asleep. Conservative MSLT criteria rather than contemporary clinical criteria were used to define the sleep latency for each nap. Specifically, sleep latency was defined as the time between the beginning of the nap trial and either the first 3 consecutive 30-sec epochs of stage 1 sleep or the first 30-sec epoch of any other sleep stage. If no sleep occurred, the trial was terminated at 20 min, and a sleep latency of 20 minutes was assigned. To minimize carryover effects from one nap to the next, each nap trial was discontinued once the sleep onset criterion was met.

Sleepiness Ratings

Immediately prior to each of their 4 MSLT naps, participants completed the Stanford Sleepiness Scale to provide measures of their subjective daytime sleepiness. This instrument was administered and scored in a standard fashion. Thus, resultant ratings were whole numbers that varied between values of 1, which reflected “Feeling active and vital; wide awake,” and 7, which indicated feeling “almost in reverie; sleep onset soon; lost struggle to stay awake.”

Performance Testing

All study participants completed four 16-min trials of a series of 3 computer-administered reaction time tasks selected from the Neurobehavioral Evaluation System (NES).34 During this testing, participants were placed individually in a testing room and seated in front of a PC computer equipped with testing software. The testing software provided testing instructions and test items on the computer screen and recorded all test responses for later analyses.

The first and least challenging test in each trial was the Simple Reaction Time Test (SRT), a test with established reliability and validity for detecting subtle cognitive impairment such as those caused by chronic low-level neurotoxin exposure.55,36 During the SRT, the participant was required to press a specially marked key on the computer keyboard whenever a figure (i.e., a small square) appeared on the computer screen. During the test, the figure appeared at intervals varying between 1000 and 2500 milliseconds (msec) and remained on the screen either until a response occurred or 1000 msec had elapsed. The total trial lasted approximately 5 min and consisted of 90 presentations of the target stimulus.

The second test, the Continuous Performance Test (CPT),37 consisted of a more challenging signal detection task during which a target (the letter S) and background stimuli (the letters, A, C, E, and T) were presented on the computer screen. Target and background letters appeared in a random order with a 1:4 target-to-background ratio throughout testing. The various letters were presented at the rate of 1 per second with each letter remaining on the screen for 50 msec. The total test lasted approximately 5 min and included 60 presentations of the target and 240 presentations of the background stimuli. In responding to this test, the participant was required to press a specially marked key on the computer keyboard when and only when the target letter appeared on the screen. Like the SRT, this test was chosen based on its proven reliability and validity for detecting mild cognitive impairments.35,38

The final and most complex test, the Switching Attention Test (SAT), lasted approximately 6 min and included a range of reaction time tasks. During both the initial and latter portions of this test, the participant was required to press specially marked keys on the right or left side of the keyboard in response to SLEEP, Vol. 31, No. 5, 2008

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stimulus presentations. The initial portion of the test was comprised of 2 tasks requiring the participant to make relatively simple response choices. During the first of these 2 tasks, a square appeared on the right or left side of the computer screen and the participant was required to press a marked key on the corresponding side of the keyboard. During the second such task, an arrow pointing right or left appeared in the center of the screen, and the participant was required to make a right or left side key press in response as directed by the arrow. During each of these tasks, the stimulus remained on the screen either until a response occurred or 2500 msec had elapsed. The former of the 2 tasks included 6 practice and 16 test presentations of the stimulus, whereas the latter included 4 practice and 16 test presentations of the stimulus during each testing trial.

During the final, most complex portion of the SAT, an arrow (pointing right or left) appeared either on the right or left side of the screen. Preceding each presentation of this arrow by 1000 msec, 1 of 2 command words, “SIDE” or “DIRECTION,” appeared on the screen. This command word served to signal the participant to respond by pressing a key on the side of the keyboard corresponding either to the side of the screen on which the arrow appeared or the direction in which the arrow was pointing. On 50% of the presentations, the side of the arrow that was pointing agreed. On the remaining presentations, these 2 stimulus characteristics were in conflict. Throughout the test, these non-conflict and conflict presentations occurred in a random sequence. Overall, this section of the switching attention test included 8 practice and 48 test presentations of the command-stimulus combination. Previous studies have attested to the reliability and validity of the SAT for detecting mild cognitive deficits such as those caused by chronic or acute exposure to neurotoxins.

