# An Open Trial of Light Therapy in Adult Attention-Deficit/Hyperactivity Disorder

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***Objective:*** In adults with attention-deficit/hyperactivity disorder (ADHD), a delayed sleep/activity rhythm and/or seasonal mood symptoms may contribute significantly to core pathology and disability. This study examined whether a chronobiologically based treatment, i.e., morning bright light therapy (LT), might have utility as an adjunctive treatment for adult ADHD in the fall/winter period.

***Method:*** Twenty-nine adults with DSM-IV ADHD were administered a standard 3-week open trial of LT during the fall or winter months. Primary outcome measures included percentage reduction on the Brown Adult ADD Scale and the Conners' Adult ADHD Scale. Secondary measures were decrease in depression scores according to the Structured Interview Guide for the Hamilton Depression Rating Scale, Seasonal Affective Disorder version; improvements on various neuropsychological tests; and shift toward an earlier circadian preference as measured by the Horne-Ostberg Morningness-Eveningness questionnaire. Regression analyses determined which variables at baseline best predicted improvement on a given outcome measure and which variables changed in parallel with one another. The study was conducted from November 2003 through February 2004.

***Results:*** Morning bright light therapy was associated with a significant decrease in both subjective and objective measures of core ADHD pathology, improved mood symptoms, and a significant phase advance in circadian preference. Multiple regression showed that the shift toward an earlier circadian preference with LT was the strongest predictor of improvement on both subjective and objective ADHD measures. Neither baseline global seasonality scores nor baseline depression scores strongly predicted LT effects on most measures of ADHD.

***Conclusion:*** These findings suggest that during the fall/winter period, LT may be a useful adjunct in many adults with ADHD. Strikingly, the strongest correlate of improvement in core ADHD pathology was a phase advance in circadian preference rather than alleviation of comorbid seasonal affective disorder, suggesting important clinical benefits of LT beyond the treatment of seasonal affective disorder.

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A majority of children with attention-deficit/hyperactivity disorder (ADHD) will go on to have residual symptoms into late adolescence and adulthood.[1] While in children disruptive behavior is often the presenting complaint, in adolescents and adults it is deficits in mood regulation, arousal, and organization that often come to the forefront.[2] As the pressure to conform to work schedules increases over time, an inability to adapt daily activity schedules to occupational demands contributes to truancy and poor performance. This inability is often related to difficulty falling asleep, awakening on time, and maintaining arousal when performance demands are maximal.[3] In chronobiological terms, these difficulties are consistent with a phase delay in circadian activity rhythms.

In clinical settings, one way to estimate circadian phase is to administer the Horne-Ostberg Morningness-Eveningness questionnaire (MEQ),[4] which asks about the timing of sleep/wake cycles and other activities. The MEQ correlates highly with objectively measured circadian rhythms[5,6] and has been used as a proxy for these rhythms in prior research.[7] Our recent pretreatment study[8] of adults with ADHD taking part in the current protocol found that over 40% reported an evening circadian preference (designated "evening types") based on the MEQ. This finding is highly discrepant with a large European study of the general population, which found only 10.8% of evening types.[9] Of great clinical relevance, in these

  

adults with ADHD we found a strong correlation between eveningness as measured by the MEQ and both subjective and objective deficits in functioning.[8] A later circadian preference was most strongly correlated with subjective problems sustaining effort and both a higher level of impulsive responding and more difficulty discriminating between target and nontarget stimuli on objective testing. Unexpectedly, these findings were independent of both state depression and global seasonality scores, 2 factors that can strongly contribute to both a phase delay and neurocognitive dysfunction in some cases. Taken as a whole, these results suggest that a substantial subgroup of adults with ADHD have a mood-independent circadian phase delay, which significantly impacts their core pathology. These findings also establish a potential new target for chronobiologically based treatments in this complex population.

The goal of the current report was to assess the effectiveness of morning bright light therapy (LT) as a treatment for adult ADHD during the fall or winter period. While one goal was to treat the seasonal mood symptoms that are commonly seen in adult ADHD,[10] we also explored the phase advancing effect of LT, as LT can robustly advance circadian rhythms in disorders such as delayed sleep phase syndrome.[11] Furthermore, Rosenthal[12] has described a case report of a 9-year-old girl with a symptom triad of ADHD, seasonal affective disorder, and delayed sleep phase syndrome who, with adjunctive bright light therapy in the early morning, showed a marked improvement in energy and concentration and an ability to fall asleep at conventional times. In following this patient over subsequent years it was concluded that methylphenidate was most important for treating her core attention difficulties while light therapy helped her seasonal affective symptoms and sleep phase delay.

