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Bright light, negative air ions and auditory stimuli produce rapid mood changes in a student population: a placebo-controlled study

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ABSTRACT

Background. Bright light and high-density negative air ion exposure are efficacious for winter and non-seasonal depression compared with a low-density negative ion placebo. Similarly, auditory stimuli improve mood in clinical populations. This study compared the short-term effects of bright light, an auditory stimulus, and high- and low-density negative ions on mood and alertness in mildly depressed and non-depressed adults.

Method. One hundred and eighteen subjects, 69 women and 49 men (mean age $\pm$ S.D., $19{\cdot}4 \pm 1{\cdot}7$ years), participated once across the year. Subjects were randomly assigned to one of four conditions: bright light (10 000 lux; $n=29$), auditory stimuli (60 dB; $n=30$), or high-density ($4{\cdot}5 \times 10^{14}$ ions/s flow rate; $n=29$) or low-density ($1{\cdot}7 \times 10^{11}$ ions/s; $n=30$; placebo control) negative ions. Exposure was for 30 min on three consecutive evenings between 1900 and 2100 hours. Mood and alertness assessments, using standardized scales, occurred before, and 15 and 30 min during exposure. The Beck Depression Inventory classified subjects as depressed ($\geqslant 10$; $n=35$) or non-depressed (<10; $n=83$).

Results. The three active stimuli, but not the low-density placebo, reduced depression, total mood disturbance (a global affect measure) and/or anger within 15–30 min. Neither testing season nor degree of depressive symptoms affected response to stimuli.

Conclusions. The auditory stimulus, bright light and high-density ions all produced rapid mood changes – with small to medium effect sizes – in depressed and non-depressed subjects, compared with the low-density placebo, despite equivalent pre-study expectations. Thus, these stimuli improve mood acutely in a student sample, including a subset with depressive symptoms.

INTRODUCTION

Bright light and high-density negative ion exposure both are effective for the treatment of seasonal affective disorder (SAD) and non-seasonal depression compared with a low-density negative ion placebo in multi-week clinical trials (Terman & Terman, 1995; Terman *et al*. 1998; Goel *et al*. 2005).

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Although these non-pharmacologic stimuli are successful in depressed populations, their effects in general populations – those without subsyndromal depressive symptoms – remain unclear. For example, while some studies demonstrate improved mood and alertness following bright light exposure (Dawson & Campbell, 1991; Daurat *et al*. 1993; Partonen, 1994; Foret *et al*. 1998; Partonen & Lönnqvist, 2000; Åkerstedt *et al*. 2003; Phipps-Nelson *et al*. 2003; Rüger *et al*. 2003; Lowden *et al*. 2004), others report no effects (Rosenthal *et al*. 1987; Kasper *et al*. 1989*a*, 1990; French *et al*. 1990;

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Dollins *et al*. 1993; Bauer *et al*. 1994; Leproult *et al*. 1997; LaFrance *et al*. 1998). Moreover, most prior bright light research has used low-intensity (e.g. 1000–3000 lux) and/or long duration exposures (e.g. 2–13.5 h); the latter are not optimal for use in a daily routine. Therefore, we used a daily intensity-duration dose of 10 000 lux for 30 min – efficacious in clinical trials (Terman *et al*. 1998; Goel *et al*. 2005) – to investigate bright light's short-term effects across three evenings.

High-density negative air ions also enhance mood and alertness in healthy subjects (Soyka, 1977; Tom *et al*. 1981; Buckalew & Rizzuto, 1982; Baron *et al*. 1985; Yates *et al*. 1986; Baron, 1987; Nakane *et al*. 2002), while positive air ions produce opposite effects, increasing depression, tension, irritability and fatigue (Charry & Hawkinshire, 1981). A few studies, however, have failed to find appreciable effects with negative ion exposure (Hedge & Collins, 1987; Reilly & Stevenson, 1993; Watanabe *et al*. 1997); thus, further research is needed to clarify ions' effects in normal populations. Employing a similar strategy as that for the bright light condition, we investigated the acute effects of exposure to a high-output negative ionizer ($4{\cdot}5 \times 10^{14}$ ions/s) for 30 min, a dose and duration effective in clinical populations (Terman *et al*. 1998; Goel *et al*. 2005).