During each trial of the various tests, the NES software automatically recorded the respondent’s reaction time (in msec) between the presentation of the stimulus on the PC screen and the computer key-press response. For each trial of each test, the NES software recorded the participant’s response latency. In addition, the test software computed the participant’s mean response latency as well as a within-subject standard deviation of response latencies across stimulus presentations for the SRT, CPT, and each section of the SAT for each of the 4 testing trials. The mean response latency, which reflected the overall performance and the within-subject standard deviation, which reflected behavioral and/or attentional instability, served as indices of psychomotor performance employed for group comparisons.

Procedure

All participants underwent 3 consecutive nights of sleep monitoring (home or lab) just prior the daytime testing. Following the third PSG night, performance/MSLT trials were conducted in the sleep laboratory under the supervision of trained laboratory technologists. Immediately prior to initiating performance/MSLT testing, each participant’s PSG electrodes were checked and readjusted if necessary. Performance/MSLT trials then were commenced at the instruction of the assigned technologist, and participants were supervised between trials to prevent unscheduled sleep episodes. PSG electrodes were worn for the entire day of laboratory testing and were not removed until after the final trial was completed. Once the fourth performance/MSLT trial was completed and electrodes were removed, the participant was allowed to leave the laboratory.

After all participants had completed the study, we conducted preliminary inspections of the data to assure their suitability for study analyses. Since all performance tests were administered and scored via computer software, we anticipated there would be very few questionable outlier values in the performance data set obtained. Nevertheless, we constructed plots of each of the 12 performance indices to identify questionable data points (e.g., responses that were too early or too late to be genuine). From visual inspection of these plots, we identified and eliminated a small number of outlier data points (<1% of all responses obtained) that fell well outside the range of the remainder of data obtained for the measures in question. We then scrutinized the remaining data to determine if our dependent measures were normally distributed and performed arithmetic normalizing operations (e.g., logarithmic transformation) where required. Subsequently we conducted the previously mentioned analyses to assess the demographic similarity of our participant groups. Following these analyses, we conducted a series of statistical analyses to address our study objectives.

RESULTS

Nocturnal Sleep Measures

To determine if the PI and normal groups differed in regard to their nighttime sleep prior to daytime testing, we compared these groups using the mean measures derived from their nocturnal PSG monitoring and concomitant sleep diaries. As a control for type 1 error, we first conducted separate 2 (PI vs. normal sleeper) × 5 (sleep measures) multivariate repeated measures analysis of variance with the sets of PSG and diary measures to determine if the groups differed across the objective and subjective sleep measures obtained. Significant group effects were then tested with univariate ANOVAs conducted with each individual sleep measure. We performed these statistical analyses using the GLM procedure included in the SAS 9.1 software package.

Table 1 shows the mean and standard deviation terms for the PSG and diary measures. Results of multivariate tests showed significant group x sleep measure effect for both PSG (Wilks lambda = 0.92; $F = 7.16$, $P = 0.001$) and sleep diary (Wilks lambda = 0.76; $F = 24.68$, $P = 0.0001$) measures. Results of univariate tests, which are also shown in Table 1, indicated that the groups differed significantly on PSG measures of WASO and SE, and on all 5 of the sleep diary measures. Consistent with previous studies, sleep diary data suggested relatively greater sleep disturbance among the PI group than did PSG measures. Nonetheless, both sets of measures indicated that the PI group had more disturbed sleep (greater wakefulness, less efficient sleep) than did the normal group.