The specific hypotheses for the current study were as follows: (1) In adult ADHD patients treated in the fall/winter months, morning LT would produce the same chronobiological effects as it does in other populations in (a) alleviating depressive symptoms in the subgroup of patients with comorbid SAD and (b) causing a phase advance in daily sleep and activity rhythms as measured by the MEQ. (2) That LT might improve the core subjective symptoms of ADHD and/or neuropsychological functioning either related to or independent of these 2 well-established effects.

We report here the results from our LT study of 29 subjects with adult ADHD.

## METHOD

### Subjects

The current study sample consisted of 29 adults (15 male, 14 female) 18 to 60 years of age recruited via notices posted on local internet Web sites and via posters and pamphlets distributed at local clinics and organizations working with adult ADHD clients. In order to limit a possible recruitment bias favoring ADHD patients with seasonality in mood and/or ADHD symptoms, the notices referred to "a novel nonpharmacologic treatment study of adult ADHD" and did not refer specifically to seasonality or light therapy. Given the ultimate treatment focus on light therapy, recruitment was done in the late summer through late winter months. All potential subjects underwent an initial telephone screen to confirm a history of ADHD in childhood and whether symptoms were ongoing.

Prospective study subjects were next invited to come to the Centre for Addiction and Mental Health (CAMH), Toronto, Ontario, Canada, for a more detailed assessment interview. All were given a consent form with a summary of the purposes, procedures, and potential risks of the study and provided informed written consent. The protocol was approved by the CAMH Research Ethics Board.

On the day of the structured assessment at CAMH, potential study subjects were administered 3 self-report ADHD scales, including the Wender Utah Rating Scale (WURS)[13] for childhood ADHD symptoms and both the Brown Adult ADD Scale[14] and the Conners' Adult ADHD Rating Scale (CAARS).[15] The last includes 18 items to assess DSM-IV criteria for ADHD including 9 items each for the inattentive and hyperactive/impulsive categories. These 18 core items were each scored on a 4-point scale from 0 (not at all) to 3 (very much, very frequently). A given item was considered positive if it was endorsed at a level of 2 (pretty much, often) or higher. As per the DSM-IV, subjects had to have 6 of 9 items positively endorsed to meet criteria for a respective category.

To delineate comorbidity, subjects were also administered a semistructured interview by a trained research assistant who was blind to the results of the ADHD self-report scales. This interview included the modules from the Structured Clinical Interview for DSM-IV (SCID)[16] that assess mood disorders, anxiety disorders, substance abuse disorders, and eating disorders; the Structured Interview Guide for the Hamilton Depression Rating Scale, Seasonal Affective Disorders version (SIGH-SAD)[17] depression scale (29 items) was also administered as part of this interview to assess current mood symptoms.

Individuals who continued to meet DSM-IV ADHD criteria at the end of the structured assessment day were given a package of self-report questionnaires for completion at home to assess key chronobiological variables and were given an appointment to return for neuropsychological testing within 1 week. Seasonality was assessed using the Seasonal Pattern Assessment Questionnaire (SPAQ).[18] Circadian activity and sleep-wake cycles were assessed using both the Horne-Ostberg Morningness-Eveningness Questionnaire (MEQ)[4] and a

self-report sleep/wake diary to be filled out daily for 1 week before and during a 3-week trial of LT.

The neuropsychological assessment included standardized tests to measure basic cognitive functioning as well as factors relevant to ADHD. These included the North American Adult Reading Test[19] as an estimate of IQ, the Conners' Continuous Performance Test-II (CPT-II),[20] Wisconsin Card Sorting Test (WCST),[21] Controlled Oral Word Association Test,[21] digit span, Trail Making Tests A and B, Hopkins Verbal Learning Test–Revised (HVLT-R),[21] and Benton Judgment of Line Orientation test (JLO).[21] All measures were completed before and after a 3-week trial of light therapy in the fall or winter. In order to minimize practice effects, tests were selected to include alternate forms where possible, as well as tests resistant to practice.

Final inclusion criteria included the following: (1) A childhood clinical diagnosis of ADHD established by a specialist in the field and/or a WURS score above established cut-offs on a validated 25-item subscale of the WURS,[13] i.e., > 46 for patients with a history of major depression and > 36 for subjects without major depression; (2) A chronic course of ADHD symptoms from childhood to adulthood with functional impairment attributed to those symptoms; (3) Subjects not taking psychostimulants had to meet current DSM-IV criteria for ADHD based on CAARS, i.e., 6 of 9 items positively endorsed for the inattentive or hyperactive/impulsive category. Consistent with prior research,[22] subjects receiving psychostimulants who endorsed 3 to 5 out of 9 possible DSM-IV items for the inattentive and/or hyperactive/impulsive categories were designated as having "ADHD in partial (therapeutic) remission." These individuals were included in the final sample if they met other study criteria; (4) An IQ within the normal range; and (5) Ability and willingness to provide informed consent.

