



A randomized, placebo-controlled trial of bright light and high-density negative air ions for treatment of Seasonal Affective Disorder

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ABSTRACT

This study, conducted over the course of 5 years, assessed the antidepressant efficacy of two active treatments, bright white light and high-density negative ions, and the efficacy of two placebo treatments, dim red light and low-density negative ions, for Seasonal Affective Disorder (SAD). In a controlled laboratory setting, 73 women with SAD were exposed to one of the four treatment conditions over 12 consecutive days. Pretreatment expectation ratings did not significantly differ among the four treatment groups; however, expectation scores and treatment benefits were positively related. Over the course of treatment, subjects in all four groups showed significant score decreases on the Structured Interview Guide for the Hamilton Depression Rating Scale–Seasonal Affective Disorder Version–Self Rating (SIGH-SAD-SR) and on the Beck Depression Inventory (BDI). For raw scale scores, neither main effects of treatment nor interactions between treatment and time were significant. When remission outcome criteria were used, bright white light was significantly more effective than any of the other three treatments, and exposure to high-density negative ions was more effective than either of the two placebo conditions, although the difference was not significant.

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1. Introduction

Seasonal Affective Disorder (SAD) is a subtype of recurrent mood disorder with a characteristic pattern of onset and remission (American Psychiatric Association, 1994). Episodes of SAD predominantly occur in fall and winter and are characterized by typical symptoms of depression as well as atypical symptoms including excessive sleep with difficulty waking, craving for carbohydrates, weight gain, irritability, social withdrawal, daytime fatigue, and loss of concentration (Rosenthal et al., 1984a,b; Tam et al., 1997; Thompson et al., 1999; Partonen and Rosenthal, 2001). The incidence of SAD is four times more prevalent in women than in men (Blazer et al., 1998) and is highest among individuals with a history of recurrent mood disorders (Lam and Levitt, 1999). Explanations of how SAD develops include delayed circadian rhythms (Lewy et al., 1988), irregularities in the level and/or regulation of specific neurotransmitters, and genetic factors (Madden et al., 1996; Lam and Levitan, 2000).

Although antidepressant medications are effective in alleviating the symptoms of SAD (Ruhmann et al., 1998; Kasper et al., 2001; Moscovitch et al., 2004; Lam et al., 2006), bright light is also a viable

treatment for individuals with this disorder (Terman et al., 1989; Terman and Terman, 1995; Tam et al., 1995; Wesson and Levitt, 1998; Terman and Terman, 2005). Light therapy has relatively few side effects as compared to those of antidepressant medications (Labbate et al., 1994; Terman and Terman, 1999, 2005). The superiority of light therapy over placebo treatments, however, remains equivocal. Whereas some investigations found light therapy to be more effective than dim or brief duration light control conditions for treating SAD (Rosenthal et al., 1985; Terman and Terman, 2005), others reported little or no difference in antidepressant response between bright light and an inert photic placebo treatment (Levitt et al., 1996; Wileman et al., 2001). For example, Eastman et al. (1992) reported that treatment with either a deactivated ion generator or bright light produced significant and equivalent reductions of depression ratings in patients with SAD. Exposure to high levels of negative air ions is also an effective treatment for both the depressive and atypical symptoms of SAD (Terman and Terman, 1995, 2006; Terman et al., 1998). More broadly, exposure to high levels of negative ions increases relaxation and mental alertness, decreases irritability and tension, enhances motor performance and energy level, and alleviates depressed mood (Charry and Hawkinshire, 1981; Tom et al., 1981; Buckalew and Rizzuto, 1982; Yates et al., 1986; Baron, 1987; Nakane et al., 2002). Exposure to high concentrations of positive air ions, in contrast, typically produces opposite effects including tension, irritability, depression, insomnia, social withdrawal, and reduced motor performance (Krueger and Reed, 1976; Charry, 1987).

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Previous research suggests that bright light and high-density negative ions are generally more effective than either photic or nonphotic control conditions, but not both (Eastman et al., 1998; Terman et al., 1998). To assess the effectiveness of bright light as compared with that of high-density negative ions for treating SAD and to further evaluate the degree to which placebo expectancies contribute to the effects of these treatments, the present study utilized a parallel-group design to evaluate the efficacy of both treatments not only relative to each other but also relative to dim red light and to low-density negative ions. Unlike previous studies in which subjects self-administered treatments in their places of residence, this study required that all subjects received treatments in a controlled laboratory setting.

We predicted that exposure to bright white light or to high-density negative ions would produce comparable reductions in the depressive and atypical neurovegetative symptoms of SAD and that the efficacy of either of these treatments would be superior to that of dim red light or of low-density negative ions.

2. Methods

2.1. Subjects

A total of 73 female students and staff at Hollins University in Roanoke, Virginia (latitude 37° 16', North; average sunrise time ~0732 a.m.) participated in this study that was conducted each January over 5 consecutive years. The group included 67 White (90.5%) and 7 Black (9.5%) women, and subjects ranged in age from 18 to 51 years ($M = 20.8$ years; $S.D. = 5.69$ years). None had prior experience with either light or negative ion therapy.

A request for subjects was announced in campus media in November prior to each January study. Respondents to these announcements completed the Seasonal Pattern Assessment Questionnaire (SPAQ; Rosenthal et al., 1984a,b), a retrospective self-report rating of pattern and degree of seasonal variation in sleep, social activity, mood, weight, appetite, and energy level. The global seasonality score (GSS), derived from categorical scales of mood and behavior, ranges from 0 to 24. To meet the initial screening criterion for inclusion in the study, a respondent was required to score the following on the SPAQ: a GSS of at least 11, a winter pattern (feels worse, eats more, socializes less, and sleeps more in the winter months than in summer months), and to experience at least moderate personal discomfort as a result of these seasonal changes.