Daytime Sleepiness

Preliminary analyses with both the objective (MSLT) and subjective (sleepiness ratings) measures of daytime sleepiness
since age had little influence on the effects detected. The results of the MANOVA showed a significant group main effect ($F = 8.08, P = 0.005$). Follow-up ANOVAs showed the PI group had significantly longer response latencies across 3 of the 4 SAT subtests as well as significantly larger within-subject standard deviations of latencies. Given this finding, we computed mean values of MSLT sleep latencies and Stanford Sleepiness Scale ratings across the 4 trials and then used these mean values as dependent measures in simple one-way ANOVAs to compare the 2 study samples. Results of these analyses showed that the groups differed significantly in regard to their mean MSLT sleep latencies ($F = 5.24, P = 0.02$) and sleepiness ratings ($F = 10.75, P = 0.0001$) across the day. The PI group (Mean = 10.3 min.; SD = 5.0 min.) had a longer mean MSLT latency than did the normal sleepers (Mean = 8.6 min.; SD = 5.2 min). In contrast, the PI sufferers (Mean rating = 2.97; SD = 1.0) rated themselves as more sleepy on the Stanford Scale than did the normal sleepers (Mean rating = 2.47; SD = 1.0).

### Performance Measures

The performance testing software computed a mean response latency and within-subject standard deviation of response latencies for the SRT, CPT, and each of the 4 sections of the SAT for each testing trial. As a result each participant obtained a total of 12 performance indices for each testing trial. Preliminary analyses with these measures showed no differential time of day effects across the 2 study samples (i.e., no significant group × trial interaction). Given this finding, we computed mean values of MSLT sleep latencies and Stanford Sleepiness Scale ratings across the 4 trials and then used these mean values as dependent measures in simple one-way ANOVAs to compare the 2 study samples. Results of these analyses showed that the groups differed significantly in regard to their mean MSLT sleep latencies ($F = 5.24, P = 0.02$) and sleepiness ratings ($F = 10.75, P = 0.0001$) across the day. The PI group (Mean = 10.3 min.; SD = 5.0 min.) had a longer mean MSLT latency than did the normal sleepers (Mean = 8.6 min.; SD = 5.2 min). In contrast, the PI sufferers (Mean rating = 2.97; SD = 1.0) rated themselves as more sleepy on the Stanford Scale than did the normal sleepers (Mean rating = 2.47; SD = 1.0).

### Table 1—Means, Standard Deviations, and Results of Group Comparisons with Sleep Measures

<table>
<thead>
<tr>
<th>MEASURE</th>
<th>PI Group</th>
<th>Normal Sleepers</th>
<th>F</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>PSG</td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>TIB–Min</td>
<td>462.7</td>
<td>51.5</td>
<td>447.8</td>
<td>51.5</td>
</tr>
<tr>
<td>TST–Min</td>
<td>369.9</td>
<td>50.9</td>
<td>376.0</td>
<td>52.1</td>
</tr>
<tr>
<td>SOL–Min</td>
<td>23.0</td>
<td>17.7</td>
<td>20.0</td>
<td>19.8</td>
</tr>
<tr>
<td>WASO–Min</td>
<td>64.6</td>
<td>37.3</td>
<td>44.8</td>
<td>24.6</td>
</tr>
<tr>
<td>SE–%</td>
<td>80.7</td>
<td>8.1</td>
<td>84.9</td>
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<tr>
<td>Sleep Diary</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TIB–Min</td>
<td>468.5</td>
<td>49.6</td>
<td>452.5</td>
<td>53.5</td>
</tr>
<tr>
<td>TST–Min</td>
<td>356.5</td>
<td>76.7</td>
<td>394.8</td>
<td>61.8</td>
</tr>
<tr>
<td>SOL–Min</td>
<td>40.9</td>
<td>30.2</td>
<td>17.9</td>
<td>13.1</td>
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<tr>
<td>WASO–Min</td>
<td>49.7</td>
<td>43.2</td>
<td>25.9</td>
<td>28.9</td>
</tr>
<tr>
<td>SE–%</td>
<td>76.1</td>
<td>13.7</td>
<td>87.2</td>
<td>9.1</td>
</tr>
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</table>

Table 1 Caption: PSG = polysomnography; PI = primary insomnia; SD = standard deviation; TIB = time in bed; TST = total sleep time; SOL = sleep onset latency; WASO = wake time after sleep onset; SE = sleep efficiency.