In addition to bright light and negative ions, healthy subjects show improved mood and alertness after exposure to various musically based auditory stimuli (Fisher & Greenberg, 1972; Smith & Morris, 1976; Pignatiello *et al*. 1986; Davis & Thaut, 1989; Smith & Noon, 1998; Unwin *et al*. 2002; Johnson, 2003). Notably, only a handful of studies exist in depressed patients, whereby music improves overall mood (Lai, 1999; Tornek *et al*. 2003; Hsu & Lai, 2004). The aforementioned studies assume underlying physiological causes for resultant mood changes, similar to other sensory-based stimuli such as light or ions, and are distinct from music therapy studies, which involve activities beyond music exposure such as imagery or relaxation techniques (Aldridge, 1993). Therefore, further examination of this solely music-based approach in normal populations, including those with depressive symptoms, is warranted. We tested an auditory stimulus with a musical component, which reduces fatigue (Goel, 2005, 2006) and total mood disturbance (Goel, 2006) in normal subjects, and postulated that it would produce mood changes comparable to those of bright light and negative ions.

This study compared the short-term, rapid mood and alertness effects, after 15 and 30 min of exposure on three days, of bright light, high-density ions and a musically based auditory stimulus with a placebo control condition, low-density ions, in depressed and non-depressed adults. It was predicted that the three active conditions – bright light, high-density ions and the auditory stimulus – would produce larger changes in mood and alertness measures than the control, with comparable changes across stimuli. This study also investigated seasonal and depressive state dependencies on stimulus responsiveness. While depressed subjects were predicted to show larger responses than non-depressed subjects to all active stimuli, seasonal dependency in response to light or ions was not predicted, based on data from non-seasonally depressed patients.

METHOD

Subjects

One hundred and eighteen healthy university students, 69 women (58·5%) and 49 men (41·5%), ages 18–28 (mean age ± S.D., 19·4 ± 1·7 years) enrolled in a three-consecutive evening study. Each subject participated once across the year, with the following seasonal distribution: spring ($n=28$), summer ($n=44$) and autumn ($n=46$). Subjects were tested both on weekdays and weekends, with no differences in the distribution of test days across seasons or stimuli. Past exposure to bright light, negative ions or the musically based auditory stimulus was exclusionary. Wesleyan University's Institutional Review Board approved the study protocol and all procedures conformed to the Declaration of Helsinki. Subjects signed informed consent before study entry and received monetary compensation ($n=68$; $21 total or $7 per session) or Introductory Psychology course credit ($n=50$) for participation. Neither author was affiliated with this course; subjects could freely withdraw from the study at any time without penalizing their course grade. There were only five drop-outs from

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the study, all due to post-entry scheduling conflicts.

Apparatus

Bright light exposure was delivered by SPX-30 triphosphor fluorescent lamps at 3000 Kelvin color temperature, encased in a metal box ($27{\cdot}9 \times 58{\cdot}5$ cm) with a translucent plastic diffusing screen (Uplift Technologies Inc., Dartmouth, Nova Scotia, Canada). The light box – mounted on a height-adjustable table-top stand and tilted on a downward angle of 30° toward the head – provided illuminance of approximately 10 000 lux. The center of the screen was placed approximately 32 cm from each subject's eyes and the gaze direction was toward the illuminated area beneath the light source. Subjects did not look directly at the screen.

The high- and low-density negative ion generators produced different flow rates but were identical in appearance ($4{\cdot}5 \times 10^{14}$ ions/s *v.* $1{\cdot}7 \times 10^{11}$ ions/s; SphereOne Inc., Silver Plume, CO, USA). Differences in ion density are imperceptible (Yates *et al.* 1986), since at present the sensory organ for ions remains unknown. Moreover, both flow rates recently have been used in a clinical trial with chronically depressed patients, in which the low-density dose served as an effective placebo (Goel *et al.* 2005). Subjects sat approximately 32 cm from the ionizer and wore a grounded wrist strap to maximize ion flow toward the body.

The auditory stimulus was a compact disc of birdsong melodies, enhanced with a classical music background (Unison Music, Nashville, TN, USA). Using a standardized player, the stimulus was administered at 60 dB, intensity equivalent to normal conversation (Holand *et al.* 1999). This stimulus has been similarly administered in other studies from our laboratory (Goel, 2005, 2006). The background music was consistent in melody, tempo and decibels across the 30 min testing period. To maintain uniformity across sessions and subjects, the stimulus was played from the beginning of the compact disc, rather than from random points. This procedure was used to match the three other conditions, in which the exact same form of the stimulus was presented for each session. For all sessions, subjects were required to remain seated and awake, with their eyes open. The experimenter monitored strict compliance with testing instructions.