Subjects were excluded if they had 1 or more of the following: (1) an IQ below 85; (2) a significant neurologic disorder that would confound neuropsychological testing; (3) acute suicidal ideation; (4) current substance dependence; (5) an inability or unwillingness to provide informed consent; (6) previous exposure to light therapy; (7) an eye condition precluding the use of bright light therapy; or (8) current use of a photo-sensitizing drug such as lithium or the phenothiazines.

### Light Therapy Trial Procedure

Treatment involved a standard 3-week trial of light therapy self-administered at home each morning using a full-spectrum fluorescent light box that emitted 10,000 lux at a distance of 24 inches. Light boxes were fitted with a screen that filtered out ultraviolet wavelengths. Subjects were instructed to begin treatment before 8:00 a.m. daily and to use the light continually for a half hour. Compliance was assessed using both daily treatment logs and direct verbal questioning after days 10 (by phone) and 21 (in person). Subjects were also asked to complete daily sleep diaries. The study was conducted from November 2003 through February 2004.

***Outcome measures.***

Hypothesis 1. We hypothesized that in an adult ADHD population treated in the fall or winter months, morning bright light therapy would (a) alleviate symptoms associated with comorbid seasonal affective disorder and (b) cause a phase shift in daily sleep and activity rhythms. The corresponding outcome measures for these hypotheses were the raw decrease in SIGH-SAD depression scores and the raw change on the MEQ, respectively. Raw decreases on the SIGH-SAD were used because several subjects had low baseline scores, which inflated the percentage change with treatment. Raw change was used for the MEQ based on the scalar properties of this instrument.

Hypothesis 2. Our second hypothesis was that, either related to or independent of the 2 well established effects outlined in hypothesis 1, morning light therapy might also improve subjective core ADHD symptoms and/or neuropsychological functioning. The main outcome measures for these analyses included percentage reduction in CAARS and Brown Adult ADD Scale scores as well as improvements (increase or decrease as appropriate) on various neuropsychological tests. As this was the first study to assess LT effects in an adult ADHD population, both total scores and subscale scores were included in this analysis.

***Statistics.*** As a first step, paired t tests with effect sizes were calculated for each outcome measure based on 21 days of light treatment. To account for the possible effect of baseline circadian preference on MEQ change scores, we also performed an analysis of covariance (ANCOVA) calculating the mean raw change in MEQ score using the baseline MEQ score as a covariate. To assess MEQ responses based on the 5 widely used categorical chronotypes (definite morning, moderate morning, neutral, moderate evening, definite evening),[4] the distribution of these chronotypes was also compared before and after treatment using Pearson $\chi^2$. For the SIGH–SAD, Brown Adult ADD Scale, and CAARS, the proportion of subjects meeting criteria for a partial or full response to light treatment was also tabulated. For these scales, a 25% improvement was considered a partial response, and a 50% improvement was considered a full response. To establish meaningful response rates on the SIGH-SAD, only subjects who started with a score above 10 were considered.

Neuropsychological tests were scored according to published normative guidelines based on comparison with age-, gender-, and education-matched peers. Pretreatment and posttreatment change scores were calculated. When alternate forms of individual tests were used, statistics were based on paired t tests; otherwise, a reliable change index was used to determine if the proportion

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of change exceeded that predicted by chance or practice effects alone. Having established which outcome variables responded best to light treatment, the next goal was to further characterize possible mechanisms of change. To do this, pretreatment and posttreatment change scores were calculated for the Brown Adult ADD Scale, CAARS, SIGH-SAD, MEQ, and those neuropsychological measures that showed a significant change with treatment. Percentage change scores were calculated for the ADHD scales, while raw change scores were used for the MEQ, SIGH-SAD, and neuropsychological measures. Pearson correlations were then calculated across these various change scores. To help predict likely LT responders for future research, change scores were also correlated with selected baseline measures.

Finally, to explore in a preliminary way whether the 3 categorical subtypes of adult ADHD (inattentive, hyperactive/impulsive, or combined) might influence responses to LT, we compared mean change scores across these groups using analysis of variance. Significance was set at $p < .01$.

## RESULTS

### Sample Characteristics

A total of 37 subjects met initial screening criteria, with 4 dropping out early in the treatment phase. Based on verbal reports, 4 other subjects missed 3 consecutive days of treatment early on and were thus excluded. The final sample consisted of 29 adult patients with ADHD with a mean ± SD age of 40.4 ± 10.2 years (range, 20–60 years). Subtype designations based on DSM-IV criteria as assessed by the CAARS were inattentive, N = 14; hyperactive-impulsive, N = 2; and combined, N = 11. Two other subjects treated with psychostimulant medication were designated as in partial therapeutic remission as defined in the Method section.