### Figure 1—Group Comparisons Across the Various Performance Subtests

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deviations of their response latencies (i.e., more response instability) on the SRT and across all SAT subtests. Figure 1 shows the group differences across the various performance indices and P values for the significant group differences noted for these measures. In contrast to these findings, ANOVAs showed the PI and normal sleeper groups did not differ significantly in their performances on the SRT latency measure or on the 2 CPT subtests. Thus, group differences were noted primarily on the more challenging SAT subtests.

Nocturnal Sleep and Daytime Performance

To determine how nighttime sleep obtained prior to daytime testing affected the performances of our study participants, we conducted a series of regression analyses in which sleep measures taken from PSG and diary were used as predictors of each of the 8 performance measures found to differentiate our PI and normal groups. These regression analyses were conducted with the entire study sample using the MAXR procedure included in the SAS statistical software package. The MAXR procedure was chosen for these analyses since it uses all variables for each solution and finds the best single predictor, the best 2 predictors, and the best “n” variable predictors. Regression analyses were conducted first using PSG and diary values of TST, SOL, WASO, and SE taken from the single night prior to daytime testing and secondly using mean values of these sleep measures taken from all available PSG nights immediately prior to daytime testing.

Table 2—Results of Regression Analyses Using PSG and Sleep Diary Measures to Predict Performance Measures

<table>
<thead>
<tr>
<th>Performance Measure</th>
<th>Best Single Predictor</th>
<th>Best Prediction Model</th>
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<tbody>
<tr>
<td></td>
<td>Variable</td>
<td>R²</td>
</tr>
<tr>
<td>SRT SD</td>
<td></td>
<td></td>
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<tr>
<td>Prior Night</td>
<td>4</td>
<td>0.051</td>
</tr>
<tr>
<td>Prior 3 Nights</td>
<td>4</td>
<td>0.051</td>
</tr>
<tr>
<td>SAT SD</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prior Night</td>
<td>3</td>
<td>0.042</td>
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<tr>
<td>Prior 3 Nights</td>
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<td>0.053</td>
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<tr>
<td>SAT Direction Latency</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prior Night</td>
<td>3</td>
<td>0.024</td>
</tr>
<tr>
<td>Prior 3 Nights</td>
<td>3</td>
<td>0.065</td>
</tr>
<tr>
<td>SAT Direction SD</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prior Night</td>
<td>3</td>
<td>0.035</td>
</tr>
<tr>
<td>Prior 3 Nights</td>
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<tr>
<td>SAT Switching Sides Latency</td>
<td></td>
<td></td>
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<tr>
<td>Prior Night</td>
<td>8</td>
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</tr>
<tr>
<td>Prior 3 Nights</td>
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<td>0.083</td>
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<tr>
<td>SAT Switching Sides SD</td>
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<tr>
<td>Prior Night</td>
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<tr>
<td>Prior 3 Nights</td>
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<td>0.062</td>
</tr>
<tr>
<td>SAT Switching Directions Latency</td>
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<tr>
<td>Prior Night</td>
<td>3</td>
<td>0.051</td>
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<tr>
<td>Prior 3 Nights</td>
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<tr>
<td>SAT Switching Directions SD</td>
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<tr>
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</tr>
<tr>
<td>Prior 3 Nights</td>
<td>3</td>
<td>0.050</td>
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</tbody>
</table>