Subjects were instructed to maintain pre-established prescription medication regimens, if any, throughout the 12 consecutive treatment sessions and during the week prior to the study and to also verify these regimens in a posttreatment questionnaire. Of the 73 subjects, 11 remained on prescribed medications other than psychotropic drugs, and 8 remained on a psychotropic medication regimen of either a selective serotonin reuptake inhibitor (6 subjects) or a norepinephrine/dopamine reuptake inhibitor (2 subjects). The distribution of these latter 8 subjects across the four treatment groups was, respectively, 2, 2, 3, and 1.

During each January study, subjects received research participation credit in psychology courses and were eligible for a monetary lottery drawing following completion of the study. Subjects read and signed a written informed consent prior to their participation, and the study received institutional review approval from Hollins University.

2.2. Apparatus

2.2.1. Light boxes

Two light boxes (Bio-Light Ultra, Enviro-Med, Vancouver, WA) were each located in similar testing rooms each measuring approximately 2.0 m × 3.0 m × 2.5 m. The bright white light (BWL) box consisted of three 40 W, 4100 K twin tri-phosphor fluorescent tubes mounted within a 30.5 cm × 61.0 cm rectangular metal box equipped with a white reflector and a translucent plastic diffusing screen. The BWL unit provided approximately 10,000-lux illuminance (measured with a digital lux meter: Model LX-101, D.A. S. Inc., Suffield, CT) of white light at a distance of 37 cm from the center of the diffusing screen to the subject's eyes. The dim red light (DRL) box contained a single twin tube and was equipped with a translucent red plastic panel mounted in front of the unit's diffusing screen. This modified box provided approximately 300 lux illuminance of red light at a distance of ~61.0 cm from the center of the screen to the subject's eyes.

Each light box was mounted vertically on a 76.0-cm high table at an approximately 30° glancing angle immediately to the right side of a television monitor on which subjects could watch a variety of pre-recorded movies during treatment sessions. The center of the light box screen was located at eye level so that maximum light was directed toward the subject's face. Furthermore, to ensure that the correct distance between the subject's face and the light box screen was maintained throughout treatment sessions, each subject was instructed to maintain contact between her forehead and the end of a lightweight bead chain that was suspended at the criterion distance from the front of the light source.

2.2.2. Ultraviolet and ozone measuring devices

Because of safety concerns associated with bright light exposure (Kogan and Guilford, 1998; Terman and Terman, 2005), ultraviolet (UV) radiation and ozone emitted directly from the fluorescent tubes and at distances of ≥ 3 cm from the light box diffusing screen were measured with a UV meter (Model UVP J-225, UVP Inc, Upland, CA, USA) and an ECO ozone meter (Model EZ-1X, Eco Sensors, Inc. Santa Fe, NM, USA). Because ozone levels can vary greatly within a closed space, we monitored ozone at various locations within the testing room during light box operation.

2.2.3. Negative ion generators

Two negative ion generators (Model VI-2500, SphereOne, Inc., Silver Plume, CO, USA), each measuring 19.7 cm × 16.5 cm × 7.6 cm, were located in testing rooms similar to those containing the light boxes. The generator was placed on a 76.0-cm high table that was identical to those that supported the light boxes and positioned ~46.0 cm to one side of a television monitor. Although identical in appearance, the two generators emitted high and low levels of ionization. The ion output of both generators was measured using AlphaLab Air Ion Counters (AlphaLab, Inc., Salt Lake City, UT, USA). At the subject's sitting position of ~60 cm from the generator, the ion output of the high-density unit was $\geq 2.0 \times 10^6$ ions/cm³, while that of the low-density unit was $\sim 4.0 \times 10^3$ ions/cm³. A grounded wrist strap maximized ion flow toward the subject's body, and doors to the testing rooms were closed during treatment sessions.

2.3. Treatment assessment inventories

2.3.1. Treatment Expectation Questionnaire (TEQ)

This self-report scale, modeled on the concepts of Borkovec and Nau (1972), provided a rating, ranging from 0 to 4, of the subject's belief that she would benefit from completing her assigned treatment, her expectation that the treatment would make symptoms worse, her belief that the treatment was logical, and her degree of comfort in recommending her treatment to a friend with SAD. Rating data from all four questions on the TEQ were used for analysis.

2.3.2. Structured Interview Guide for the Hamilton Depression Rating Scale–Seasonal Affective Disorder Version–Self Rating (SIGH-SAD-SR)

The SIGH-SAD-SR consists of two scales: a structured interview for the 21-item Hamilton Depression Rating Scale (HAM-D) and an 8-item scale that assesses the atypical characteristics of SAD (ATYP) (Williams et al., 1994) including hypersomnia, hyperphagia with associated weight gain, and daytime fatigue. Previous studies (Terman and Terman, 1995; Terman et al., 1998) reported that both scales of the SIGH-SAD were of value in determining treatment response to light as well as to negative ions. The self-rating version of the SIGH-SAD (SIGH-SAD-SR) has been shown to produce results consistent with the interviewer-administered version (Terman and Williams, 1994, 2001) and has been used as a primary measure of seasonal depression (Partonen et al., 1993; Partonen et al., 1998; Wileman et al., 2001) and nonseasonal depression (Ando et al., 1999; Loving et al., 2002; Leppämäki et al., 2004).

2.3.3. Beck Depression Inventory (BDI)

The BDI (Beck et al., 1961) is designed to assess the severity of depression in adolescents and adults and has been validated in college populations (Bumberry et al., 1978; Goel and Grasso, 2004). Each of the 21 multiple-choice questions on the BDI consists of a 4-point scale ranging in symptom severity from 0 to 3. Total scores of 0–9 are within the minimal range, scores of 10–16 are indicative of mild depression, scores of 17–29 designate moderate depression, and scores of 30–63 indicate severe depression.

