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**Premenstrual mood and empathy after a single light therapy session**

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**Abstract**

To examine whether acute changes in cognitive empathy might mediate the impact of light therapy on mood, we assessed the effects of a single light-therapy session on mood and cognitive empathy in 48 premenstrual women, including 17 who met Premenstrual Symptoms Screening Tool criteria for moderate-to-severe premenstrual syndrome / premenstrual dysphoric disorder (PMS/PMDD). Using a participant-blind between-groups design, 23 women underwent 30 minutes of morning light therapy (5000 lux; blue-enriched polychromatic light, 17000 K) while 25 women had a sham session (200 lux, polychromatic light, 5000 K). We administered the Positive Affect and Negative Affect Schedule and the Affect Grid right before and after the intervention, and 60 minutes later upon completion of a computerized empathic accuracy task. There were no significant effects of light condition on cognitive empathy as assessed using the computer task. Nonetheless, bright light reduced negative affect, specifically in women not using hormonal contraceptives. No effects of bright light on mood were observed in women who were using contraceptives. If a single light-therapy session does not alter cognitive empathy, then cognitive empathy may not mediate the impact of light therapy on mood in premenstrual women.

**Keywords**

Empathy; Gender; Light therapy; Mood; Premenstrual Syndrome; Seasonal Affective Disorder; Women

## 1. Introduction

For women with distressing premenstrual symptoms, several treatment options exist (Pearlstein and Steiner, 2008; Rapkin, 2003). The ideal intervention should work rapidly once premenstrual symptoms emerge, have few side effects, and not require continuation during other ovulatory cycle phases. While light therapy is a potential candidate, there have been few controlled studies (Krasnik et al., 2005). As acute psychological changes might mediate its impact on mood, we assessed the effects of a single morning light therapy session on mood and cognitive empathy in 48 premenstrual women.

Women experience varying degrees of somatic and psychological changes during the ovulatory cycle. Distressing premenstrual symptoms can result in a diagnosis of premenstrual syndrome (PMS) or premenstrual dysphoric disorder (PMDD). In PMS functional impairment may be mild and related to either somatic or psychological symptoms; in PMDD at least one psychological symptom is markedly present and associated with functional impairment (American Psychiatric Association, 2013). PMS affects ~20% of reproductive women; for PMDD this is 2-8% (Borenstein et al., 2003; Dennerstein et al., 2012; Epperson et al., 2012).

In the current fifth edition of the Diagnostic and Statistical Manual of Mental Disorders, PMDD is considered a depressive disorder. Women with PMDD have a relatively high risk of being diagnosed with another depressive disorder as well; the risk of co-morbidity may be as high as 69% (Kim et al., 2004) and includes major depressive disorder with seasonal pattern, or seasonal affective disorder (SAD; Rosenthal et al., 1984b). PMDD has been associated with worse mood and social functioning in winter compared to summer (Maskall et al., 1997), which suggests there is a link with SAD. Similarly, the prevalence of PMDD among women with SAD is many times higher than among women without a depressive disorder (Praschak-Rieder et al.,

2001). A positive correlation between seasonality and premenstrual symptom severity has also been found in non-clinical samples (Portella et al., 2006).

Light therapy, which involves controlled exposure to bright light for at least 30 minutes, is the first choice for SAD treatment (Gordijn et al., 2012; Meesters et al., 2011; Rosenthal et al., 1984b; Winkler et al., 2006). It is also considered acceptable for non-seasonal depression (Even et al., 2008; Lam et al., 2016; Terman and Terman, 2005). Moreover, a review of four placebo-controlled studies of light therapy for PMDD found small to large effect sizes for its impact on depressive symptoms (Krasnik et al., 2005). However, the largest effect was observed in an unpublished study that did not conceal the sham condition from the active condition, which suggests expectancies may have driven the effect. This has previously been found in SAD patients (Knapen et al., 2014). Nonetheless, many studies of SAD and non-seasonal depression support the use of light therapy for depressive disorders (Golden et al., 2005).

The working mechanism of light therapy is thought to involve serotonin. Experimental evidence comes from acute tryptophan depletion (ATD) studies in which brain serotonin levels were temporarily reduced (Nishizawa et al., 1997). In SAD patients, ATD reverses the antidepressant effect of light therapy (Lam et al., 1996; Neumeister et al., 1997). ATD may also worsen mood in healthy women (Ruhe et al., 2007). Two studies have found that bright light exposure during ATD can prevent this mood worsening (aan het Rot et al., 2008; Defrancesco et al., 2013). Importantly, as both studies lasted only several hours, bright light exposure can apparently have fairly immediate effects on mood.

In line with this, Leppamaki et al. (2003) exposed nurses repeatedly to brief bright light periods during their night shift and found they reported less stress. When Goel and Etwaroo (2006) exposed students to evening bright light, within 30 minutes their depression scores were

lower. Moreover, in several studies a single light therapy session had rapid effects on the circadian rhythm of melatonin secretion, subcortical brain responsiveness, sleepiness, fatigue, core body temperature, and heart rate (Parry et al., 2011; Ruger et al., 2006; St Hilaire et al., 2012; Vandewalle et al., 2006).