Most study subjects were never married, the vast majority was educated beyond high school, and most were currently employed or enrolled in postsecondary education. This sample would be considered relatively highly educated and employed relative to prior samples of adult ADHD.[23] Seven subjects were taking psychostimulants only, 4 were taking antidepressants only, and 4 were taking both.

Regarding psychiatric comorbidity, 12 subjects (41.4%) had current major depressive disorder (MDD), while 7 others had lifetime but not current MDD. The rate of full-syndrome seasonal affective disorder was 4/29 (13.8%), while 3 other subjects (10.3%) reported significant seasonal worsening of chronic forms of depression. Eight subjects (27.6%) had a history of substance abuse disorders, lower than in prior studies.[24] The relatively high rate of depression and low rate of substance abuse in the current sample most likely reflects the greater proportion of female subjects than in prior adult ADHD samples.

At baseline, the greatest neuropsychological difficulties were noted on tests of attention and response inhibition, with lesser relative deficits seen on measures of verbal memory and executive functioning. Participants demonstrated an above-average level of commission errors (mean ± SD t = 55.8 ± 10.9), an above-average detectibility (mean ± SD t = 55.4 ± 9.6) indicating difficulty discriminating between targets and nontargets, and atypically fast responding across all trials of the CPT-II (mean ± SD hit reaction time, t = 35.7 ± 7.4). Together, these results indicate impulsivity and poor behavioral inhibition prior to LT in this sample. Mild memory impairment was also noted on a verbal learning task (HVLT-R).

### Responses to Light Therapy

The mean scores for the clinical variables and neuropsychological tests before and after 21 days of light treatment are summarized in Tables 1 and 2, respectively. As shown in Table 1, there were significant changes on the Brown Adult ADD Scale, CAARS, MEQ, and SIGH-SAD measures after 3 weeks of light therapy. Of the 2 measures of current ADHD symptoms, the Brown Adult ADD Scale score appeared to be more improved following LT based on percentage change scores, although the effect sizes were similar for the CAARS. Most of the subscale scores for both the Brown Adult ADD Scale and CAARS showed changes with a moderate effect size with treatment; the 2 exceptions were the affective subscale of the Brown Adult ADD Scale and the hyperactive/restlessness subscale of the CAARS, which showed only small effect sizes.

As expected, SIGH-SAD depression scores had a marked improvement following LT, with an effect size of 0.74. Sixteen patients (55.2%) had a baseline SIGH-SAD score in a clinically elevated range (> 9). Of these, 9/16 (56.3%) were considered light responders on the basis of a > 50% improvement. The MEQ results also changed significantly following LT in the direction of higher scores or increased morningness, with an effect size of 0.49 based on the paired t test. The ANCOVA, which analyzed raw change in MEQ using baseline MEQ as a covariate, further confirmed the significant shift towards morningness with treatment (change score, $F = 11.81$, $df = 1,25$; $p = .002$), as did the $\chi^2$ analysis based on the 5 chronotypes listed in the Method section ($\chi^2 = 18.12$, $df = 6$, $p = .006$). The most common change in chronotype was from a moderate evening chronotype pretreatment to a neutral chronotype posttreatment (N = 5).

Using categorical measures of response, 3 study subjects (10.3%) had a full response based on the Brown Adult ADD Scale total score, while another 5 (17.2%) had a partial response. Seven patients (24.1%) who had a total Brown Adult ADD Scale score above the threshold

Table 1. Clinical Variables Before and After 3 Weeks of Bright Light Therapy (LT) in 29 Adults With ADHD

| Clinical Variable | Before LT Mean ± SD | After LT Mean ± SD | Paired t | df[a] | p Value | Mean ± SD Change, % | Cohen d |
|---|---|---|---|---|---|---|---|
| Brown Adult ADD Scale | | | | | | | |
| Total | 84.7 ± 20.4 | 71.4 ± 24.4 | –3.83 | 28 | .001 | –15.2 ± 22.3 | 0.59* |
| Activation | 20.1 ± 5.7 | 17.0 ± 6.6 | –3.35 | 28 | .002 | –14.7 ± 27.1 | 0.50* |
| Attention | 20.0 ± 5.0 | 17.1 ± 6.2 | –3.43 | 28 | .002 | –14.1 ± 24.9 | 0.51* |
| Effort | 19.6 ± 5.5 | 16.2 ± 5.5 | –3.37 | 28 | .002 | –13.4 ± 29.5 | 0.62* |
| Affect | 12.3 ± 5.0 | 10.4 ± 5.4 | –2.90 | 28 | .007 | –13.0 ± 29.1 | 0.36** |
| Memory | 12.6 ± 3.8 | 10.6 ± 4.5 | –3.71 | 28 | .001 | –16.9 ± 22.9 | 0.48* |
| CAARS | | | | | | | |
| Total | 577.9 ± 62.5 | 535.4 ± 95.2 | –3.72 | 28 | .001 | –7.7 ± 10.9 | 0.53* |
| Inattention/memory | 77.6 ± 10.5 | 71.6 ± 13.5 | –3.36 | 28 | .002 | –7.7 ± 12.3 | 0.50* |
| Hyperactivity/restlessness | 63.4 ± 9.8 | 61.2 ± 11.1 | –2.11 | 28 | .044 | –3.6 ± 9.1 | 0.21** |
| Impulsivity/lability | 66.8 ± 11.4 | 61.6 ± 14.0 | –3.17 | 28 | .004 | –8.0 ± 12.1 | 0.40* |
| Self-concept problems | 66.0 ± 11.1 | 60.2 ± 13.7 | –3.24 | 28 | .003 | –8.6 ± 14.0 | 0.46* |
| MEQ[b] | 46.2 ± 10.3 | 51.2 ± 10.2 | 2.58 | 26 | .016 | | 0.49* |
| SIGH-SAD (29 items)[c] | 14.5 ± 11.3 | 7.5 ± 7.0 | –3.80 | 28 | .001 | | 0.74*** |