Assessment instruments

The Beck Depression Inventory (BDI; Beck *et al.* 1961) is a 21-item self-rated questionnaire that determines severity of depression and has been validated in college populations (Bumberry *et al.* 1978). The BDI contains multiple-choice questions on a 4-point scale, ranging from 0–3 in terms of symptom severity. BDI scores (mean $\pm$ S.D., $7{\cdot}79 \pm 6{\cdot}54$) classified subjects as currently depressed ($\geqslant 10$; $n = 35$; 30%) or non-depressed (< 10; $n = 83$; 70%); these cut-off scores were the same as those used in other college populations (e.g. Bumberry *et al.* 1978; Oliver & Burkham, 1979; Goel & Grasso, 2004). Our study distribution also approximates that of other college samples (Oliver & Burkham, 1979; Robbins & Tanck, 1987; Goel & Grasso, 2004).

The Profile of Mood States Questionnaire (POMS; McNair *et al.* 1992), a 65-item self-report scale, assesses transient affective states in response to sensory stimuli including bright light (e.g. Kasper *et al.* 1989*a*; French *et al.* 1990; Dollins *et al.* 1993), negative ions (Baron *et al.* 1985) and auditory cues (Smith & Noon, 1998; Unwin *et al.* 2002; Tornek *et al.* 2003; Goel, 2005, 2006). The POMS also has been validated in repeated measures designs (reviewed in Schiffman *et al.* 1995) and tested with repeated acute sampling periods (McNair *et al.* 1992). Each item is rated on a scale from 0 (not at all) to 4 (extremely), on one of six factors: depression-dejection (Depression), tension-anxiety (Tension), anger-hostility (Anger), confusion-bewilderment (Confusion), vigor-activity (Vigor), fatigue-inertia (Fatigue). The total score for each factor is calculated by adding together the respective set of adjectives corresponding to that factor. The total mood disturbance score (TMD), a global estimate of affective state, derives from summing the factors together, with vigor-activity weighted negatively.

The Karolinska Sleepiness Scale (KSS; Åkerstedt & Gillberg, 1990) quantifies the progressive, subjective stages of the sleep-alertness continuum, with a scale from 1 to 9 (1, extremely alert; 9, extremely sleepy), and has been tested with repeated acute sampling

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Table 1. *Demographic characteristics by season for the study population*

Season		Gender		Mood state	
		Women	Men	Depressed	Non-depressed
Spring	28 (23·7%)	18 (26·1%)	10 (20·4%)	11 (31·4%)	17 (20·5%)
Summer	44 (37·3%)	26 (37·7%)	18 (36·7%)	13 (37·1%)	31 (37·3%)
Autumn	46 (39·0%)	25 (36·2%)	21 (42·9%)	11 (31·4%)	35 (42·2%)
Total	118 (100·0%)	69 (58·5%)	49 (41·5%)	35 (29·7%)	83 (70·3%)

periods. Likert scales assessed four aspects of stimulus perception using a 7-point scale. Subjects rated stimulus hedonics (1, very unpleasant; 4, neutral; 7, very pleasant) and intensity (1, very weak; 4, neutral; 7, very intense), as well as its effects on mood (1, very depressing; 4, neutral; 7, very elating) and on alertness (1, very sedating; 4, neutral; 7, very stimulating).

Procedure

Subjects were randomly assigned, using a random-number table, to one of four conditions: bright light (10 000 lux; $n=29$), auditory stimuli (60 dB; $n=30$), or high-density ($4{\cdot}5\times10^{14}$ ions/s flow rate; $n=29$) or low-density ($1{\cdot}7\times10^{11}$ ions/s; $n=30$; placebo control) negative ions. Before study entry, subjects were only told they would be exposed to an environmental stimulus and were not provided with further information regarding any of the four stimuli. We have found that this particular college population is naïve regarding the existence, and effects of, non-drug stimuli such as negative ions and bright light (Goel, unpublished observations). Before randomization, subjects provided expectation ratings regarding the degree of predicted mood change for all four stimuli on a scale of -3 to $+3$ (-3, major worsening; 0, no change; $+3$, major improvement). The BDI was administered once, before study entry. Stimulus exposure was for 30 min on three consecutive evenings (between 1900 and 2100 hours); subjects completed the KSS and POMS a total of three times: before exposure (baseline) and after 15 and 30 min of exposure to assess rapid mood changes. At the end of each testing day session, subjects rated stimulus perceptual qualities using Likert scales.