2.3.4. Diagnostic and Statistical Manual of Mental Disorders (DSM-IV) criteria for Seasonal Affective Disorder

As specified by the DSM-IV (American Psychiatric Association, 1994), the criteria for Major Depressive Episodes in Bipolar I Disorder, Bipolar II Disorder, or Major Depressive Disorder, Recurrent, With Seasonal Pattern include (1) a history of either Bipolar Disorder (Manic Depressive Disorder) or Major Depressive Disorder (Unipolar depression without episodes of mania), (2) depression, over the past 2 years during particular, predictable seasons of the year, (3) no other depressive episodes outside of recurrent seasonal episodes of depression over the past 2 years, and (4) more episodes of seasonal than nonseasonal depression throughout the individual's lifetime.

2.4. Inclusion criteria

Each respondent meeting the initial SPAQ screening criteria 6 weeks prior to the beginning of the study was required to complete the SIGH-SAD-SR, the BDI, and a DSM-IV criteria checklist within 24 h prior to the first treatment session. To qualify for inclusion in the study, a respondent was required to score at least 20 points on the overall SIGH-SAD-SR, including a score of at least 10 on the Hamilton Depression Rating Scale and a score of at least 5 on the atypical symptom scale (Terman et al., 1990). Respondents were also required to meet each of the four DSM-IV criteria for SAD by answering "yes" to the four questions provided in a symptom checklist derived from the Criteria for Seasonal Pattern Specifier (DSM-IV, 1994, p. 291). No pretreatment criterion score was required on the BDI.

2.5. Procedure

During each of five consecutive years, data were collected in January when the daily photoperiod was relatively short. The average outdoor commute time to the treatment laboratory was approximately 3 to 4 min, limiting pretreatment light exposure. A four-group, pretreatment/posttreatment design was used. Subjects were randomly assigned to one of the four treatment conditions: bright white light (BWL: $n = 19$), dim red light (DRL: $n = 16$), high-density negative ions (HDNI: $n = 18$), or low-density negative ions (LDNI: $n = 20$). On the first treatment day, each subject was seated in front of the treatment device to which she was assigned and was asked to read a description of the treatment. This description included the known side effects of the assigned treatment and its effectiveness for SAD based on previous research. The four treatment descriptions were worded as similarly as possible. Fifty-six of the 73 subjects then completed the TEQ. Each subject was scheduled for a specific 30-min treatment session, between 0730 and 1100 a.m., in one of three nearly identical treatment rooms. Subject treatment schedules remained constant across the 12 consecutive days of the study. Although previous studies (Terman et al., 1998; Goel et al., 2005; Terman and Terman, 2006) arranged treatments to occur immediately after awakening, we were unable to follow this protocol because of limited treatment devices and rooms and because of subject schedule constraints. During sessions, subjects could watch pre-recorded movies, listen to music, read (which required their holding the reading material at approximately eye level), or do nothing. Those assigned to the BWL or DRL conditions were required to keep their eyes open during treatment sessions. One-way observation windows permitted visual observation of treatment sessions.

Within 24 h of the completion of the 12th treatment session, subjects again completed the SIGH-SAD-SR and BDI inventories and were then provided the opportunity to ask questions about the study.

3. Results

3.1. Ultraviolet and ozone measurements

Without the diffusing screens in place, ultraviolet radiation output at the fluorescent tube surface of the BWL box was less than 1% of the total output of the 10,000 lux light box and was not detectable from the surface of the DRL box tube surface. With diffusing screens in place, ultraviolet output measured at the screen was reduced to substantially less than 0.01% of the total BWL box output and was not detectable for the DRL box. Ultraviolet radiation measurements taken at distances of ≥ 3 cm from the diffusing screen were at zero levels for either light box. Routine monitoring during operation of either light box revealed no detectable levels of ozone at any of several locations within the treatment room including at the tube surface. No ozone was detected with either of the negative ion generators.

3.2. Pretreatment expectations

No significant differences among median treatment expectation scores on the TEQ were found (Kruskal Wallis One-Way Analysis of Variance by Ranks; $H[3, N = 56] = 6.48, P = 0.09$). The highest mean treatment expectations, based on all four questions of the TEQ, were found in the HDNI group ($M = 8.4, S.D. = 2.77$) followed by the BWL group ($M = 8.3, S.D. = 2.34$), the DRL group ($M = 6.3, S.D. = 2.65$), and finally the LDNI group ($M = 6.4, S.D. = 2.94$).

Table 1 shows Spearman rank-order correlation coefficients between TEQ scores and percent improvement from pretreatment to posttreatment in SIGH-SAD-SR, HAM-D, ATYP, and BDI scores. Rating of expected treatment benefit was positively correlated with percent improvement score for each of the four dependent variable measures; thus, those subjects reporting higher initial expectations tended to report greater treatment benefits.

3.3. Effects of psychotropic medication regimens

Improvement in SAD symptoms, as assessed by pretreatment to posttreatment percent change in total SIGH-SAD-SR scores, was compared between those subjects who were ($n = 8$) or were not ($n = 65$) taking psychotropic medications. A 2 (taking or not taking medication) \times 4 (treatment group) factorial ANOVA showed no significant main effect for taking medication $F(1,65) = 2.76, P = 0.10$, no

significant main effect for treatment group, $F(3,65) = 0.41, P = 0.75$, and no significant interaction between medication regimen and treatment group, $F(3,65) = 2.72, P = 0.29$). Thus, the use of psychotropic medication by some subjects had little or no effect on the overall results.