[a]Discrepancies in degrees of freedom were due to missing data.
[b]MEQ scores were analyzed on the basis of raw change scores based on the scalar properties of this measure. Higher MEQ scores suggest a shift to greater morningness (phase advance) following treatment.
[c]SIGH-SAD scores were analyzed on the basis of raw change scores, as percentage change scores were exaggerated for subjects with very low values at baseline.
*Moderate effect size.
**Small effect size.
***Strong effect size.
Abbreviations: ADD = attention-deficit disorder, ADHD = attention-deficit/hyperactivity disorder, CAARS = Conners' Adult ADHD Rating Scale, MEQ = Horne-Ostberg Morningness-Eveningness Questionnaire, SIGH-SAD = Structured Interview Guide for the Hamilton Depression Rating Scale, Seasonal Affective Disorders version.

of 50 used in prior research[26] experienced a drop below this cutoff level following treatment. Response rates based on the CAARS were more modest (3 partial responders). An examination of Table 1 suggests that the discrepancy of effects across the Brown Adult ADD Scale and CAARS was largely attributable to the lack of treatment effect on core symptoms of hyperactivity and restlessness. Anecdotally, 5 patients reported feeling overstimulated with light. In sum, the results suggest that the dimensions of psychopathology measured by the Brown Adult ADD Scale are more amenable to light treatment than are those measured by the CAARS.

In terms of neuropsychological changes following light therapy, significant improvement was noted in several areas that was in excess of what could be expected on the basis of chance or practice effects alone (Table 2). Most notably, improvement from impaired to a normative range was noted on several measures of attention, including basic auditory attention span (digit span), as well as domains of attention tapped by the CPT-II, particularly the measures of impulsivity measured by commission errors and signal detectibility. Improvement was also noted on a measure of visual perceptual ability (JLO). Statistically significant improvement was noted on the WCST measure of executive function; however, neither an alternate form nor reliable change index was available, thus this change likely reflects some degree of practice. No significant improvement was noted on a measure of verbal memory. For the sample on average, mild deficits in verbal memory persisted despite improved attention abilities with bright light therapy.

## Correlates of Change Following Light Therapy

***Role of seasonality at baseline.*** Having found positive results of light therapy on subjective ADHD symptoms, objective neuropsychological tests, and mood ratings, the next question to address was whether these various results were simply attributable to the subgroup of patients with full-syndrome seasonal affective disorder (N = 4) and/or seasonal worsening of chronic depression (N = 3). To do this, several different approaches were used. Firstly, of the 9 light responders based on the SIGH-SAD, 2 had a diagnosis of seasonal affective disorder, 1 had seasonal worsening of chronic depression, and 6 had neither of these diagnoses. This suggests that the decrease in depression scores with LT was not simply attributable to subjects with a seasonal mood disorder. Similarly, of the 8 subjects considered to be partial or complete responders based on the Brown Adult ADD Scale, 3 had a diagnosis of seasonal affective disorder while 5 had no seasonal diagnosis. Finally, the global seasonality score based on the SPAQ,[18] which is a continuous measure of seasonality, did not predict changes in the ADHD scales, SIGH-SAD, MEQ, or CPT-II scores.

In sum, neither a categorical diagnosis of seasonal depression nor a high global seasonality score at baseline could account for the positive effects of light therapy on both subjective measures and neuropsychological testing in this population.