Statistical analyses

The χ^2 test was used for categorical comparisons. Repeated measures multivariate analyses of variance (rmANOVAs), with condition as the primary ('core') comparison, assessed differences in POMS and KSS scores across the three days (Days 1, 2 and 3) and three assessment time points (baseline, 15 and 30 min). Thus, the primary analysis utilized a 3 (day) $\times$ 3 (assessment time) $\times$ 4 (condition) design. BDI classification ($3\times3\times4\times2$) and season ($3\times3\times4\times3$) were added singly to the primary core as between-subjects factors, thus maximizing available sample sizes. Similarly, rmANOVAs analyzed condition differences in perceptual qualities and expectations. *Post hoc* comparisons using Bonferroni-adjusted probabilities examined significant interactions and group differences for all measures. The magnitude of between-group differences in scores was expressed as effect size, d, the standardized difference between means ($d=0{\cdot}3$, small; 0·5, medium; 0·8, large; Cohen, 1988). For all tests, $\alpha<0{\cdot}05$ was set as the threshold for significant differences. For *post hoc* analyses, the α-level was corrected and data are presented with corrected p values.

RESULTS

Demographic characteristics

Table 1 presents the demographic characteristics by testing season for gender and depressed/non-depressed mood state. Chi-square analyses indicated no significant differences in the proportion of depressed and non-depressed subjects grouped by gender, season or condition, in the proportion of men and women grouped by season or condition, or in the proportion of subjects in each condition grouped by season.

Stimulus effects

There were significant stimulus $\times$ time interactions for TMD ($F=3{\cdot}12$, df = 3, 113, $p<0{\cdot}03$),

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Table 2. *Mean ± S.E.M. POMS scores for the four stimulus conditions by assessment time*

POMS scale	Stimulus: Bright light	High-density ions	Low-density ions	Auditory stimulus
TMD				
Baseline	6·08 ± 2·96	0·22 ± 2·70	12·31 ± 4·30	13·90 ± 2·89
15 min	5·90 ± 3·04	1·21 ± 2·46	14·03 ± 4·75	9·76 ± 2·71
30 min	5·14 ± 2·88	1·49 ± 2·41	12·82 ± 4·39	7·99 ± 2·90
Anger				
Baseline	3·47 ± 0·72	1·34 ± 0·34	3·77 ± 0·92	3·62 ± 0·68
15 min	3·08 ± 0·61	0·95 ± 0·26	3·30 ± 0·90	2·56 ± 0·56
30 min	2·26 ± 0·53	0·95 ± 0·25	2·91 ± 0·83	3·29 ± 0·62
Depression				
Baseline	3·23 ± 0·68	2·75 ± 0·68	4·37 ± 1·46	5·60 ± 0·56
15 min	2·08 ± 0·56	1·80 ± 0·50	4·15 ± 1·61	4·67 ± 0·68
30 min	1·44 ± 0·38	1·64 ± 0·40	4·24 ± 0·52	4·08 ± 1·07
Vigor				
Baseline	11·84 ± 0·96	13·92 ± 0·96	10·91 ± 1·09	10·06 ± 1·02
15 min	9·87 ± 1·01	11·96 ± 1·01	7·60 ± 0·99	9·26 ± 1·01
30 min	8·83 ± 1·00	11·02 ± 1·00	7·49 ± 1·08	8·82 ± 1·09
Tension				
Baseline	4·83 ± 0·55	4·40 ± 0·55	5·78 ± 0·55	5·27 ± 0·75
15 min	3·52 ± 0·56	3·69 ± 0·56	4·89 ± 0·55	4·32 ± 0·72
30 min	3·22 ± 0·55	2·95 ± 0·55	4·22 ± 0·54	2·78 ± 0·78
Fatigue				
Baseline	5·41 ± 0·79	4·72 ± 0·77	7·17 ± 0·79	7·36 ± 0·90
15 min	5·44 ± 0·86	5·44 ± 0·86	7·28 ± 0·85	5·50 ± 0·96
30 min	6·33 ± 0·88	5·67 ± 0·88	7·22 ± 0·87	5·02 ± 0·94
Confusion				
Baseline	1·03 ± 0·66	0·93 ± 0·63	2·13 ± 0·65	2·11 ± 0·66
15 min	1·65 ± 0·66	1·30 ± 0·66	2·01 ± 0·65	1·97 ± 0·66
30 min	0·80 ± 0·63	1·30 ± 0·65	1·72 ± 0·62	1·64 ± 0·63