While most placebo-controlled studies on light therapy for depression have involved at least one week of daily therapy sessions and only tested participants before and after treatment, even a single session has been found to improve mood in SAD patients (Reeves et al., 2012). This finding confirms anecdotal reports of antidepressant effects of light therapy after 2-4 days (Rosenthal et al., 1985), within 5 hours (Kripke et al., 1983), and within 1 hour (Sher et al., 2001). In the latter study, early improvement predicted clinical benefit after 1-2 treatment weeks.

Depressive disorders have been associated with interpersonal problems. Social interaction impairments (Baddeley et al., 2013) and social withdrawal (Goel et al., 2002) are common. Patients often exhibit social skill deficits (Hames et al., 2013). For example, they experience high distress when others are suffering, considered a form of affective empathy, and are less able to interpret others' affective states, i.e. cognitive empathy is impaired (Schreier et al., 2013).

Derntl et al. (2013) studied empathy in menstrual and premenstrual women. The two groups scored comparably on several trait questionnaires of affective and cognitive empathy. Nonetheless, the premenstrual group responded faster to sentences describing others in emotional situations than the menstrual group, and performed worse on an emotion recognition task. This suggests affective empathy may increase premenstrually, and cognitive empathy may decrease.

Depressed individuals who benefit from light therapy experience improved mood and global functioning. However, no prior studies have considered the effects of light therapy on specific aspects of interpersonal functioning such as empathy. In one relevant study, healthy men

received light therapy and underwent functional brain imaging to measure the effects on “threat-related brain function” (Fisher et al., 2014), but no behavioral data were reported.

The objective of our study was to answer some unresolved questions on light therapy. Primarily, as bright light exposure may have rapid positive effects on mood in both healthy women and individuals with depressive disorders, we examined the impact of a single light therapy session on mood in premenstrual women with complaints indicating a premenstrual disorder. Previous light-therapy studies have often been limited by their within-subject design, with participants receiving the active treatment and the sham treatment in counterbalanced order. This compromises the blind and may yield different expectations about the active treatment in the two treatment-order groups. We employed a between-groups design and did not inform participants about the two conditions. We hypothesized that women who received the active treatment (light therapy) would show a larger mood improvement than women who received the sham treatment.

A second aim was to study the acute effects of light therapy on cognitive empathy. If cognitive empathy is relatively poor in the premenstrual phase, then it might be improved by light therapy. Consequently, after the intervention participants completed a cognitive empathy task. We hypothesized that women who received light therapy would perform better on this task than women who did not.

## **2. Methods**

### *2.1. Participants*

The local Psychology Ethics Committee approved the study. Healthy women aged 18-40 years with regular ovulatory cycles, no current or past psychological/psychiatric treatment, no current

use of confounding medication (e.g., antidepressants, antibiotics), no light hypersensitivity, no history of allergic reactions to ECG electrode stickers, and the ability to not smoke during the study, were recruited using a participant pool and advertisements in university buildings, public spaces, and local newspapers. Fifty-six women were excluded based on age ( $n=12$ ), ovulatory cycle ( $n=16$ ), treatment history ( $n=16$ ), medication use ( $n=8$ ), or light sensitivity ( $n=4$ ). Twenty-eight included women did not participate due to time constraints.

There were 50 participants but 2 participants were dropped from the analyses due to late menstruation. The data analyses were thus conducted on 48 participants.

## 2.2. Materials

We used the Premenstrual Symptoms Screening Tool (PSST, Steiner et al., 2003) to detect PMS and PMDD and to assess severity of premenstrual symptoms; to create a continuous score we summed items 1-14. We used the Global Seasonality Scale (GSS) of the Seasonal Pattern Assessment Questionnaire (SPAQ, Rosenthal et al., 1984a) to assess sensitivity to seasonal variation in day length and the Quick Inventory of Depressive Symptoms (QIDS, Rush et al., 2003) to assess severity of depression. We administered the Munich Chronotype Questionnaire (MCTQ, Roenneberg et al., 2003) to assess chronotype, defined by mid-sleep on work-free days corrected for oversleep due to the sleep debt accumulated during work days (MSFsc; Roenneberg et al., 2004).

Two complementary questionnaires measured changes in mood state. The affect grid (Russell et al., 1989) assessed affect valence and affect arousal; scores ranged from 1 (most unpleasant or lowest arousal) to 11 (most pleasant or highest arousal). The Positive Affect and Negative Affect Schedule (PANAS, Thompson, 2007) assessed a variety of mood states. Item scores ranged from 1 (not at all) to 5 (extremely). Positive affect (PA) and negative affect (NA)



scores were based on the average of 10 positive and 10 negative items, respectively. We assessed side effects by adding dizziness, headache, eye strain, and nausea, to the PANAS items.

