# EXPOSURE TO BRIGHT LIGHT AND SOCIAL INTERACTIONS IN EVERY-DAY LIFE IN HEALTHY MILDLY SEASONAL PEOPLE

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## ABSTRACT

We examined the effects of bright light on social interaction and mood in healthy individuals with mild seasonality. In a cross-over design, 38 mildly seasonal individuals received three weeks of bright light and three weeks of placebo (low-density negative ions). Using an event-contingent method participants recorded their mood and behaviours during social interactions and wore a light-sensor actigraphy at the wrist to monitor adherence to home based light exposure. During light administration, 23 participants adhered to the light protocol and exhibited more quarrelsome behaviours and no change in mood. Participants who provided no evidence of adherence had similar mood and social behaviour during both interventions. The results indicate the need for effective methods for determining adherence to the protocol in light studies. Furthermore, in individuals with mild seasonality light administration may not improve mood and may have adverse effects on social behaviour.

## ABRÉGÉ

Nous avons examiné les effets de la lumière forte sur les interactions sociales et l'humeur chez des individus sains avec un caractère saisonnier léger. En utilisant un plan d'étude croisé, 38 individus légèrement saisonniers ont été exposés à trois semaines de lumière forte et trois semaines d'un placebo (ions négatifs à intensité basse). En utilisant la méthode des événements liés (les participants ont enregistré leur humeur et comportement durant leurs interactions sociales et ont porté un détecteur de lumière au poignet pour vérifier leur adhérence à l'exposition à la lumière à la maison. Durant l'administration de la lumière, 23 participants ont adhéré au protocole de lumière et exhibé plus de comportements querelleurs et aucun changement d'humeur. Parmi les autres participants qui n'ont fourni aucune preuve d'adhérence, et leur humeur et comportement social étaient semblables pendant les deux interventions. Les résultats indiquent un besoin de méthodes efficaces pour déterminer l'adhérence au protocole de lumière. Qui plus est, chez les individus avec caractère saisonnier léger, il est possible que l'administration de lumière n'améliore pas l'humeur et exerce des effets adverses sur le comportement social.

# CHAPTER 1: INTRODUCTION

## 1.1 Overview

Bright light therapy is the recommended treatment for the disorder described in DSM-IV-TR as Major Depressive Disorder, Recurrent with Seasonal Pattern but labeled more often as seasonal affective disorder (SAD). Most of the existing literature found the effect of bright light to be equivalent to an antidepressant. Although only a small percentage of the population suffers from SAD, a significant percentage of the general population experiences some seasonal changes to their mood and behaviour. The effect of bright light administration on healthy individuals with mild sensitivity to changes in season is as yet inconclusive. Some studies found bright light improved mood and vitality, while other studies found bright light induced negative mood. It is however important to underline that despite the potential effect of light on mood and well-being found in some studies, no known studies have looked at the effect of light treatment on social behaviour. However, a recent naturalistic study found an association between greater exposure to bright light over short periods (a morning or afternoon) and not only improved mood but also decreased quarrelsome behaviour and increased agreeable behaviour. The aims of the study described in this thesis were to administer, during the winter, bright light and a plausible placebo, using a cross-over design, to people with mild seasonality in order to (i) study adherence to bright light exposure when a lamp is used at home, and (ii) see if bright light improves mood and social behaviour.