***Other correlates of response.*** Table 3 summarizes the Pearson correlations among various rating scale change scores based on 3 weeks of light therapy. As shown, de-

  

**Table 2. Changes in Neuropsychological Measures Before and After Light Therapy (LT) in Adults With ADHD**

| Measure | Before LT Mean ± SD | After LT Mean ± SD | Paired t | df | p Value | Cohen d |
|---|---|---|---|---|---|---|
| Attention | | | | | | |
| Trails A (t score) | 39.79 ± 14.03[a,b] | 45.17 ± 18.87 | –2.93 | 28 | < .01 | 0.32* |
| Trails A time (sec) | 34.48 ± 14.0[c,b] | 32.52 ± 3.33 | 1.23 | 28 | NS | |
| Digit span (t score) | 52.74 ± 8.71[d] | 57.26 ± 8.82 | –2.58 | 18 | < .01 | 0.51** |
| CPT-II omission errors (t score) | 48.36 ± 10.70[d] | 49.93 ± 15.78 | –0.38 | 22 | NS | |
| CPT-II commission errors (t score) | 55.80 ± 10.90[d,b] | 50.08 ± 11.42 | 4.66 | 28 | < .001 | 0.51** |
| CPT-II detectibility (t score) | 55.36 ± 9.60[d,b] | 50.46 ± 10.71 | 3.11 | 28 | < .01 | 0.49** |
| Processing speed | | | | | | |
| CPT-II hit reaction time (t score) | 35.72 ± 7.37[d,b] | 38.36 ± 11.42[b] | –1.75 | 28 | < .05 | 0.27* |
| Executive function | | | | | | |
| Trails B (t score) | 53.52 ± 17.04[a] | 52.69 ± 10.64 | 0.28 | 28 | NS | |
| Trails B time (sec) | 61.03 ± 20.10[c] | 55.17 ± 20.29 | 1.51 | 28 | NS | |
| COWAT (z score) | 0.63 ± 0.99[d] | 0.78 ± 0.95 | –1.05 | 25 | NS | |
| WCST total errors (t score) | 46.32 ± 9.89[a] | 51.82 ± 8.77 | –3.46 | 27 | < .001 | 0.59** |
| WCST perseverative responses (t score) | 45.50 ± 7.93[a] | 51.46 ± 5.91 | –3.90 | 23 | < .001 | 0.85*** |
| WCST perseverative errors (t score) | 43.93 ± 9.56[a] | 49.82 ± 10.79 | –3.36 | 27 | < .01 | 0.58** |
| WCST conceptual level responses (t score) | 46.15 ± 7.64[a] | 50.77 ± 6.11 | –3.29 | 25 | < .01 | 0.67** |
| Memory | | | | | | |
| HVLT-R trial one (z score) | –0.77 ± 0.85[d,b] | –0.77 ± 0.74[b] | –0.02 | 14 | NS | |
| HVLT-R total recall (z score) | –0.85 ± 1.20[d,b] | –0.53 ± 1.11[b] | –1.36 | 26 | NS | |
| HVLT-R delayed recall (z score) | –0.47 ± 1.21[d] | –0.43 ± 1.20 | –0.16 | 26 | NS | |
| Visual perception | | | | | | |
| JLO (age corrected score) | 26.07 ± 3.40 [d] | 27.33 ± 2.95 | –3.38 | 26 | < .01 | 0.39* |

[a]No reliable change index available; t tests used but most likely influenced by practice.
[b]Denotes clinically impaired or below average.
[c]Reliable change index used to calculate significance of change.[25]
[d]Alternate forms used and/or resistant to practice; 1-tailed t tests used to evaluate change.
*Small effect size.
**Moderate effect size.
***Strong effect size.
Abbreviations: ADHD = attention-deficit/hyperactivity disorder, COWAT = Controlled Oral Word Association Test, CPT-II = Conners' Continuous Performance Test-II, HVLT = Hopkins Verbal Learning Test–Revised, JLO = Benton Judgment of Line Orientation test, WCST = Wisconsin Card Sorting Test.

**Table 3. Correlations Among Key Rating Scale Change Scores Based on 3 Weeks of Light Therapy in Adults With ADHD**

| Variable | Percentage Reduction in Brown Adult ADD Scale | Percentage Reduction in CAARS | Raw Reduction in SIGH-SAD | Raw Increase in MEQ |
|---|---|---|---|---|
| Percentage reduction in Brown Adult ADD Scale | | .77* | .40** | .55* |
| Percentage reduction in CAARS | .77* | | .33 | .52* |
| Raw reduction in SIGH-SAD | .40** | .33 | | .49** |
| Raw increase in MEQ | .55* | .52* | .49** | |

*p < .01 (2-tailed).
**p < .05 (2-tailed).
Abbreviations: ADD = attention-deficit disorder, ADHD = attention-deficit/hyperactivity disorder, CAARS = Conners' Adult ADHD Rating Scale, MEQ = Horne-Ostberg Morningness-Eveningness Questionnaire, SIGH-SAD = Structured Interview Guide for the Hamilton Depression Rating Scale, Seasonal Affective Disorders version.