To assess cognitive empathy, we used an empathic accuracy (EA) task programmed in E-Prime 2.0 (Psychology Software Tools, Sharpsburg, PA). During the task participants watched 20 video clips of 9 targets narrating positive and negative autobiographical situations and, while watching, used a dial to continuously rate how the targets were feeling while narrating. Targets previously rated the clips to indicate how they were feeling while narrating. Empathic accuracy scores were calculated per participant per clip following van der Rot and Hogendoorn (2014), who previously found task performance to vary by targets' emotional expressivity and by participant levels of autism spectrum traits.

### *2.3.Procedures*

Advertisements invited women with premenstrual complaints to complete questionnaires and a computer task and be exposed to a 'special lamp.' Respondents received a brief study explanation and underwent a telephone screening. Selected women visited the laboratory at 9-9.30am, 1-5 days before their expected menstruation, and read an information sheet stating that we aimed to examine the effect of light on coping with premenstrual stress. Women who decided to participate provided written informed consent.

Testing took place between November and May, in a room with the window blinds and curtains closed. At baseline the room illumination at eye level was ~220 lux in sitting position. Participants first completed the mood state questionnaires (T1). After placing electrodes on the chest for continuous electrocardiography (data not presented), we randomly assigned participants to one of the light conditions (see Table 1 for details concerning light intensity, light color, color enrichment, and color temperature). We debriefed participants about this after the study. The

EnergyLight HF3308 and HF3319/01 (Philips, Eindhoven, Netherlands) were used for the active and sham sessions, respectively. A session lasted 30 minutes, during which participants completed the PSST, SPAQ, MCTQ, and QIDS. Immediately afterwards they completed the mood state questionnaires again (T2). This was followed by the EA task and, 60 minutes after T2, by final mood state questionnaires (T3). At T2 and T3 participants also produced a saliva sample for cortisol assessment (data not presented). At the end, participants were remunerated and instructed to inform us of the actual date of their following menstruation.

#### *2.4.Data analyses*

We used SAS 9.3 for Windows (SAS Institute, Cary, NC) for all analyses. The  $\alpha$  was set at 0.05.

In our primary analyses we examined the effects of light therapy on mood and EA using hierarchical linear models with maximum likelihood estimation, following Kenward and Roger (1997) for computing the denominator degrees of freedom. For mood we considered Time (T1-T3), Condition (active, sham), and their interaction. For EA we considered Condition, Valence (positive, negative) and their interaction. Post-hoc simple contrasts included a Tukey-Kramer correction for multiple comparisons.

In secondary analyses we examined several moderators of the effect of Condition on mood and EA. Presence of PMS/PMDD was the first moderator (see Table 2) and a dichotomous variable. We added the main effect for the moderator variable, the Condition by moderator interaction, and the Condition by Time by moderator interaction (for the mood variables) or the Condition by Valence by moderator interaction (for EA). Subsequently we followed Baron and Kenny (1986) to examine if severity of PMS, seasonality, depression, and chronotype moderated the effect of Condition on mood and EA. Each of these four continuous moderator variables was centered to a mean of zero. We examined significant interactions involving one of these

moderators by estimating simple intercepts and slopes for predictor scores that were 1 standard deviation (SD) above or below the sample mean (“high” or “low”, respectively) and testing the significance of the difference between the slope estimates (Aiken and West, 1991). Finally, in response to a comment of an anonymous reviewer, we examined contraception as a (dichotomous) moderator of the effect of Condition on mood and EA. Findings are reported using estimated least-squares means and standard errors (SE).

### 3. Results

#### *3.1. Baseline data*

The final sample averaged 23.1 years in age. There were 30 hormonal contraceptive users, 6 smokers, and 17 cases of PMS including 1 with PMDD (see below). Mean scores on the GSS, QIDS, and MSFsc were 8.5 (SD 4.3), 8.2 (SD 3.6), and 7.4 (SD 7.2), respectively, indicating the sample was characterized by subsyndromal seasonality (Rosenthal et al., 1984a), mild depression (Rush et al., 2003), and a late chronotype (Antypa et al., 2016). There were no significant baseline differences between the two light groups, i.e. 23 women who received light therapy versus 25 women who underwent the sham session (Table 1).

According to the PSST, 17 women (35%) had moderate to severe PMS. This subgroup scored higher on the PSST and QIDS,  $t's > 5.32$ ,  $p's < 0.0001$ , indicating more severe premenstrual symptoms and higher depression levels than in the subgroup with no or mild PMS. The two subgroups had similar scores on the GSS and MSFsc,  $t's < 1.23$ ,  $p's > 0.22$ , indicating there were no significant between-group differences in seasonality and chronotype.

#### *3.2. Effect of light condition on mood state*

The outcomes of the primary analyses for the mood state variables are subsequently presented.