## 1.2 Seasonal variability in depression and other psychiatric disorders

Seasonal changes in mood and behaviour have been observed both among individuals with psychiatric illnesses and among the general population (Fossey & Shapiro, 1992). Seasonal patterns in symptom severity have also been documented with respect to their influence on various illnesses. Patients with depression and bulimia nervosa reported feeling worse in the winter than during other times of the year (Brewerton, Krahn, Hardin, Wehr, & Rosenthal, 1994; Levitan, Kaplan, & Rockert, 1996), whereas mania and suicide peak during summer (Kim et al., 2004). The most common form of mood disorder with a seasonal pattern is seasonal affective disorder (SAD). SAD is a subtype of mood disorder with recurrent major depressive episodes following a seasonal pattern according to DSM-IV-TR (American Psychiatric Association, 1994). In 1984, Rosenthal et al. systematically documented and described symptoms of SAD with a winter pattern among a group of 29 patients. These patients experienced hypersomnia, increased appetite (particularly carbohydrate craving), weight gain, lack of energy and loss of interest in socialization as well as depressed mood. These symptoms develop in fall and winter and fully remit during the spring and summer seasons. Epidemiological surveys using retrospective questionnaires or diagnostic interviews demonstrated that prevalence rates of SAD in the general population are between 1.2% to 9.7% in North America (Kasper, Wehr, Bartko, Gaist, & Rosenthal, 1989b*;* Levitt & Boyle, 2002; Levitt, Boyle, Joffe, & Baumal, 2000; Magnusson & Axelsson, 1993; Rosen et al., 1990), and that SAD is most commonly diagnosed in women of reproductive age (Chotai, Smedh, Johansson, Nilsson, & Adolfsson, 2004; Levitt et al., 2000; Rosen et al., 1990). SAD with a summer pattern has also been

verified, but primarily in countries with hot summer climates such as India (Avasthi et al., 2001), Philippines (Ito et al., 1992), Japan (Ozaki, Ono, Ito, & Rosenthal, 1995), and China (Han et al., 2000). Patients there experienced lowered mood, decreased energy and irritability, but their other symptoms are the opposite from those of winter depression; hyposomnia, decreased appetite, and weight loss.

Seasonal variability in mood and behaviour occurs in differing degrees in the population. A survey conducted in Maryland found that over 90% of the 416 respondents experienced some degree of change in mood and behaviour during the winter months. One-third of these individuals reported mild dysfunction and vegetative symptoms similar to individuals with SAD, while falling short of diagnostic criteria for major depression (Kasper et al., 1989b). Kasper et al. (1989b) described this condition as a subsyndromal form of seasonal affective disorder (S-SAD). With a majority of the population experiencing seasonal changes in mood and behaviour, seasonality has been considered part of a human norm occurring along a continuum, with individuals with clinical diagnosis of SAD at one end and individuals experiencing no seasonal influences whatsoever at the other.

### 1.3 Effect of bright light exposure in depressed patients

Bright light therapy is the recommended treatment for SAD. Many studies have found that bright artificial light administered before dawn and after sunset, in a manner mimicking the average summer day's photoperiod length, is an effective treatment for SAD (Michalon, Eskes, & MateKole, 1997; Rosenthal et al., 1985; Rosenthal et al., 1984; Schwartz et al., 1997). However, other studies have found bright light (>1000 lux) to be either equivalent to placebo light control (≤300 lux) in that both conditions reduce

depressive symptoms in SAD patients (Grota, Yerevanian, Gupta, Kruse, & Zborowski, 1989; Wileman et al., 2001), or alternatively that bright light has no antidepressant effects in SAD patients (Avery, Eder et al., 2001). In spite of these negative results three meta-analyses (Golden et al., 2005; T. M. C. Lee & Chan, 1999; Terman et al., 1989) and one systematic review (Tam, Lam, & Levitt, 1995) confirmed the therapeutic benefits of bright light therapy, given primarily in the morning, for SAD and it is now an accepted treatment.

Indoor light is usually between 100-300 lux, and bright light greater than 1000 lux, the minimum level usually used in light treatment studies, is usually only achieved outdoors. Inconsistent findings among controlled studies of bright light therapy for SAD may be attributed in part to different design methodologies with respect to treatment intensity (usually varies between 2500 lux and 10,000 lux), treatment duration (varies between 30 minutes to 6 hours), sample sizes, and placebo controls. The general light treatment recommendations for patients with SAD include 30 minutes of light exposure at an intensity of 10,000 lux administered immediately upon awakening, or one to two hours of treatment duration at 2500 lux (Lewy et al., 2007; Magnusson & Kristbjarnarson, 1991; Terman et al., 1989). Moreover, both morning and evening light treatments have tested better than placebo, but with morning light superior to evening light (Eastman, Young, Fogg, Liu, & Meaden, 1998; Terman, Terman, & Ross, 1998). Control treatments for bright light therapy have until recently always employed light sources of various intensities that are equivalent to indoor lighting. However, light at a level commonly found indoors (≤300 lux) is a potentially flawed control since patients can easily distinguish between light of less than 300 lux and greater than 2500 lux, and

they will presumably assume that bright light will be more helpful in reducing their symptoms (Rosenthal et al., 1984).