a. SRT = Simple Reaction Time Task; SAT = Switching Attention Task. b. Numbers shown represent PSG and diary sleep measures which are coded as follows: 1 = PSG total sleep time; 2 = PSG sleep onset latency; 3 = PSG wake time after onset; 4 = PSG sleep efficiency; 5 = sleep diary total sleep time; 6 = sleep diary sleep onset latency; 7 = sleep diary wake time after sleep onset; 8 = sleep diary sleep efficiency. c. Sleep measures used for regression analyses were taken from the night immediately prior to the daytime performance testing or were averaged sleep measures taken from all available PSG nights immediately prior to daytime testing.
Table 3 are similar to those shown in Table 2 for the 2 samples combined. The most notable exceptions to this conclusion are the contrasting $R^2$ values found for our PI sufferers and normal sleepers for the SRT response variability measure. Among our normal sleepers, nocturnal sleep measures were much more strongly predictive of this performance index than they were among our PI group. However the majority of these analyses suggested that the modest relationship between objective/subjective sleep and performance noted for the sample as a whole persisted when the PI and normal groups were considered separately.

**Discussion**

Previous studies designed to document the daytime performance deficits of which PI sufferers complain have had a number of limitations including modest sample sizes, poorly characterized subject samples, and use of insensitive psychomotor performance tests. The current study was conducted to overcome these limitations by enrolling large, well-characterized samples of PI sufferers and normal sleepers and by employing a battery of tests that ranged in their complexity. Consistent with our prediction, results showed that our PI sample performed more poorly across many of the performance tests than did our sample of normal sleepers. Specifically, our data showed that the PI sample had longer response latencies and more variability on each of the study samples considered separately. Hence, we conducted a second set of regression analyses (MAXR) to examine the relationship between our sleep measures and daytime performance within both the PI and normal groups. In these analyses, mean values of PSG and diary sleep measures across all available nights prior to daytime testing were used to predict each of the 8 performance measures listed in Table 2. We again used the MAXR procedure to test the best single variable and multiple variable prediction models shown in Table 2 for each performance measure within each of our subgroups. However, since these 2 sets of analyses each included about half of the study sample, we recognized they had much less power for affirming the statistical significance of the regression models tested than did those MAXR analyses conducted with the sample as a whole. Thus, we conducted these analyses without strict regard to the tests of statistical significance for the regression models tested. Rather, we used these analyses to determine if the single variable and multivariate regression models shown in Table 2 would produce comparable $R^2$ values within our PI and normal groups.

Results of this second set of analyses are summarized in Table 3. As expected, many of the regression models tested in this set of analyses were not found to be statistically significant likely due to the reduced sample sizes considered compared to the size of the combined sample used in the analyses shown in Table 2. Nonetheless, in most cases the $R^2$ values shown in Table 3 are similar to those shown in Table 2 for the 2 samples combined. The most notable exceptions to this conclusion are the contrasting $R^2$ values found for our PI sufferers and normal sleepers for the SRT response variability measure. Among our normal sleepers, nocturnal sleep measures were much more strongly predictive of this performance index than they were among or PI group. However the majority of these analyses suggested that the modest relationship between objective/subjective sleep and performance noted for the sample as a whole persisted when the PI and normal groups were considered separately.
ability in their reaction times across many of our performance tests than did the normal control group. As such, our PI participants responded more slowly and evidenced more attentional/behavioral instability in their performances than did our normal sleepers. Thus, unlike many previous smaller studies on this topic, the current study provides support for the clinical complaints of PI patients.

In addition to these general conclusions, there are several aspects of the study results that deserve comment. First, it should be noted that all but one of the significant group differences occurred on the reaction time measures taken from the Switching Attention (SAT) subtests. The SAT includes a series of progressively challenging psychomotor tasks assessing the respondent’s abilities to concentrate, attend to both the position and orientation of test stimuli, and to select position- or orientation-based responses to test stimuli in response to brief commands presented visually. In the latter sections of the SAT, the position and orientation of the test stimuli are frequently presented in conflict so as to require the respondent to inhibit a position-based response in favor of an orientation-based response and vise-versa. As such, optimal performance on the SAT would seem to require intact concentration, attention, response inhibition, and rapid decision making. This collection of abilities may closely approximate the deficits PI sufferers present clinically when they complain of inability to concentrate and a general lack of mental sharpness. For this reason, tests like the SAT may be needed to identify the relative performance deficits of PI sufferers. It is possible that more extended testing times with tests such as the SRT and CPT may also produce reaction time measures that consistently differentiate PI sufferers from normal sleepers. However, with repeated testing protocols like the one used herein, investigators may wish to limit testing time so as to minimize subject burden. Under such circumstances, complex tests like the SAT may prove most useful for investigations having goals similar to the current study.