### 3.2.1. *Positive affect.*

There were no significant effects for Condition,  $F(1,48)=1.19$ ,  $p>0.28$ ,  $d=0.31$ , and for the Time by Condition interaction,  $F(2,96)=0.25$ ,  $p>0.78$ . There was a main effect for Time,  $F(2,96)=7.23$ ,  $p<0.002$ ,  $d=0.55$ . Post-hoc testing revealed a decrease in PA from T1 to T2,  $t(96)=3.80$ ,  $p<0.0004$ ,  $d=0.78$ . The changes in PA from T1 to T3,  $t(96)=1.98$ ,  $p>0.12$ ,  $d=0.40$ , and from T2 to T3,  $t(96)=1.82$ ,  $p>0.16$ ,  $d=0.37$ , were not significant.

### 3.2.2. *Negative affect.*

There were no significant effects for Condition,  $F(1,48)=0.04$ ,  $p>0.83$ ,  $d=0.06$ , and for the Time by Condition interaction,  $F(2,96)=0.13$ ,  $p>0.87$ . There was a main effect for Time,  $F(2,96)=13.89$ ,  $p<0.0001$ ,  $d=0.55$ . Post-hoc testing revealed a decrease in NA from T1 to T2,  $t(92)=4.41$ ,  $p<0.0001$ ,  $d=0.90$ , and from T1 to T3,  $t(92)=4.70$ ,  $p<0.0001$ ,  $d=0.98$ . The change in NA from T2 to T3 was not significant,  $t(92)=0.29$ ,  $p>0.77$ ,  $d=0.06$ .

### 3.2.3. *Affect valence.*

There were no significant effects for Condition,  $F(1,48)=1.36$ ,  $p>0.24$ ,  $d=0.34$ , Time,  $F(2,96)=2.57$ ,  $p>0.08$ ,  $d=0.33$ , and their interaction,  $F(2,96)=1.43$ ,  $p>0.24$ .

### 3.2.4. *Affect arousal.*

There were no significant effects for Condition,  $F(1,48)=1.87$ ,  $p>0.17$ ,  $d=0.40$ , Time,  $F(2,96)=2.99$ ,  $p>0.05$ ,  $d=0.36$ , and their interaction,  $F(2,96)=0.50$ ,  $p>0.60$ .

In sum, our primary analyses suggested there was no impact of the light therapy session versus the sham session on mood state.

### 3.3. *Effect of light condition on empathic accuracy*

The mean EA score ( $r$ ) across all 960 participant / video clip combinations was 0.59.

There were no significant effects for Condition,  $F(1,48)=0.79$ ,  $p>0.37$ ,  $d=0.26$ , and for the Valence by Condition interaction,  $F(1,225)=0.19$ ,  $p>0.66$ . There was a main effect for Valence,  $F(1,225)=199.55$ ,  $p<0.0001$ ,  $d=1.88$ . Participants obtained higher EA scores when watching positive clips (mean  $r=0.71$ ) compared to negative clips (mean  $r=0.45$ ). Given the large size of this within-subject effect, we analyzed the data for positive and negative film clips separately. The effect for Condition was not significant for the positive clips,  $F(1,47)=0.47$ ,  $p>0.49$ ,  $d=0.20$ , nor for the negative clips,  $F(1,104)=0.16$ ,  $p>0.69$ ,  $d=0.08$ . These findings were unchanged after controlling for target emotional expressivity (results not shown).

In sum, our primary analyses suggested there was no impact of the light therapy session versus the sham session on EA.

### 3.4. *Secondary analyses of mood and empathy*

Results of the secondary analyses for the mood variables are summarized in Table 2. The lack of significant moderator by Condition by Time interactions when the PSST, QIDS, or GSS were entered as moderators suggests there were no differential effects of the light therapy session versus the sham session on mood in participants with higher versus lower levels of PMS severity, depression, or seasonality. Similarly, while the moderator by Condition by Time interaction was significant when MSFsc was the moderator, post-hoc testing of the MSFsc by Condition by Time interaction revealed no significant differences in levels of NA between participants with earlier versus later chronotypes at any of the three time points ( $p$ 's  $>0.22$ ). In contrast, however, post-hoc testing of the Contraception by Condition by Time interaction revealed a decrease in NA from T1 to T2 in the subgroup who underwent light therapy and did not use hormonal contraceptives,

$t(96) = 4.23, p < 0.0003, d = 0.86$ ; there was no significant change in NA over time in the other three subgroups, see Figure 1. Thus, there was a differential effect of the light therapy session versus the sham session on mood in two subgroups defined by their contraception status.