A better control for bright light that has been used recently, and like light is an environmental factor, is a low-density negative ion treatment (produced by a room air purifier). Four randomized controlled trials with large sample sizes have demonstrated low-density negative ions emitted from a negative ion generator are less effective than either high-density negative ions or bright light for treating winter depression (Eastman et al., 1998; Goel & Etwaroo, 2006; Terman & Terman, 2006; Terman et al., 1998). Moreover, both high-density ions and bright light, in contrast to low-density ions, reduced depressive mood and anger in both depressed patients and healthy individuals (Goel & Etwaroo, 2006). As participants in light studies can be told that negative ions can raise mood and that they will be exposed to negative ions (without being told they are at low level), this treatment is a plausible control for bright light which is more believable than room level light. Along with three meta-analyses (Golden et al., 2005; T. M. C. Lee & Chan, 1999; Terman et al., 1989) and controlled studies (Eastman et al., 1998; Goel & Etwaroo, 2006; Terman & Terman, 2006; Terman et al., 1998) using a low level of negative ions as a placebo control showed that bright light therapy is an effective treatment for SAD with response rates of 60-90% (Tam et al., 1995).

Several studies have looked at the effect of bright light treatment in other mood disorders. Results were promising in the treatment of mood disorders associated with pregnancy, such as antepartum depression (depressions experience by women during pregnancy) (Epperson et al., 2004), and postpartum depression (Corral, Wardrop, Zhang, Grewal, & Patton, 2007), and in premenstrual dysphoric disorder (Lam et al., 1999).

The effect of light monotherapy for the treatment of nonseasonal depression is less apparent, with some studies showing positive results (Goel, Terman, Terman, Macchi, & Stewart, 2005; Wirz-Justice, Graw, Roosli, Glauser, & Fleischhauer, 1999; Yamada, Martin-Iverson, Daimon, Tsujimoto, & Takahashi, 1995), and other studies demonstrating efficacy primarily when light is an adjunct treatment (Benedetti et al., 2005; Benedetti et al., 2003; Martiny, Lunde, Unden, Dam, & Bech, 2005). Moreover, two studies have used a naturalistic approach to see if greater natural exposure to bright light is associated with a better outcome in depressed patients. For example, depressed patients admitted to hospital and stayed in sunny rooms had an average of 2.6 days shorter hospitalization than those stayed in rooms receiving no direct sunshine (Beauchemin & Hays, 1996). This finding was replicated with bipolar depressed patients. Benedetti et al. (2001) reported that bipolar inpatients whose rooms received direct sunlight in the morning had a mean 3.67-day shorter hospitalization than those staying in rooms facing west where bright light was received in the evening. These results suggest a causal association between bright light and better mood in clinically depressed individuals.

Controlled trials on the effect of bright light for nonseasonal depression have been assessed in two meta-analyses (Golden et al., 2005; Tuunainen, Kripke, & Endo, 2004) and two systematic reviews (Even, Schroder, Friedman, & Rouillon, 2008; Kripke, 1998). In general, these reviews concluded that bright light was superior to placebo in the treatment of nonseasonal depression. Kripke (1998) found light to be effective after one week of treatment, demonstrating such results when light was used as monotherapy and as an adjunct treatment to augment antidepressant treatment. However, this finding was

not supported by Golden et al. (2005), since while they found the effects of light monotherapy to be equivalent to those of antidepressants, but bright light did not have an effective augmentation effect to antidepressant in their findings. The Cochrane review by Tuunainen et al. (2004) examined augmentation trials involving the combination of bright light and either antidepressant, sleep deprivation, or both. They found that bright light administered in the morning showed modest but promising antidepressant effects as an adjunctive treatment to sleep deprivation responders. Based on evidence of controlled trials as of November 2004, the International Society for Affective Disorders (ISAD) has made the following recommendation: "… As an adjuvant to conventional antidepressants in unipolar patients, or lithium in bipolar patients, morning light hastens and potentiates the antidepressant response" (Wirz-Justice, Benedetti, Berger, & Lam, 2005).