3.4. Effects of scheduled treatment times

Although we did not have data regarding interval duration between subjects' awakening times and daily administration of treatment, Pearson correlations between session onset times and percent improvement in SIGH-SAD-SR total score between pretreatment and posttreatment showed no significant relationship for any of the four treatment groups. This analysis indicates that subjects receiving treatment during early morning session times did not show stronger treatment effects than did subjects receiving treatment later in the morning.

3.5. Group and treatment phase effects

No significant differences among groups were found in pretest scores for either the SIGH-SAD-SR, $F(3, 69) = 0.69, P = 0.56$, or the BDI, $F(3, 69) = 1.04, P = 0.38$, indicating that groups were equivalent before treatment began. Descriptive statistics for pretreatment and posttreatment scores are shown in Table 2.

Fig. 1 shows that all four treatments reduced depression, as measured by both the BDI and the HAM-D scale of the SIGH-SAD-SR, and also reduced the atypical symptoms of SAD as measured by the ATYP scale of the SIGH-SAD-SR. The four treatment groups differed little from each other either prior to or after the 12-session treatment regimen. Mixed-model 4 (Group: BWL, DRL, HDNI, LDNI) \times 2 (Treatment phase: pre/posttreatment) factorial ANOVAs were conducted for each inventory. For total SIGH-SAD-SR scores, neither a main effect for group, $F(3, 69) = 1.12, P = 0.35$, nor an interaction between group and treatment phase, $F(3, 69) = 1.17, P = 0.33$, was found. All four treatment groups showed a highly significant and equivalent decrease in SIGH-SAD-SR scores between the pretreatment and posttreatment measures, $F(1, 69) = 105.95, P < 0.0001$.

Similar results were found for the two scales comprising the SIGH-SAD-SR. Scores on the HAM-D scale showed a significant decrease between pretreatment and posttreatment scores, $F(3, 69) = 102.99, P < 0.0001$, but showed no main effect of group, $F(3, 69) = 0.73, P = 0.54$, and no group-by-treatment phase interaction, $F(3, 69) = 0.91, P = 0.44$. Similarly, scores on the ATYP scale showed a main effect for treatment phase, $F(1, 69) = 60.0, P < 0.0001$, but showed neither a significant main effect for group, $F(3, 69) = 1.06, P = 0.37$, nor a group-by-treatment phase interaction, $F(3, 69) = 1.40, P = 0.25$. BDI scores for all four treatment groups also significantly decreased across treatment phase, $F(1, 69) = 143.1, P < 0.0001$, with no main effect of group, $F(3, 69) = 0.66, P = 0.58$. The group-by-treatment phase interaction approached statistical significance, $F(3, 69) = 2.52, P = 0.065$.

Table 1

Spearman rank-order correlation coefficients between expectation of treatment benefit scores and percent improvement for each dependent measure.

Treatment	n^a	Total SIGH-SAD	HAM-D subscale	ATYP subscale	BDI
BWL	14	0.57*	0.50	0.01	0.26
DRL	11	0.29	0.32	0.23	0.42
HDNI	15	0.49	0.53*	0.41	0.59*
LDNI	16	0.39	0.19	0.42	0.52*
Combined	56	0.43*	0.40*	0.33*	0.45**

Note. BWL = bright-white light group, DRL = dim-red light group, HDNI = high-density negative ion group, LDNI = low-density negative ion group.

* $P < 0.05$, ** $P < 0.01$.

^a Not all subjects were given expectation inventories.

Table 2
Pretreatment and posttreatment means and standard errors for each treatment group.

Treatment	n	Total SIGH-SAD-SR		HAM-D subscale		ATYP subscale		BDI	
		Pre	Post	Pre	Post	Pre	Post	Pre	Post
BWL	19	29.8 (2.1)	13.2 (2.1)	19.3 (1.4)	9.0 (1.4)	10.5 (0.9)	4.2 (1.0)	18.7 (2.0)	6.6 (1.8)
DRL	16	28.6 (1.7)	18.4 (1.9)	18.1 (1.3)	11.7 (1.3)	10.6 (0.9)	6.8 (0.9)	15.0 (1.4)	8.0 (1.1)
HDNI	18	32.4 (1.9)	18.1 (2.7)	20.7 (1.5)	11.7 (1.9)	11.7 (1.2)	6.4 (1.0)	18.8 (1.8)	9.9 (1.7)
LDNI	20	30.0 (1.6)	18.1 (1.5)	20.1 (1.1)	11.7 (1.2)	9.9 (0.8)	6.4 (0.9)	17.3 (1.5)	9.8 (1.4)

Note. BWL = bright-white light group, DRL = dim-red light group, HDNI = high-density negative ion group, LDNI = low-density negative ion group.

Fig. 2 shows a scatterplot of each subject's SIGH-SAD-SR pretreatment and posttreatment scores in each treatment group. Pretreatment scores ranged from 20 to 54, and posttreatment scores ranged from 0 to 41. The predominance of scores below the major (solid) diagonal line indicates that each of the four treatments generally reduced the symptoms of SAD as compared to pretreatment. Scores on or below the dashed line indicate at least a 50% improvement from pretreatment to posttreatment; a larger percentage of subjects in the BWL group met this criterion compared to the other groups (see Table 3 for percentages). Across all four treatments, a smaller percentage of subjects met a more stringent, previously established remission criterion (Terman and Terman, 1995) consisting of at least a 50% reduction in SIGH-SAD-SR score together with posttreatment HAM-D and ATYP scale scores each of 7 points or less, indicated by the filled data points; again more subjects in the BWL group met this criterion (Table 3). Fig. 3 shows individual BDI scores across all treatments. Scores ranged from 9 to 42 prior to treatment and from 0 to 36 following treatment. Similar to their effects on SIGH-SAD-SR scores, all treatments generally reduced this second measure of depression as indicated by the large majority of BDI scores that fall below the major

(solid) diagonal line. The number of subjects showing a 50% reduction in BDI score from pretreatment to posttreatment is indicated by filled data points on or below the dashed lines; a greater percentage of BWL subjects reached this criterion compared to the other groups (Table 3).