The results of the secondary analyses for EA are summarized in Table 3. There was no significant main effect for any of the potential moderators on EA,  $p's > 0.14, d's < 0.44$ , and the moderator by Condition interactions,  $p's > 0.07$ , and the moderator by Condition by Valence interactions,  $p's > 0.07$ , were never significant. Similarly, when we repeated the analyses for positive and negative clips separately, there were no significant effects for Condition,  $F's < 0.52, p's > 0.47$ , and no significant moderator by Condition interactions,  $F's < 4.04, p's > 0.05$ . These findings did not change after adding target emotional expressivity as a covariate (results not shown). In conclusion, there were no differential effects of the light therapy session versus the sham session on EA, even when between-person differences in the presence or absence of moderate to severe PMS/PMDD, PMS severity, seasonality, depression, chronotype, and contraceptive use were taken into account.

### 3.5. Side effects

#### 3.5.1. Dizziness.

There were no significant effects for Condition,  $F(1,48)=0.56, p>0.45, d=0.22$ , and for the Condition by Time interaction,  $F(2,96)=0.74, p>0.48$ . There was a main effect for Time,  $F(2,96)=10.25, p<0.0001, d=0.65$ . Post-hoc testing revealed that dizziness decreased from T1,  $M=1.48, SE=0.10$ , to T3,  $M=1.21, SE=0.10, t(96)=-3.20, p<0.006, d=0.65$ , and from T2,  $M=1.58, SE=0.10$ , to T3,  $t(96)=-4.37, p<0.0001, d=0.89$ . The change from T1 to T2 was not significant,  $t(96)=1.17, p>0.47, d=0.24$ .

#### 3.5.2. Nausea.

There was a main effect for Time,  $F(2,96)=4.76$ ,  $p<0.02$ ,  $d=0.45$ , but none of the post-hoc contrasts were significant,  $t's<1.94$ ,  $p's>0.13$ ,  $d's<0.40$ . There was also a significant main effect for Condition,  $F(1,48)=6.37$ ,  $p<0.02$ ,  $d=0.73$ . Participants in the active condition were in general more nauseous,  $M=1.61$ ,  $SE=0.15$ , than participants in the sham condition,  $M=1.39$ ,  $SE=0.14$ . However, the Time by Condition interaction was not significant,  $F(2,96)=0.23$ ,  $p>0.79$ , suggesting there was no differential effect of the light therapy session versus the sham session on nausea.

### 3.5.3. Headache.

There were no significant effects for Condition,  $F(1,48)=2.82$ ,  $p>0.09$ ,  $d=0.48$ , Time,  $F(2,96)=1.68$ ,  $p>0.19$ ,  $d=0.26$ , and their interaction,  $F(2,96)=2.56$ ,  $p>0.08$ .

### 3.5.4. Eye problems.

There were no significant effects for Condition,  $F(1,48)=1.16$ ,  $p>0.28$ ,  $d=0.31$ , Time,  $F(2,96)=2.27$ ,  $p>0.10$ ,  $d=0.31$ , and their interaction,  $F(2,96)=0.23$ ,  $p>0.79$ .

In sum, there was no evidence that the light therapy induced any side effects.

## 4. Discussion

A single, 30-minute light therapy session at 5000 lux of blue-enriched polychromatic light can improve mood in premenstrual women. Specifically, while there were no significant changes in mood in contraceptive users who underwent the light therapy session, we found a decrease in negative affect in women who were not using hormonal contraceptives (Figure 1). In contrast, we found no evidence that the light therapy session altered cognitive empathy.

We had hypothesized that the light therapy session would improve mood and increase empathy because there is prior evidence that bright light exposure can have fairly immediate

psychological effects (Goel and Etwaroo, 2006; Reeves et al., 2012; Sher et al., 2001). Most relevant is the study by Goel and Etwaroo (2006), which also used a between-groups design ( $n=29-30$  per group) in a non-clinical sample. Goel and Etwaroo (2006) compared the effects of polychromatic bright light (10000 lux for 30 minutes), birdsong plus classical music, high-density negative ions, and low-density negative ions (placebo). Independent of baseline depression levels, mood improvement was seen within 15 minutes after starting the light intervention. This effect was also seen in the other two active conditions, but not in the placebo condition. As there were no significant differences in expectancy ratings between the four groups, these results provide good evidence that 30 minutes of polychromatic bright light can have an immediate positive effect on mood. Our findings add to those of Goel and Etwaroo (2006) and suggest light intensities lower than 10000 lux can have similar effects.

Another between-groups study, on the frequency and intensity of common side effects (Botanov and Ilardi, 2013), found no difference between an active condition (30 minutes of polychromatic light at 10000 lux) and a sham condition (red light at 450 lux). A small but significant increase in eye strain was observed in both groups. The active condition did not involve color enrichment. While blue-enriched bright light is thought to be as effective in SAD treatment as non-enriched bright light, it is superior in eliciting emotional processing (Gordijn et al., 2012; Meesters et al., 2011; Vandewalle et al., 2010). Thus, it may be speculated that the color enrichment used in our study contributed to the rapid mood improvement that was seen.