**1.4 Effect of bright light exposure in healthy people**

Given the common occurrence among the general population of seasonal changes in mood and behaviour similar to those associated with SAD, several studies have examined the effect of light administration on mood in healthy individuals. A number of studies (Avery, Kizer, Bolte, & Hellekson, 2001; Kasper, Rogers, Madden, Joseph-Vanderpool, & Rosenthal, 1990; Kasper et al., 1989a*;* Partonen & Lonnqvist, 2000) found that bright light (2500 lux) improved mood and vitality in healthy individuals, who reported experiencing winter changes with their mood and behaviour, but considered such fluctuations as normal seasonal experiences. Two trials demonstrated that 5 hours of daily bright light exposure for one week, divided between the morning and evening hours, reduced depressive moods in healthy individuals (Kasper et al., 1990; Kasper et al., 1989a). Similarly, two other studies found bright light improved mood, energy,

alertness and vitality when the treatment was administered in the workplace (Avery, Kizer et al., 2001; Partonen & Lonnqvist, 2000). It is however important to note that these two studies lacked placebo control, and that therefore any positive effect of bright light might have been more attributable to the presence of a treatment compared to no treatment. Lastly, in a study of elderly women, one week of bright light administration (1000 lux) significantly improved sleep quality and increased alertness, mood and happiness more than the control treatment (Kohsaka et al., 1999).

Studies have been conducted that did not support the positive findings of bright light on healthy people. In the first controlled study of 26 healthy individuals, Rosenthal et al. (1987) found that 2 hours of morning bright light (2500 lux) failed to improve mood when compared to dim light (300 lux) control. In a study of normal controls, four weeks of bright light administration failed to improve mood but induced hypomanic symptoms, such as racing thought, decreased sleep, and irritability (Bauer, Kurtz, Rubin, & Marcus, 1994), which are possible side effects of bright light treatment. However, these individuals were not screened for seasonality. In another study, which included healthy elderly females with virtually no seasonal variation in mood and behaivour, one week of bright light administration (2500 lux) worsened their mood and increased irritability, anxiousness and agitation (Genhart, Kelly, Coursey, Datiles, & Rosenthal, 1993). Overall the effect of bright light administration is still not clear among healthy people who experience some degree of seasonal changes in mood and behaviour.

**1.5 Effects of bright light on the brain**

The mechanism underlying bright light's effects on mood is still unknown. Some researchers have suggested that the therapeutic effects of bright light may be mediated in

whole or in part through the serotonergic system by increasing brain serotonin function. Evidence supporting this hypothesis includes one study that compared the effects of the serotonergic precursor L-tryptophan, placebo and evening light treatment on the depressive symptoms of SAD patients. The results demonstrated that L-tryptophan and bright light conditions both improved symptoms in patients more than placebo, and the effects of L-tryptophan and light were not significantly different (McGrath, Buckwald, & Resnick, 1990). Moreover, another study showed that bright light normalized the blunted secretion of growth hormone response to the serotonin agonist (5-$HT_{1D}$) sumatriptan (Yatham, Lam, & Zis, 1997), indicating that bright light may correct abnormal serotonin functioning in patients with SAD. Jacobsen et al. (1994) reported similar results with the behavioural response to the serotonin agonist meta-chloropiperazine. Patients with SAD showed a different behavioural response from healthy controls that normalized after light treatment. Further support comes from studies showing decreased brain serotonin levels via acute tryptophan depletion causes depressive relapse in SAD patients in remission after light therapy (Lam et al., 2000; Lam et al., 1996; Neumeister et al., 1997; Neumeister et al., 1998; Stastny et al., 2003). Acute tryptophan depletion is a technique involving the use of a tryptophan-deficient amino acid drink that decreases serotonin synthesis by depleting its precursor tryptophan (Young, 1993; Young & Leyton, 2002). In addition, the mood lowering effect of acute tryptophan depletion was prevented among those exposed to bright light at 3000 lux, but not those who were exposed to dim light (aan het Rot, Benkelfat, Boivin, & Young, 2008). Moreover, a number of studies have demonstrated seasonal variations in serotonin metabolism. In humans, postmortem levels of brain serotonin are higher in those who died during summer than those who died in winter (Carlsson,