spite measuring somewhat different aspects of ADHD, there was a very strong correlation between the Brown Adult ADD Scale and CAARS change scores. Interestingly, each of these change scores was also significantly correlated with the raw increase in the MEQ score, i.e., subjective ADHD symptoms decreased with the shift toward greater morningness following light treatment. There was also a moderate correlation between the drop in Brown Adult ADD Scale scores and the raw decrease in SIGH-SAD depression scores with light. When a multiple regression was performed predicting the change in Brown Adult ADD Scale scores with both the change in MEQ score and change in SIGH-SAD score, the overall model was highly significant ($F = 5.88$, $df = 2,24$; $p = .008$), with only the MEQ change score being a significant individual predictor of response ($t = –2.35$, $p = .027$). This suggests that the improvement in subjective ADHD symptoms with light therapy was related more to a phase advance in circadian preference than to amelioration of depression.

Table 4 summarizes the correlations between rating scale change scores and the key neuropsychological change scores based on the CPT-II. The MEQ change score was significantly correlated with the decrease in

**Table 4. Correlations Between Key Rating Scale Change Scores and Changes in Key Conners' Continuous Performance Test (CPT) Measures Following 3 Weeks of Light Therapy in Adults With ADHD**

| Variable | Percentage Reduction in Brown Adult ADD Scale | Percentage Reduction in CAARS | Raw Reduction in SIGH-SAD | Raw Increase in MEQ |
|---|---|---|---|---|
| Raw decrease in CPT-II commission errors | .38* | .17 | .02 | .40* |
| Raw improvement in CPT-II detectibility | .23 | .24 | .09 | .41* |
| Raw increase in CPT-II hit reaction time | –.02 | .04 | .24 | .16 |

*p < .05 (2-tailed).
Abbreviations: ADD = attention-deficit disorder, ADHD = attention-deficit/hyperactivity disorder, CAARS = Conners' Adult ADHD Rating Scale, CPT-II = Conners' Continuous Performance Test, MEQ = Horne-Ostberg Morningness-Eveningness Questionnaire, SIGH-SAD = Structured Interview Guide for the Hamilton Depression Rating Scale, Seasonal Affective Disorders version.

CPT-II commission errors and the improvement in detectibility, while there was no significant correlation between these CPT-II change scores and the decrease in depression scores. This suggests that the improvement in objective neuropsychological functioning with light therapy was again related to a phase advance in circadian preference rather than to amelioration of depression.

While there was a significant correlation between MEQ change scores and improvements in various measures of ADHD pathology as outlined above, baseline MEQ scores were less strongly correlated with these improvements. The only such correlation that met at least a trend level of significance was between baseline MEQ score and the decrease in Brown Adult ADD Scale total score ($r = .34$, $p = .085$). Baseline depression scores as measured by the SIGH-SAD had no clear relationship with key ADHD change scores.

***Demographic and clinical variables.*** There was no significant effect of age, gender, or medication status (ongoing use of psychostimulants or antidepressants) on any of the change scores discussed above. Furthermore, no significant differences in these change scores were found across the 3 ADHD categorical subtypes. When the 2 individuals with hyperactive/impulsive subtype were removed from this analysis, no significant differences were noted between the inattentive and combined subtypes.

***Light therapy logs and sleep diaries.*** While we hoped to assess LT compliance and sleep times using daily logs, many subjects had difficulty completing these reports, particularly at the outset of the study. We did get verbal reports of compliance from all patients on days 10 and 21, and excluded 4 subjects based on these reports (see Sample Characteristics). Our overall impression was that this sample of adults with ADHD had greater difficulty waking up on time to use the light in comparison to patients with seasonal affective disorder recruited at the same time of year, which may reflect greater circadian disturbance in the former group. Anecdotally, a few individuals reported difficulty using the light before 8:00 a.m. early in treatment but were able to shift to earlier LT use as the treatment progressed. None of the subjects reported beginning LT after 11:00 a.m. at any time.

## Summary of Study Hypotheses

***Hypothesis 1.*** Our first hypothesis was that in an adult ADHD population treated in the fall/winter months, morning LT would (a) alleviate symptoms associated with comorbid SAD and (b) cause a phase shift in daily sleep and activity rhythms."

The results only partially confirmed this hypothesis as indicated by a highly significant drop in SIGH-SAD depression scores overall but a nonsignificant correlation between baseline global seasonality scores and improvements in mood. Most of the subjects who began the trial in a depressed state and then experienced a significant improvement in mood were not diagnosed with a seasonal depression at baseline. This is, however, consistent with a series of studies showing that nonseasonal depression is often responsive to LT.[27] Furthermore, in the subgroup of patients with either full-syndrome seasonal affective disorder or seasonal worsening of chronic depression, only half would be considered responders to light on the basis of SIGH-SAD depression scores. Regarding hypothesis 1b, the MEQ data suggest that light was indeed able to phase advance circadian sleep and activity rhythms, with important implications for both subjective and objective functioning as discussed next.