POMS: Profile of Mood States Questionnaire; TMD: total mood disturbance score.

anger ($F = 5{\cdot}35$, df = 3, 113, $p < 0{\cdot}002$) and depression scores ($F = 3{\cdot}21$, df = 3, 113, $p < 0{\cdot}03$) (Table 2). The auditory stimulus, bright light and high-density negative ions all significantly reduced depression scores after both 15 (auditory: $d = 0{\cdot}28$; light: $d = 0{\cdot}35$; high-density ions: $d = 0{\cdot}30$) and 30 min (auditory: $d = 0{\cdot}35$; light: $d = 0{\cdot}61$; high-density ions: $d = 0{\cdot}37$) of exposure. In addition, the auditory stimulus and bright light significantly reduced anger, after 15 ($d = 0{\cdot}31$) and 30 min ($d = 0{\cdot}36$) of exposure, respectively. Finally, the auditory condition produced significant TMD reductions after 15 min ($d = 0{\cdot}28$). By contrast, the low-density ion control, but not the other stimuli, significantly reduced vigor from day 1 to day 2 (mean ± S.E.M., day 1: 9·91 ± 1·04; day 2: 7·64 ± 0·86; $d = 0{\cdot}43$; significant stimulus × day interaction, $F = 5{\cdot}67$, df = 3, 113, $p < 0{\cdot}001$).

Perceptual qualities also showed substantial differences across stimuli (Table 3). Bright light was significantly more intense than the three other stimuli (overall condition effect: $F = 9{\cdot}22$, df = 3, 100, $p < 0{\cdot}001$, d's = 1·08–1·34) and more stimulating than the low-density ion control (overall condition effect: $F = 3{\cdot}23$, df = 3, 99, $p < 0{\cdot}03$, $d = 0{\cdot}78$). By contrast, the auditory stimulus was significantly more pleasant than the three other stimuli (overall condition effect: $F = 4{\cdot}86$, df = 3, 100, $p < 0{\cdot}004$, d's = 0·74–0·86) and more elating than low-density ions (overall condition effect: $F = 2{\cdot}81$, df = 3, 99, $p < 0{\cdot}05$, $d = 0{\cdot}66$).

Despite the aforementioned mood and perceptual differences, the four stimuli did not show significant differences in expectation ratings (mean ± S.D., bright light: 0·14 ± 1·65; high-density ions: 0·13 ± 1·39; auditory stimulus: 0·26 ± 1·46; low-density ions: 0·04 ± 0·99). Ratings also were similar across the four testing conditions and across seasons and between depressed and non-depressed subjects.

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Table 3. *Mean ± S.D. Likert Scale ratings of perceptual characteristics for each stimulus*

Perceptual characteristic	Stimulus: Bright light	High-density ions	Auditory stimulus	Low-density ions
Intensity	4·71 ± 0·72[a]	3·67 ± 0·94	3·80 ± 0·95	3·64 ± 0·88
Pleasantness	3·85 ± 1·12	3·92 ± 0·61	4·65 ± 1·03[a]	3·87 ± 0·75
Sedating/stimulating	4·05 ± 1·03[b]	3·78 ± 0·71	3·47 ± 1·04	3·35 ± 0·69
Depressing/elating	4·12 ± 0·94	3·92 ± 0·49	4·31 ± 0·76[b]	3·74 ± 0·65

[a] Significantly higher than all other stimuli.
[b] Significantly higher than low-density ions.