3.6. Remission rates

Significant group differences were revealed for SIGH-SAD-SR scores when previously employed remission criteria (Terman and Terman, 1995; Wileman et al., 2001) were employed. These were (1) a moderate remission criterion of at least a 50% reduction in SIGH-SAD-SR score from pretreatment to posttreatment and (2) a more strict joint criterion consisting of at least a 50% reduction in SIGH-SAD-SR score as well as ATYP and HAM-D scores each of 7 points or below following treatment (Terman and Terman, 1995). When the moderate criterion was used, the upper portion (A) of Fig. 4 shows that BWL and, to a lesser extent, HDNI resulted in higher SIGH-SAD-SR remission rates than did either of the placebo control treatments. As illustrated in the middle portion (B) of this figure, the differential effectiveness of the BWL and HDNI treatments was even more pronounced when the

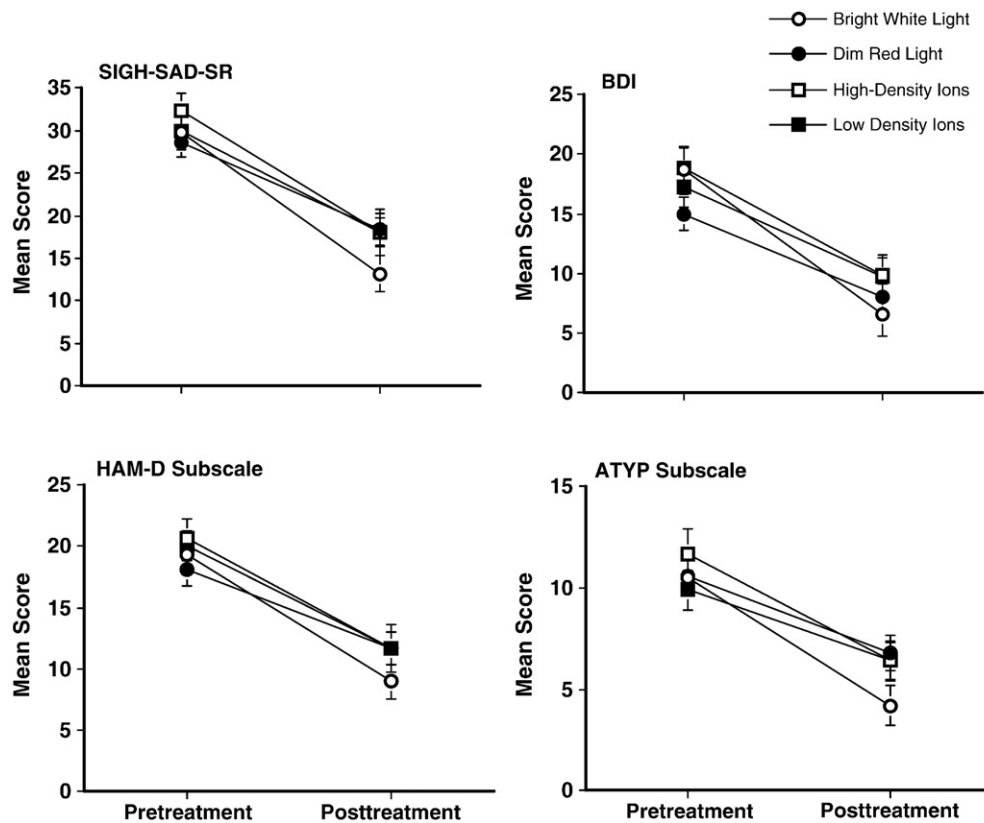


Fig. 1. Mean pretreatment and posttreatment group scores on the Structured Interview Guide for the Hamilton Depression Inventory–Seasonal Affective Version–Self Rating (SIGH-SAD-SR), the Beck Depression Inventory (BDI), and the two subscales (21-item Hamilton Depression Rating Subscales [HAM-D] and 8-item Atypical Items Subscales [ATYP]) of the SIGH-SAD-SR. Vertical lines depict standard error of the means.