Differences in sample characteristics may also help explain why the findings of Botanov and Ilardi (2013) differed from our findings. Botanov and Ilardi (2013) studied participants of both genders and did not report on hormonal contraceptive use in the women. We focused on premenstrual women and found that mood only improved in those women not using hormonal



contraceptives. This group had higher NA levels at the start of the study (Figure 1) and thus more room for mood improvement during the light therapy session. As hormonal contraceptives stabilise mood (Oinonen and Mazmanian, 2002), they may have precluded an effect on mood in the women who used them, both in our study and in the study by Botanov and Ilardi (2013).

There have been two relevant studies in SAD patients. In one study (Reeves et al., 2012) a single 60-minute, 10000-lux light therapy session yielded a modest mood improvement compared to a 10-lux placebo. In the other study (Sher et al., 2001) a single 60-minute, 8200-lux light therapy session reduced atypical symptoms by on average 50%; this predicted depression reduction after two weeks of treatment. These two studies differed from ours in that participants presumably had higher baseline NA levels, because they were clinically depressed, and the light therapy session lasted twice as long. Besides, in terms of light intensity, one study (Reeves et al., 2012) used a more potent active condition and a less potent sham condition, thereby increasing the likelihood of a condition effect. Nonetheless, we found a significant effect of the light therapy session on mood. Thus, as previously suggested (aan het Rot et al., 2008; DeFrancesco et al., 2013), bright light exposure can lead to rapid mood improvement even in non-clinical samples and at a relatively moderate light intensity.

An important strength of our study was the between-groups design. To minimize differences in expectancies between the groups, we did not inform participants about their randomization into one of two conditions. It is unlikely that their expectancies changed during the session, particularly since polychromatic light was used in both conditions. In contrast, one of the SAD studies mentioned in the previous paragraph did not use a placebo (Sher et al., 2001). Participants in this study may have reported early reductions in symptoms simply because they expected the treatment to work. Similarly, while the other SAD study used a within-subject

design with a placebo control (Reeves et al., 2012), the differences in light intensity and color between the active and sham conditions were large, so participants likely did not remain blind and their differential expectancies about the active versus sham conditions might have contributed to the mood effect that was reported.<sup>1</sup> However, given that our study yielded similar findings even though participant expectancies were presumably similar across the two conditions, the findings of the two SAD studies cannot be explained by expectancy effects alone.

A limitation of our study is that the two light conditions not only varied in light intensity and color enrichment, but also in color temperature (17000 K in the active condition versus 5000K in the sham condition). Nevertheless, this would mostly have been problematic if we had used a within-subject design. As we used a between-groups design, the difference in color temperature probably did not confound the effects of bright light exposure.

Another limitation is that the PANAS has not been validated in PMS studies. Additionally, no formal psychological or psychiatric assessment was conducted in the study sample. Therefore the presence of common disorders such as depression could not be ruled out. Finally, our study is limited by the use of a non-treatment-seeking sample of women with varying levels of premenstrual symptoms as per retrospective self-report. The sample was characterized by subsyndromal seasonality, mild depression, and a late chronotype, all of which have previously been associated with mood improvement after light therapy (Hsu et al., 2014; Knäpen et al., 2016; Levitt et al., 2002). Nonetheless, the possibility remains that our study suffered from a floor effect, at least among the women using hormonal contraceptives.

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<sup>1</sup> While Reeves et al. (2012) reported that participant expectancies did not differ between the conditions, they did not consider the order in which the conditions were administered, thereby masking the possibility that participant expectancies about each condition varied by order.

Future studies might examine the effects of a single bright light therapy session versus placebo in clinical samples consisting of women with a diagnosis of PMDD who either use or do not use hormonal contraceptives. We recommend using a between-groups design, carefully controlling and tracking patient expectancies, comparing the active condition with a sham condition and with no intervention, and studying the effects of light therapy on components of psychological functioning other than mood.

### **Conflict of Interest Statement**

M. aan het Rot, K. Miloserdov, and A.L.F. Buijze, declare no conflicts of interest. Y. Meesters has received research funding and been a consultant for The Litebook Company Ltd. M.C.M. Gordijn is a consultant for Philips Consumer Lifestyle, Drachten, Netherlands, and founder and director of Chrono@Work, Groningen, Netherlands.

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## Tables

Table 1. Details on the two light conditions and scores on various baseline variables.

	Sham session (n = 25)	Light therapy session (n = 23)	$X^2$ test or $t$ test
<i>Condition details</i>			
Light color	Polychromatic	Polychromatic	
Color enrichment	None	Blue	-
Color temperature	5000 K	17000 K	-
Photopic Light intensity	200 lux	5000 lux	-
Lamp-to-eyes distance <sup>1</sup>	50-60 cm	30-40 cm	-
<i>Demographic variables</i>			
Age in years (M,SD)	23.9 (5.9)	22.2 (3.9)	1.21
Body mass index (M,SD)	20.9 (8.2)	19.7 (6.7)	0.57
Hormonal contraceptive use ( $n$ )	14	16	0.94
Smoker ( $n$ )	4	2	0.58
Right-handedness ( $n$ )	20	22	2.68
<i>Premenstrual variables</i>			
PSST score (M,SD)	30.0 (6.8)	29.8 (7.6)	0.06
Moderate to severe PMS ( $n$ )	10	7	0.48
PMDD ( $n$ )	1	0	0.94
Days before menstruation (M,SD)	2.7 (1.6)	3.0 (1.8)	-0.66
<i>Chronobiology</i>			