In addition, a few comments about the PI sample enrolled in this study deserve mention. Despite our traditional and relatively conservative scoring of the MSLT, the PI group in the current study appeared significantly more alert on this test than did the normal sleepers. Yet our PI group reported greater daytime sleepiness than did the matched normal controls. Also, as noted in previous studies, PSG- and diary-based sleep measures showed our PI group had both objective and subjective sleep deficits relative to our normal control group. Considered collectively, these findings reiterate the common impression that our PI group was a hyperaroused group that had relative difficulty sleeping during the night and during the day despite a relatively elevated level of subjective daytime sleepiness. Given these characteristics, it seems particularly noteworthy that such hyperaroused individuals would respond relatively slowly and have more response variability than would matched normal individuals presumed to have less sleep-preventing arousal. Such findings suggest that physiological hyperarousal, if indeed present in PI sufferers, does not override their mental sluggishness as it does their objective sleepiness. These comments are speculative since we did not include common measures reflective of physiological hyperarousal (e.g., heart rate variability, metabolic rate). Nonetheless, the current findings implying both hyperarousal and slowed and unstable psychomotor performance warrant additional studies that correlate physiological indices of arousal with measures of mental and behavioral functioning.

In addition to these comments, it should also be mentioned that this study implies a link between objective sleep disturbance in PI and daytime psychomotor functioning. In fact, this study’s results did suggest a slightly stronger link between objective sleep measures and diurnal performance than it did between subjective sleep and performance. Nonetheless, results also suggested that some subjective aspects of sleep contributed to performance differences noted between PI sufferers and normal sleepers as well. On the one hand, such findings imply that both objective and subjective sleep disturbances should be considered in defining the PI syndrome. However, regression analyses showed that a relatively small amount of the variance noted in the daytime performance indices scrutinized herein was predicted by the objective and subjective sleep measures we considered. We should note that our selection of sleep measures was limited since we chose only those sleep continuity measures that could be derived from both PSG and diaries. Whereas this choice allowed us to assess the relative predictive value of the objective and subjective sleep measures considered, it is possible that the inclusion of other types of PSG measures (e.g., sleep stage percentages; relative spectral power indices) as predictors in our regression analyses may have suggested a stronger relationship between objective sleep and daytime functioning. Of course, the role of subjective and objective sleep in PI also may benefit by future research studies that include daytime testing after good and bad sleep nights or testing after nights wherein certain selected aspects of the sleep process are experimentally manipulated. Thus, additional research will be needed to determine if some aspects of sleep not measured herein or factors other than sleep are more strongly related to the relative performance deficits noted for our PI group in this investigation.

Admittedly, this study had a number of limitations. The PI sample was well characterized with thorough screening procedures, but it was largely composed of research volunteers. As such, results may not generalize to more severely impaired clinical patients. Secondly, the study sample was fairly large and diverse in age, yet individuals younger than 20 years of age were not enrolled, so results may not apply to younger age groups. In addition, the overall research burden imposed on our study participants led us to limit the variety of performance measures employed herein. It is possible that other types of psychomotor and cognitive measures would provide more insights into the diurnal impairments of PI sufferers. Finally, although we screened all enrollees with PSG to rule out sleep apnea, our recording montage did not include the array of respiratory indices usually employed in diagnostic polysomnograms. Consequently, it is possible that some of our participants suffered from occult sleep disordered breathing that contributed to their performance deficits. Thus, replications of this study with clinical insomniacs, other age groups, a wider range of performance measures, and more comprehensive PSG recordings may be useful. Nevertheless, our results suggest that with sufficient experimental power and sensitive laboratory tests, it is possible to document the performance deficits of which PI patients complain.
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