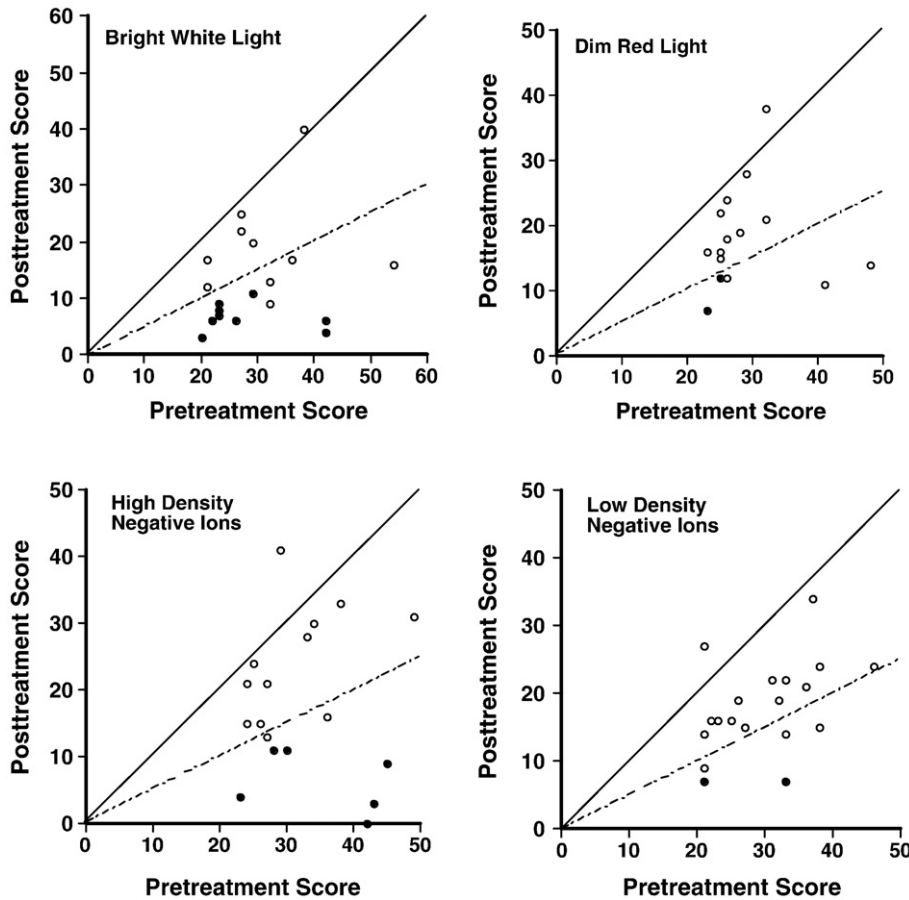


Fig. 2. Scatterplots of each subject's Structured Interview Guide for the Hamilton Depression Inventory–Seasonal Affective Version–Self Rating (SIGH-SAD-SR) scores prior to and following treatment. Solid diagonal lines indicate no change between pretreatment and posttreatment scores, dashed diagonal lines indicate a 50% reduction in SIGH-SAD-SR score from pretreatment to posttreatment, and filled data points indicate posttreatment scores that met the joint remission criteria of (a) at least a 50% reduction in SIGH-SAD-SR score from baseline as well as (b) a score on the 21-item Hamilton Depression Rating Subscale (HAM-D) of 7 points or less and (c) a score on the 8-item Atypical Items Subscale (ATYP) of 7 points or less.

stricter SIGH-SAD-SR joint remission criterion was employed. For the BDI measure of depression, the lower portion (C) of Fig. 4 shows that the percentage of subjects meeting the moderate remission criterion was clearly highest for the BWL treatment and was higher for the HDNI condition than for either of the DRL or LDNI control conditions.

Chi-square (χ^2) analyses with appropriate post hoc tests were used to determine whether an overall difference existed among the groups in the number of subjects who met/did not meet each remission criterion. To control for non-independent multiple comparisons being made in the post hoc tests, a procedure was used in which the number of post hoc comparisons is limited by the degrees of freedom in the original χ^2 test (Siegel and Castellan, 1988). Thus, in this study, post hoc χ^2 values were calculated for three 2×2 subtests whose combined χ^2 values were equal to the overall value.

The three comparisons made were (1) the number of subjects in the DRL vs. LDNI treatments (placebo groups) who met/did not meet the remission criteria, (2) the combined data from the two placebo groups vs. the HDNI group, and (3) the combined data from these three groups (DRL, LDNI, and HDNI) vs. the BWL group. The logic behind this procedure is that if no significant χ^2 value is found in a subtest, then the data from those treatments can be combined (Siegel and Castellan, 1988). A significant post hoc χ^2 value means that a particular treatment is statistically different from all the combined treatments. Table 3 summarizes the results for total SIGH-SAD-SR scores and for BDI scores at each criterion. In every case, significant post hoc χ^2 values were found only when comparing the combined data from the DRL, LDNI, and HDNI groups with those of the BWL

group, although the comparison between the HDNI group and the combined data for the placebo groups on total SIGH-SAD-SR scores approached significance. Thus, more subjects reached remission criteria in the bright white light treatment than in any of the other treatments.

Table 3

Overall χ^2 values and post hoc comparisons for subjects who met/did not meet each remission outcome criterion; brackets indicate combined-group data, and the numbers in parentheses show the percentage of subjects in each grouping who met each criterion.

Criterion	Overall χ^2 (df=3)	Post hoc comparison	Partitioned χ^2 (df=1)
Total SIGH-SAD score decrease >50%	8.59*	DRL (31) vs. LDNI (25) [DRL + LDNI] (27) vs. HDNI (44) [DRL + LDNI + HDNI] (33) vs. BWL (68)	0.14 1.36 7.08**
Total SIGH-SAD score decrease >50% & HAM-D <7 & ATP <7	9.18*	DRL (12) vs. LDNI (10) [DRL + LDNI] (11) vs. HDNI (33) [DRL + LDNI + HDNI] (18) vs. BWL (47)	0.03 3.08† 6.08*
BDI score decrease >50%	9.41*	DRL (31) vs. LDNI (40) [DRL + LDNI] (36) vs. HDNI (50) [DRL + LDNI + HDNI] (41) vs. BWL (79)	0.27 0.93 8.21**

Note. BWL = bright-white light group (n = 19), DRL = dim-red light group (n = 16), HDNI = high-density negative ion group (n = 18), LDNI = low-density negative ion group (n = 20).

†P<0.10, *P<0.05, **P<0.01.