GSS score (M,SD)	8.4 (4.7)	8.6 (4.0)	-0.10
MSFsc (M, SD) <sup>2</sup>	7.8 (7.5)	6.8 (7.0)	0.48
Sunrise time (M, range)	7:28 (5:43-8:49)	7:30 (5:53-8:48)	0.24
<i>Depression and mood state</i>			
QIDS score (M,SD)	8.8 (3.0)	7.5 (4.2)	1.26
Positive affect score (M,SD)	2.7 (0.6)	2.5 (0.7)	1.30
Negative affect score (M,SD)	1.5 (0.4)	1.5 (0.6)	-0.04
Affect valence score (M,SD)	7.1 (2.4)	6.8 (2.7)	0.40
Affect arousal score (M,SD)	5.6 (1.9)	4.9 (2.0)	1.24
<i>Side effects</i>			
Dizziness	1.4 (0.7)	1.6 (0.9)	-1.04
Eye strain	1.5 (0.9)	1.7 (1.0)	-0.64
Headache	1.2 (0.4)	1.5 (0.9)	-1.24
Nausea	1.2 (0.6)	1.6 (1.0)	-1.77

*Note.* M = mean, SD = standard deviation. PSST = Premenstrual Symptoms Screening Tool.

PMS = premenstrual syndrome. PMDD = premenstrual dysphoric disorder. GSS = Global Seasonality Score. QIDS = Quick Inventory of Depressive Symptoms. <sup>1</sup>Lamp-to-eyes distance differed between the two conditions to increase the difference in light exposure. <sup>2</sup>Missing MSFsc scores were imputed with the group mean for 2 participants in the sham group and 1 participant in the light therapy group.

Table 2. Time, condition, and the two-way interaction as predictors of mood state.

	Positive affect	Negative affect	Affect valence	Affect arousal
<i>Moderator: Presence of PMS/PMDD</i>				
Condition	1.75	0.65	2.53	1.15
Time	5.80**	12.62***	2.63	2.10
Condition by Time	0.52	0.13	0.88	0.42
PMS	4.09*	16.77***	10.48**	0.25
PMS by Condition	0.03	0.39	0.04	0.95
PMS by Time	0.31	0.03	0.37	0.67
PMS by Condition by Time	1.37	0.03	1.34	0.23
<i>Moderator: Severity of PMS (assessed using PSST)</i>				
Condition	1.40	0.07	1.75	1.96
Time	7.81***	14.02***	2.94	3.03
Condition by Time	0.28	0.13	1.65	0.52
PSST	4.86*	8.03**	8.67**	1.63
PSST by Condition	1.23	2.54	1.86	1.59
PSST by Time	1.51	0.54	4.63*	0.54
PSST by Condition by Time	2.87	0.00	2.07	0.09
<i>Moderator: Seasonality (assessed using GSS)</i>				
Condition	1.21	0.04	1.36	1.94
Time	7.71***	14.34***	2.75	3.01
Condition by Time	0.25	0.13	1.48	0.52

GSS	0.12	0.79	0.05	0.52
GSS by Condition	0.01	0.82	0.39	0.26
GSS by Time	2.92	0.38	3.41*	0.38
GSS by Condition by Time	0.67	0.70	0.02	0.12
<i>Moderator: Depression (assessed using QIDS)</i>				
Condition	1.88	0.95	5.05*	1.38
Time	7.05**	13.46***	2.82	2.81
Condition by Time	0.69	0.08	1.68	0.71
QIDS	1.76	14.05***	19.21***	1.09
QIDS by Condition	0.85	3.25	1.12	1.05
QIDS by Time	2.88	1.06	2.63	1.18
QIDS by Condition by Time	0.15	1.32	0.07	0.18
<i>Moderator: Chronotype (assessed using MSFsc)</i>				
Condition	1.04	0.03	1.47	1.96
Time	7.54**	18.38***	2.85	2.86
Condition by Time	0.19	0.11	1.33	0.52
MSFsc	1.53	0.34	0.17	0.06
MSFsc by Condition	0.28	1.55	1.33	1.53
MSFsc by Time	0.84	3.74	0.69	0.57
MSFsc by Condition by Time	0.81	7.43**	0.82	0.97
<i>Moderator: Hormonal contraceptive use</i>				
Condition	1.68	0.40	1.98	1.75
Time	6.77**	20.31***	3.79*	2.18

Condition by Time	0.16	0.43	1.83	0.73
Contraception	3.84	0.06	3.82	0.24
Contraception by Condition	0.04	3.23	0.00	0.04
Contraception by Time	0.17	3.24*	1.53	0.53
Contraception by Condition by Time	0.21	3.98*	1.49	0.62

Note. \* $p < 0.05$  \*\* $p < 0.01$  \*\*\* $p < 0.001$ . For acronyms see Table 1.