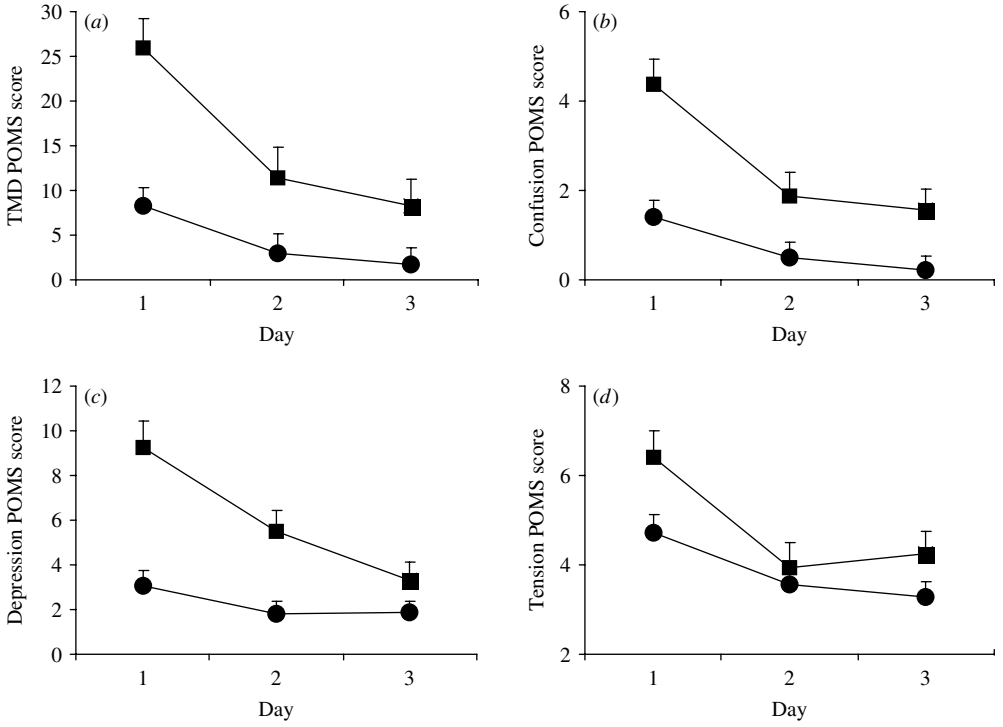


FIG. 1. Mean (± S.E.M.) Profile of Mood States Questionnaire scores for depressed (■) and non-depressed (●) subjects across test days. (*a*) Total mood disturbance score; (*b*) Confusion; (*c*) Depression; (*d*) Tension.

Depressed/non-depressed differences

There were no significant response differences between depressed and non-depressed subjects on any measure across the four conditions. However, significant depressed/non-depressed × day interactions were detected for TMD ($F = 7{\cdot}25$, df = 2, 108, $p < 0{\cdot}001$), confusion ($F = 6{\cdot}22$, df = 2, 108, $p < 0{\cdot}004$), depression ($F = 9{\cdot}81$, df = 2, 108, $p < 0{\cdot}001$) and tension scores ($F = 3{\cdot}66$, df = 2, 108, $p < 0{\cdot}03$) (Fig. 1). For all four measures, both depressed and non-depressed subjects showed significant declines across days, with larger declines between days 1 and 2 than days 2 and 3. Day changes showed small to large effect sizes (*d*'s = 0·30–0·82). Depressed subjects had significantly higher scores than

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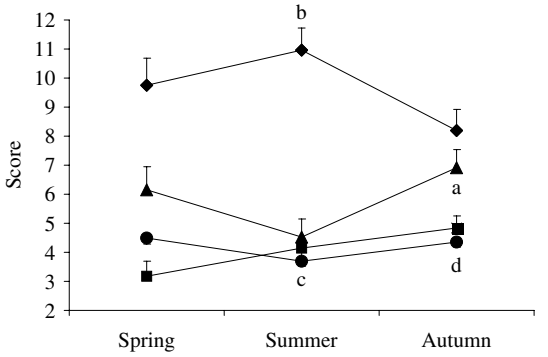


FIG. 2. Mean (±S.E.M.) seasonal changes in KSS alertness and POMS mood measures. Symbols: a, significantly greater than the summer-tested group; b, significantly greater than the autumn-tested group; c, significantly lower than the spring- and autumn-tested groups; d, significantly greater than the spring-tested group. ●, Karolinska Sleepiness Scale; ■, Tension; ▲, Fatigue; ◆, Vigor.

non-depressed subjects and steeper negative slopes for all measures, regardless of stimulus condition.

Seasonal differences

Testing season did not significantly affect responses on any measure across the four conditions. However, significant seasonal effects were observed for fatigue ($F=3{\cdot}89$, df = 2, 105, $p<0{\cdot}03$), vigor ($F=3{\cdot}49$, df = 2, 105, $p<0{\cdot}04$), tension ($F=3{\cdot}12$, df = 2, 105, $p<0{\cdot}05$) and KSS scores ($F=4{\cdot}79$, df = 2, 99, $p<0{\cdot}01$) (Fig. 2). Summer-tested subjects reported significantly more vigor ($p<0{\cdot}04$, $d=0{\cdot}58$) and less fatigue ($p<0{\cdot}04$, $d=0{\cdot}58$) than autumn-tested subjects. Summer-tested subjects also were more alert (had lower KSS scores) than autumn- ($p<0{\cdot}05$, $d=0{\cdot}53$) and spring-tested subjects ($p<0{\cdot}01$, $d=0{\cdot}67$). Finally, spring-tested subjects were less tense than autumn-tested subjects ($p<0{\cdot}03$, $d=0{\cdot}58$).