***Hypothesis 2.*** Hypothesis 2 was that either related to or independent of the 2 well established effects in hypothesis 1, morning light therapy might also improve subjective core ADHD symptoms and/or neuropsychological functioning.

The overall pattern of results suggests that morning bright light therapy did help alleviate subjective reports of deficits in maintaining effort and arousal, while improving problems with inattention. Hyperactive symptoms as measured with the CAARS were not altered with light. Results of neuropsychological testing further confirmed that LT produced significant improvements on attentional functioning. Significant improvement from the below average/impaired range before LT to the average range after LT were observed for basic auditory attention span as well as for 2 key components of the CPT-II, indicating improvements in impulsivity and behavioral inhibition. Improvement was also noted on a measure of visual perception. Somewhat surprisingly, the im-

  

provement in these measures was not attributable to the effects of LT on depression scores. That is, amelioration of depression did not appear to account for the observed improvements in cognition. It was, in fact, the circadian phase advancing effect of morning light that was most strongly associated with improvement in both subjective measures of ADHD and objective neuropsychological performance as measured by the CPT-II.

## DISCUSSION

This study represents the first evaluation of LT in an adult ADHD population. After a 3-week trial of morning LT administered during the fall or winter period, we found significant improvements in mood, core ADHD symptoms, and objective measures of attention as well as a circadian shift towards morningness in many individuals. Several subjects crossed below well established thresholds used to define ADHD pathology based on self-report questionnaires and/or neuropsychological testing. Strikingly, the strongest correlate of improvement in core ADHD pathology was a phase advance in circadian preference, rather than alleviation of comorbid depression. This suggests that in many adults with ADHD, LT has important clinical benefits beyond the treatment of seasonal affective disorder. These data are also highly congruent with our descriptive study of this same sample,[8] which found that a mood-independent delay in circadian phase may contribute significantly to core ADHD pathology.

It is important to mention that over half of the patients taking part in this study were already taking psychostimulants, antidepressants, or both, which might have diminished the overall magnitude of LT responses via ceiling effects. On the other hand, the open-label design and lack of placebo control may have increased response rates somewhat. One indirect measure of clinical efficacy is the motivation of subjects to purchase their own light box following the trial. Follow-up revealed that 9 patients (31.0%) were interested in purchasing a light box for the following season, highly similar to the rate of 29.4% found in an LT study for bulimia nervosa.[28]

The positive correlation between improvement in core ADHD measures and the shift toward greater morningness in the current study is highly consistent with Lewy and Sack's phase shift hypothesis of LT for seasonal affective disorder.[29] It is also consistent with the findings of Terman et al.[30] that patients with seasonal affective disorder with the greatest antidepressant response to LT are those with the largest phase advances. As is the case with seasonal affective disorder, ADHD has often been conceptualized as a disorder of arousal, sleep, affect, and attention[31,32] or as a primary disorder of vigilance.[33] In both seasonal affective disorder and ADHD, morning LT may enhance these various systems by correcting a core deficit in basic arousal mechanisms. Consistent with this model, core deficits in key catecholaminergic pathways tied to activation, alertness, mood, and attention have been described in both ADHD[34,35] and in seasonal affective disorder.[36–41]

In addition to the open-label design, several other limitations of this study merit consideration. The overall sample size was small, making it difficult to fully assess which particular ADHD subgroups may be most sensitive to this modality. However, this does represent one of the largest samples of adult ADHD patients with comprehensive neuropsychological testing. The sample had a higher rate of women than other studies of adult ADHD, although this did not have a major effect on baseline or posttreatment measures. The sample was also heterogeneous in terms of medication treatment at baseline, with an insufficient sample size to robustly evaluate medicated and nonmedicated groups separately. The study was carried out in the fall and winter period, and replication in the spring and summer months is needed to better characterize LT effects independently of seasonal affective disorder and winter circadian changes. It would also be of theoretical and practical interest to treat and monitor patients for more extended periods of time in order to assess the stability of the observed effects.

Paradoxically, while we hoped to assess LT compliance and sleep times using daily logs, the core deficits of these subjects often interfered with this very task. Clearly, future studies of LT for ADHD will need to implement highly systematic and objective measures of compliance such as light meters wherever possible.

In sum, the current findings suggest that LT may be an effective adjunctive treatment in the fall or winter period for a substantial proportion of adult ADHD patients. The overall results suggest that LT may correct a circadian phase disturbance contributing to both subjective and objective dysfunction in adult ADHD independently of mood. Nevertheless, given the methodological limitations discussed, further LT studies are needed in both adult and pediatric samples of this complex and still evolving diagnostic category.

*Drug name:* lithium (Eskalith, Lithobid, and others).

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