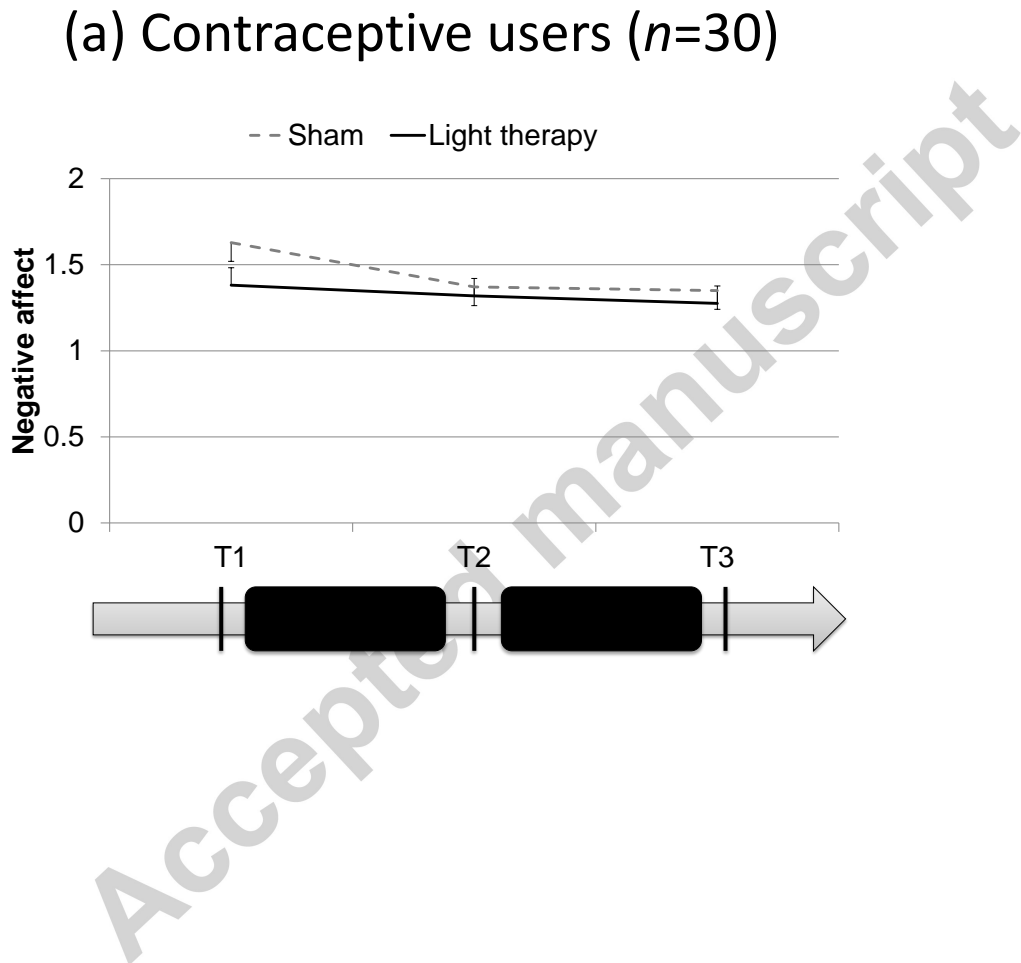
Table 3. Condition, valence, and the two-way interaction as predictors of empathic accuracy

	Moderators					
	PMS	PSST	GSS	QIDS	MSFsc	Contraception
Condition	0.21	0.84	0.85	0.66	0.36	0.35
Valence	169.64***	201.72***	198.95***	191.98***	199.24***	175.34***
Condition by	0.14	0.18	0.20	0.02	0.13	0.04
Valence						
Moderator	0.66	0.08	0.13	0.13	0.12	0.21
Moderator by	1.15	3.31	3.26	1.22	0.01	1.74
Condition						
Moderator by	2.22	0.73	0.31	2.22	0.81	0.27
Valence						
Moderator by	0.14	3.25	0.04	0.22	1.44	0.26
Condition by						
Valence						

Note. \*\*\* $p < 0.001$ . For acronyms see Table 1.

**Figure legends**

Figure 1. Changes in negative affect over time in (a) contraceptive users versus (b) non-users who underwent light therapy or a sham session



## Highlights

- Using a participant-blind between-subjects design, premenstrual women underwent morning light therapy or a sham session.
- Mood was assessed using the Positive Affect and Negative Affect Schedule and the Affect Grid.
- A computerized empathic accuracy task was used to assess cognitive empathy.
- Cognitive empathy was not significantly altered after the light-therapy session.
- Light therapy improved mood in women not using hormonal contraceptives.