Svennerholm, & Winblad, 1980). In the study by Lambert et al. (2002), whole brain serotonin turnover measured among 101 healthy men across seasons showed that the turnover was higher in summer and spring where sunlight levels are higher, and lowest in the winter. In addition there was a significant positive relationship between brain serotonin turnover and the number of hours of sunshine on the day of measurement. A review has reported similar conclusions from studies that looked at various measures related to serotonin, such as the level of 5-hydroxyindoleacetic acid (serotonin metabolite) in cerebrospinal fluid (CSF), and measurement of prolactin release into the bloodstream in response to the administration of compounds that increase serotonin function such as meta-Chlorophenylpiperazine (m-CPP) or L-Tryptophan (L-TRP) in both healthy individuals and among individuals with psychopathology. Serotonin concentration varies with the time of year, with the concentrations at their highest during summer and lowest during fall and winter (Brewerton, 1995).

**1.6 Association between natural exposure to bright light and social behaviour**

Greater natural exposure to bright light has been associated with better mood and positive social behaviour. One study that asked a group of young women to maintain morning and afternoon mood journal for 32 days showed that participants reported better mood on brighter days (Einon, 1997). These findings were supported by another naturalistic study with 459 elderly women. Grandner et al. (2006) found significant correlations between light exposure and improved quality of life, better mood and social functioning. Finally, a naturalistic study, conducted in both winter and summer with 48 mildly seasonal healthy individuals using the event-contingent recording method which reliably measures social behaviours, showed that participants were more agreeable and

less quarrelsome when social interactions occurred during short periods (a morning or afternoon) with greater bright light exposure (>1000 lux). This study suggested that greater bright light exposure is associated with more positive social behaviour and better mood (aan het Rot, Moskowitz, & Young, 2008). By and large, these results suggest that an increase of natural light is associated with better mood and social functioning in everyday life.

**1.7 How much bright light are North Americans exposed to normally?**

Although greater exposure to bright light is associated with better mood and general well-being in people, increasing our daily exposure to natural light may not seem plausibly aligned with our modern lifestyle and schedule, given that most people spend much of the day indoors. Several studies have looked at the average exposure to bright light in different locations. Even in the summer in San Diego, California at latitude of 32º N, daily exposure to natural light greater than 1000 lux occurs for less than 1.5 hours per day (Espiritu et al., 1994; Savides, Messin, Senger, & Kripke, 1986). Two studies conducted in Montreal, Quebec at latitude of 45º N found similar results. One study found that the total bright light exposure in the summer is about 2.6 hours and less than 30 minutes in the winter (Hebert, Dumont, & Paquet, 1998). Another study found daily exposure to natural bright light averages about 91.2 minutes in summer and 26 minutes in winter among individuals that work at least 30 hours per week (aan het Rot, Moskowitz et al., 2008). For these individuals working full time, spending most of their day indoors, using bright artificial light may be the best method for increasing light exposure of greater than 1000 lux.

### 1.8 Measurement of mood and social behaviour

While the conclusions of the current literature on the effect of bright light administration on healthy individuals remain unclear, one of the potential reasons for such inconsistent findings might relate to the fact that most existing studies measured treatment outcome based on a single time point measurement. More specifically, studies often used the Hamilton Rating Scale for Depression (HRSD)-SAD version (SIGH-SAD) (Williams, Link, Rosenthal, Amira, & Terman, 1988). This scale included items for vegetative depressive symptoms to measure levels of SAD symptomatology. This method of assessment is less helpful for healthy individuals without any history of major depressive disorders. Since these individuals often begin with very low baseline scores on the depression scale indicating very low or no depression, bright light administration would not tend to decrease their depression score further to show a significant positive result. Another drawback relating to the use of self-report questionnaires such as SIGH-SAD as an outcome measure is that participants usually answer the questionnaire before the treatment and after the end of the treatment trial. Their answers are likely to be influenced by both the timing of the assessment and events that have happened that day (Moskowitz & Young, 2006). Previous studies demonstrated that one's behaviour and affect vary depending on the time and location of the social interaction, as well as the role and gender of one's interacting partner (Moskowitz, Pinard, Zuroff, Annable, & Young, 2001).