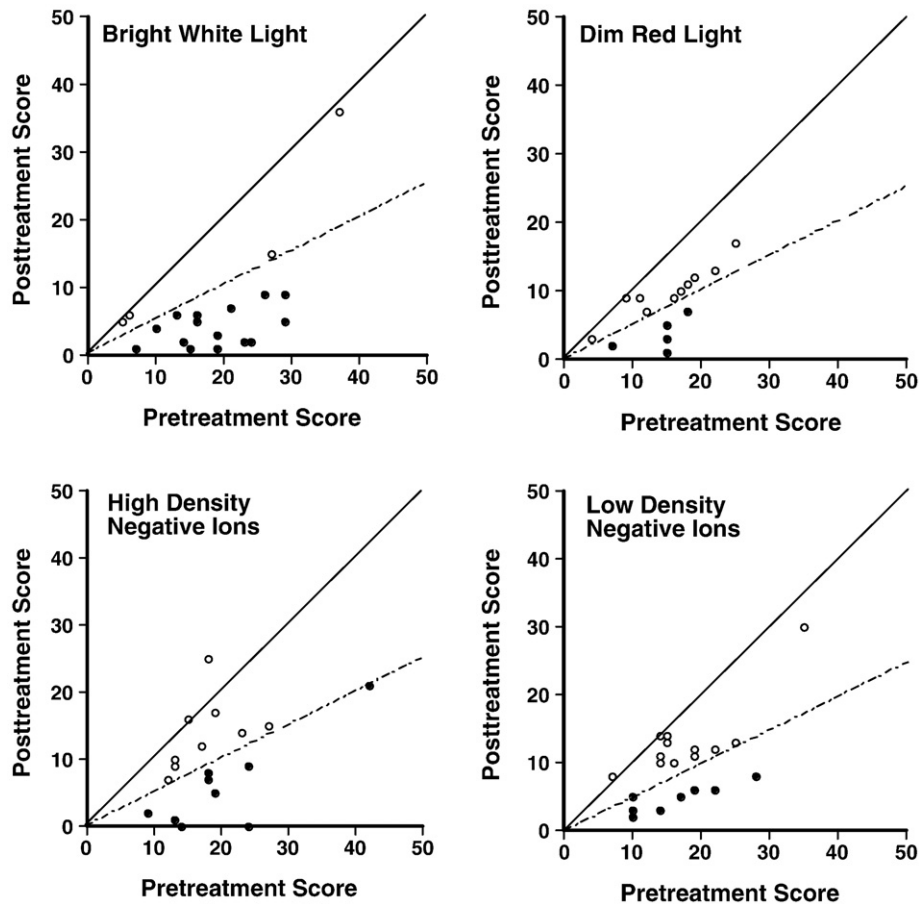


Fig. 3. Scatterplots of each subject's Beck Depression Inventory (BDI) scores prior to and following treatment. Solid diagonal lines indicate no change between pretreatment and posttreatment scores, dashed diagonal lines indicate a 50% reduction in BDI score from pretreatment to posttreatment, and filled data points indicate posttreatment scores that were at least 50% lower than at pretreatment baseline.

4. Discussion

Analyses of raw scale scores indicated that each treatment significantly reduced the symptoms of SAD and that treatment effects were equivalent for all four groups. These results corroborate those of Eastman et al. (1998) who found that bright light and an inert negative ion generator produced comparable reductions in SIGH-SAD scores but did not differ from each other and also agree with findings by Wileman et al. (2001) that bright light and dim red light both produced substantial and equivalent reductions in SIGH-SAD-SR scores. Taken together, these results support the caveat (Eastman et al., 1998) that it is not advisable to rely solely on statistical analysis of raw scores to assess the differential effectiveness of treatments for SAD.

When remission criteria were used to assess treatment efficacy, the antidepressant effect of BWL was statistically superior to that of each of the other three treatments. Although the percentage of subjects meeting the joint remission criterion was greater in the HDNI condition than in either of the placebo conditions, this superiority trended toward, but did not meet, statistical significance. Thus, BWL and, to a lesser extent, HDNI were each more effective in reducing the depressive and atypical neurovegetative symptoms of SAD than was either of the two placebo control conditions. Similarly, Eastman et al. (1998) found that bright light was significantly more effective than was a placebo only when strict response criteria were used to assess treatment efficacy. Wileman et al. (2001), however, found no significant differences between bright light and dim red light whether

broad, intermediate, or strict remission criteria were employed and proposed that a possible explanation of their findings was that dim red light was an active rather than inactive placebo. Their explanation receives some support from studies that found treatment differences between bright light and dissimilar nonphotic placebo conditions (Eastman et al., 1998; Terman et al., 1998) but is not supported by our finding that BWL was superior to either LDNI or DRL.

Previous studies reported that effectiveness of high-density negative ion exposure as a treatment for SAD was significantly superior to that of low-density negative ions and was comparable to that of bright light (Terman and Terman, 1995, 2006; Terman et al., 1998). In our study, it is likely that HDNI would have shown greater efficacy if our treatment phase had consisted of more than 12 sessions. In support of this possibility, Terman et al. (1998) found that the remission of SAD following 10–14 daily sessions of high-density ions increased substantially after an additional 10–14 days of treatment, and Terman and Terman (1995, 2006) reported a greater antidepressant effect of this treatment following 20 daily sessions than following only 10. Additionally, results by Goel et al. (2005) indicated progressively improved efficacy of negative ion treatment for nonseasonal chronic depression over a 5-week period.

Our finding that BWL showed substantial treatment superiority over DRL within only 12 sessions supports previous light box studies (Rosenthal et al., 1984a,b, 1985; Magnusson and Kristbjarnarson, 1991) that found similar effects within only 1 to 2 weeks. It is unlikely, however, that the advantage of BWL in our study was due to differences in placebo effects because treatment expectation ratings