DISCUSSION

The auditory stimulus, bright light and high-density negative ions improved depression, total mood disturbance, and/or anger within 15–30 min, with small to medium effect sizes, compared with the low-density placebo control. While stimulus expectations were equivalent, perceptions differed: bright light was rated as most intense and the auditory stimulus as most pleasant. Neither depressed/non-depressed mood state nor testing season affected mood response. Thus, these three non-pharmacologic stimuli rapidly improve mood in a college sample, including individuals with depressive symptoms. The changes are significant and important in day-to-day life; they demonstrate that 27–55% mean improvements from baseline mood are achievable in only 30 min. Moreover, the timing of stimulus presentation – with administration in the evening hours – renders these stimuli feasible for those individuals in the population who work during the daytime hours.

Bright light reduced depression scores, similar to data from clinical trials (Terman *et al.* 1998; Goel *et al.* 2005) and from other general populations (e.g. Partonen, 1994; Partonen & Lönnqvist, 2000). The auditory stimulus also improved depression and overall affect, as measured by total mood disturbance. These results agree with previous studies demonstrating that various kinds of musically based auditory stimuli reduce depression and anger, and improve overall mood state in normal subjects (Fisher & Greenberg, 1972; Smith & Noon, 1998; Unwin *et al.* 2002; Goel, 2006) and in depressed patients (Lai, 1999; Tornek *et al.* 2003; Hsu & Lai, 2004). Both the auditory stimulus and bright light also reduced anger after 15 and 30 min of exposure, respectively.

Similarly, high-density negative ions reduced depression, as has been found in clinical trials (Terman & Terman, 1995; Terman *et al.* 1998; Goel *et al.* 2005) and in normal populations (Buckalew & Rizzuto, 1982; Baron *et al.* 1985). Furthermore, ions produced this decrease as rapidly as bright light, within 15 min, in contrast to clinical populations in which the antidepressant effects of high-density ions are slower to emerge using weekly assessments (Terman *et al.* 1998; Goel *et al.* 2005). Such a difference may be due to morning *v.* evening administration time, the severity of depression or weekly sampling limitations. High-density ions did not reduce anger scores, unlike Baron and colleagues' study (1985), although this group exhibited the lowest anger scores compared with all other conditions, leaving little room for improvement.

Although 15–30 min is sufficient to produce mood changes in depression, total mood disturbance and anger, alertness measures such

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as vigor, fatigue and sleepiness scores, failed to change compared with the placebo. Similarly, other studies found no such effects after bright light exposure (French *et al.* 1990; Kasper *et al.* 1990; Dollins *et al.* 1993; Leproult *et al.* 1997; LaFrance *et al.* 1998). However, some studies demonstrate reduced sleepiness and fatigue, and improved vigor following bright light or auditory stimulus exposure (Dawson & Campbell, 1991; Daurat *et al.* 1993; Unwin *et al.* 2002; Åkerstedt *et al.* 2003; Phipps-Nelson *et al.* 2003; Rüger *et al.* 2003; Lowden *et al.* 2004; Goel, 2005, 2006). In our study, some measures may have been more easily altered than others within 30 min, such that alertness changes may not have been detected because of the short durations we employed. Furthermore, the absence of alertness changes may be due to administration time, since in some cases late-night or early-morning presentations are more alerting (Leproult *et al.* 1997; Foret *et al.* 1998). Finally, alertness increases may have been manifested in the form of counteractive declines in vigor, since the low-density ion control, but not the three other conditions, showed cumulative declines in vigor across test days.

Subjects perceived bright light as more intense and stimulating, while the auditory stimulus was perceived as more pleasant and elating, than the other stimuli. Mood changes can be separated from these post-exposure perceptions, since high-density ions reduced depression equivalently to bright light and the auditory stimulus, but showed lower ratings than these groups. Moreover, high-density ions were statistically indistinguishable from low-density ions on all perceptual measures, confirming the imperceptibility of ion concentrations (Yates *et al.* 1986) and the use of low-density ions as a suitable placebo control (Terman & Terman, 1995; Terman *et al.* 1998; Goel *et al.* 2005).