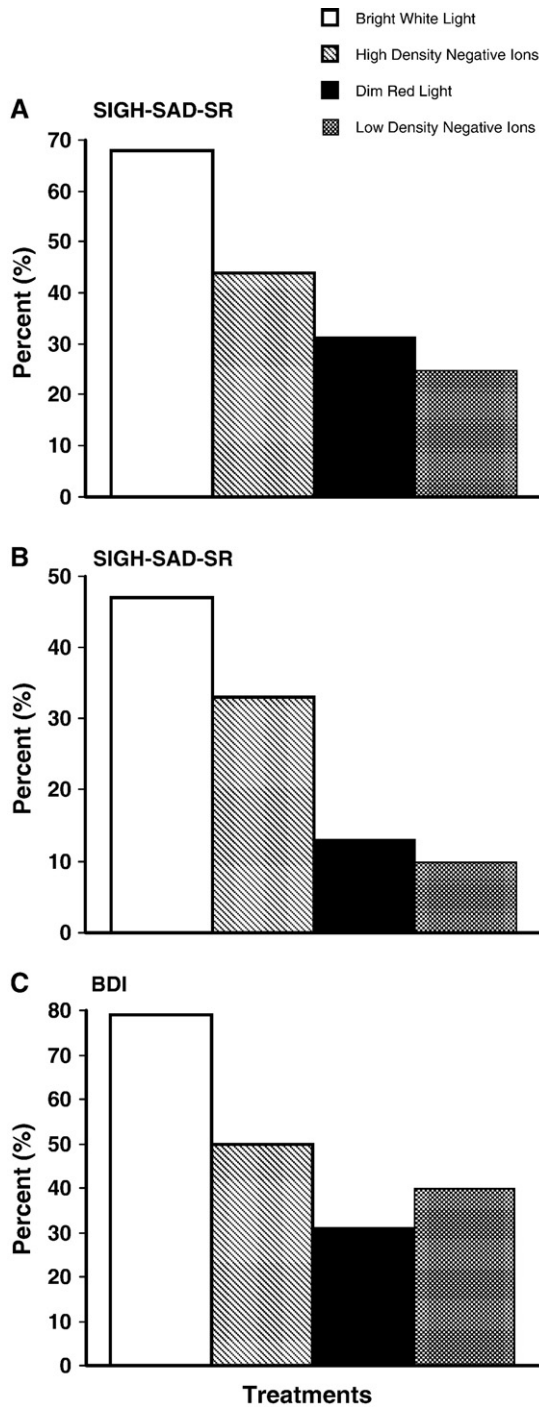


Fig. 4. Percentage of subjects meeting (A) the moderate remission criterion of at least a 50% reduction of Structured Interview Guide for the Hamilton Depression Inventory–Seasonal Affective Version–Self Rating (SIGH-SAD-SR) score from pretreatment to posttreatment, (B) the more strict joint remission criteria of a 50% or greater reduction of SIGH-SAD-SR score as well as posttreatment scores on the subscales of the SIGH-SAD-SR (21-item Hamilton Depression Rating Subscale [HAM-D] and 8-item Atypical Items Subscale [ATYP]) of 7 or less, and (C) the moderate remission criterion of at least a 50% reduction of Beck Depression Inventory (BDI) score from pretreatment to posttreatment.

among the four groups did not differ significantly and because the use of a parallel vs. crossover design minimized direct comparisons of the two treatments.

Although treatment expectation scores were comparable among the four treatment groups, the correlation between these scores and actual treatment outcomes suggests that reported treatment effects

were not entirely independent of the subject's pretreatment beliefs about the efficacy of her treatment. The strength of these correlations, however, was not consistently related to treatment type. Even though subjects in the BWL condition were clearly aware of the treatment to which they were assigned and were likely to have prior knowledge from academic and/or media sources about its efficacy for SAD, this group's correlation between treatment expectation and actual outcome was relatively strong for only two of the four treatment measures. Participants assigned to the negative ion conditions were unaware of which density to which they were exposed and were also relatively unlikely to have had previous knowledge of the treatment efficacy of negative ions for SAD. Nevertheless, each of the four treatment measures for the HDNI group and two of the outcome measures for the LDNI group showed relatively strong correlations with treatment expectation scores.

Previous investigations of light and/or negative ions as treatments for SAD have provided treatment apparatus for subjects to use at home and have monitored treatment compliance through log in telephone messages or other similar procedures. A recent pilot study (Michalak et al., 2007) found that patient self-reports of daily light box use substantially differed from actual timed light exposure and that active treatments resulted in greater treatment adherence than did inactive control conditions. Our treatment protocol avoided the potential limitations involved with monitoring treatment compliance (cf. Wileman et al., 2001) and ensured that each subject received full 30-minute treatment exposures at the same time of morning over the 12 days of treatment. Furthermore, because the actual density of negative ions reaching the subject is affected by a number of physical factors including room size/volume, the use of nearly identical treatment rooms minimized this factor as a potential confound.

The largest component of antidepressant treatments, including bright light or negative ions, can be the placebo effect (Greenberg and Fisher, 1989; Eastman, 1990), and this effect could be expected to operate differentially on subjects who adhere to a prescribed treatment regimen as opposed to those who do not. Based on the results of the Michalak et al. (2007) study, the placebo effect is likely to be greater for subjects receiving bright light than for those receiving an inactive control treatment. Our finding that all treatments produced a comparable overall decrease in SIGH-SAD-SR and BDI raw scores strongly suggests that the placebo effect was comparable across treatments and underscores the importance of ensuring equal treatment adherence for all subjects.

Because treatment sessions were primarily arranged to accommodate subjects' scheduled morning activities, the timing of their sleep–wake cycles was not standardized. Although subjects were encouraged to maintain, as much as possible, regular sleep–wake cycles during the study, we did not require them to keep daily sleep–wake logs. As a result of the absence of such data, the extent of treatment effects due to circadian phase shifting could not be determined.

In conclusion, this study indicates that bright light and to a somewhat lesser extent, high-density ions, are effective antidepressants for treating SAD in women. It is the first investigation to compare these active treatments to both photic and nonphotic placebo conditions and to provide exposure to treatments in a controlled laboratory setting. Because treatment expectations were equivalent for all conditions, we conclude that the superior effectiveness of the two active treatments was not due to their having greater placebo effects than did either of the two inactive, placebo conditions.

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