Subject bias did not confound mood changes since there were no expectation differences across test conditions, in agreement with our recent study (Goel *et al.* 2005). Furthermore, on average, our subjects predicted little to no change for all four stimuli, appreciably lower expectations than those for bright light or negative ions in clinical trials (Terman & Terman, 1995; Eastman *et al.* 1998; Terman *et al.* 1998; Goel *et al.* 2005). These lower numbers may reflect the nature of the study population, which was comprised of college students, none of whom entered the study seeking treatment or had prior knowledge of the stimuli. Expectations also did not differ across stimuli; similar ratings between bright light and negative ions have been reported previously (Eastman *et al.* 1998; Terman *et al.* 1998).

It is unlikely that the rapid mood changes produced by these stimuli represent placebo effects, independent of expectations. For example, studies using acute exposures to bright light have failed to find significant acute mood changes on the POMS in normal populations, arguing against a rapid placebo response (e.g. Kasper *et al.* 1989*a*; French *et al.* 1990). Since subjects were unfamiliar with these stimuli, they had no motivational or psychological preconceptions which typically contribute to a placebo effect. Moreover, since each group engaged in the same repetitive actions of filling out forms, assessing their mood, etc., this process was consistent across all conditions and therefore would not contribute to a cognitive-based placebo effect. Finally, the fact that a number of POMS variables (all rated on the same form) and the KSS did not change significantly by condition, argues against a uniform placebo effect.

Rapid mood changes occurred regardless of season of administration. This finding concurs with our recent trial, which failed to detect seasonal differences in response to light or negative ions in chronically depressed patients (Goel *et al.* 2005) and more broadly with findings of bright light's antidepressant effects in non-seasonally depressed patients (Kripke, 1998; Tuunainen *et al.* 2004; Golden *et al.* 2005). Interestingly, we did find seasonal differences in alertness: summer-tested subjects were more alert than autumn- or spring-tested subjects, while subjects tested in autumn showed more tension than those tested in the spring. We demonstrated similar seasonal differences in vigor and tension in another college population (Goel & Grasso, 2004) and other researchers have reported seasonal alertness and mood changes in the general population (Terman, 1988; Kasper *et al.* 1989*b*; Haggag *et al.* 1990; Ozaki *et al.* 1995; Nayyar & Cochrane, 1996; Harmatz *et al.* 2000; Palinkas *et al.* 2001). Such seasonal fluctuations in alertness may be due to

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a number of factors including increased sunlight exposure, higher temperatures, or changes in neurotransmitter or hormonal levels, during the summer compared with the autumn or spring.

Both depressed and non-depressed subjects showed rapid, positive mood changes with the auditory stimulus, bright light and high-density negative ions. These groups, however, exhibited differential improvements in depression, tension, confusion and total mood disturbance across the 3-day period. Both groups had higher scores on day 1 than on days 2 and 3, and showed the largest declines between the first two testing days; however, depressed subjects showed sharper declines, indicating greater daily improvement in these measures regardless of condition. A longer daily exposure duration and/or longer course of exposure might elucidate depressed *v*. non-depressed condition differences in depression scores and other measures.

At present, the mood-enhancing mechanisms of action underlying the environmental stimuli used in this study remain unknown. Both serotonergic and catecholaminergic activation may mediate response to light therapy (reviewed in Neumeister, 2004), while negative ions may be mediated by both central and peripheral serotonergic activity (Charry, 1987). Although the mechanism of action of the specific auditory stimulus used in this study has not been investigated, other musically based auditory cues increase epinephrine and norepinephrine, as well as melatonin (Kumar *et al*. 1999).

A limitation of this study was that formal psychiatric diagnoses, for current or past Axis I disorders, using Structured Clinical Interview for DSM-IV Axis I Disorders-based (SCID; First *et al*. 1995) assessment criteria could not be performed. However, the primary intent of this study was to test non-drug stimuli in a young, healthy, normal, college population, who showed a spectrum of depressive symptoms, without major concern for severe clinical issues. The population was intended to represent subjects outside of the clinical setting, such that the study ranked high on external validity.

Bright light and high-density ions, already established treatments for SAD and non-seasonal depression, also produce rapid mood changes in a young college-age population comprised of subjects who show a range of depressive symptoms. Furthermore, a pleasant, arousing auditory stimulus produced comparable, and in some cases, faster changes than either bright light or negative ions. Thus, these stimuli can be used singularly or adjunctively, as has been done for bright light and exercise (Leppämäki *et al*. 2002*a*, *b*) to improve mood in normal populations.

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DECLARATION OF INTEREST

None.

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