Many studies have demonstrated individuals who are sensitive to environmental changes and exhibiting tendencies to report SAD symptoms also have high scores for the personality trait of neuroticism (Ennis & McConville, 2003; Enns et al., 2006; Jang, Lam,

Livesley, & Vernon, 1997; Kane & Lowis, 1999; G. Murray, Allen, Rawlings, & Trinder, 2002; G. W. Murray, Hay, & Armstrong, 1995). According to Eysenck (1967), neuroticism involves the tendency to negative affects, vulnerability to stressors and emotional instability. Individuals scoring high on this trait demonstrate a predisposition to submissive and quarrelsome behaviours (Cote & Moskowitz, 1998; Moskowitz & Young, 2006). Given the importance of social functioning to general well-being, it is important to assess the role of bright light in social interactions along with affect in healthy individuals with mild seasonality.

Moskowitz et al. (1994) developed a method to assess aspects of social behaviour in everyday life, using event-contingent recording. This method accurately estimates interpersonal behaviour by aggregating social event data, recorded shortly after each important social interaction, accumulated over a 12-day period. Previous studies have demonstrated that this method shows reliability and validity in assessing interpersonal behaviour and affect (aan het Rot, Moskowitz, Pinard, & Young, 2006; aan het Rot, Russell, Moskowitz, & Young, 2008; Moskowitz et al., 2001; Russell, Moskowitz, Zuroff, Sookman, & Paris, 2007). The main advantage of using an event-contingent recording method in studying interpersonal behaviours and affect is that it allows such assessments to be conducted in the participants' natural environment. Since samplings of interpersonal events are taken briefly after the occurrence of a social interaction, individuals need not recollect their experiences from memory, thereby minimizing retrospective bias. Moreover, unlike a single time point assessment, event sampling is undertaken throughout the day, capturing many different social interactions. This method is sensitive to neurochemical changes. When healthy participants were given tryptophan

and placebo in a cross-over design the participants were unable to guess accurately which treatment they were on. Nonetheless, tryptophan decreased quarrelsome behaviours without altering mood (Moskowitz et al., 2001).

### 1.9 Event-contingent recording of social behaviours

Social behaviours can be represented as existing along a circle defined by two axes composed of agency or status, and affiliation or communion (Moskowitz, 1994). The axis of agency represents an individual's need for controlling individual autonomy or having an influence over the other. Individuals that have high agentic domain tend to engage in dominant behaviours. On the other hand, the axis of affiliation or communion represents one's desire to be interconnected to others, and often expressed by social behaviours extending from warm and agreeable to cold and quarrelsome. Interpersonal behaviours can be defined by any combination of communal and agentic behaviours (Moskowitz, 1994). For example, when people engage in a warm-agreeable yet dominant way the behaviour is often interpreted as engaging, while criticism if often leveled at people engaging in a dominant but quarrelsome way.

Affect can also be measured along a circle defined by an axis of valence and an axis of arousal (Moskowitz, 1994). Axis valence measures affect ranging from pleasant to unpleasant, and arousal measures a continuum of alertness to sleepiness. Moskowitz and Cote (1995) demonstrated that affect valence is associated with social behaviour in that positive affect by and large correlated positively with agreeable behaviour and negative affect correlated with quarrelsome or submissive behaviour.

### 1.10 Treatment adherence in bright light therapy

Incomplete adherence to antidepressant treatment is common among patients, with more than 50% of patients either dropping out before completion of the treatment or adhering only partly (Lingam & Scott, 2002). This issue has been researched and reviewed by five meta-analyses (Anderson & Tomenson, 1995; Colom, Vieta, Tacchi, Sanchez-Morena, & Scott, 2005; Lingam & Scott, 2002; Montgomery & Kasper, 1995; Pampallona, Bollini, Tibaldi, Kupelnick, & Munizza, 2002). Little comparative information exists concerning adherence with light therapy of patients or bright light treatment of mildly seasonal individuals. Although light therapy has fewer side effects than antidepressants, which should be important since side effects are reported as one of the primary reasons patients stop treatment, patients are nevertheless required to wake up early and sit in front of a light box for at least 30 minutes. A follow-up study of 59 SAD patients who participated in a trial of light therapy (Rosenthal et al., 1984) showed that as many as 19% of patients discontinued using light treatment due to inconvenience (Schwartz, Brown, Wehr, & Rosenthal, 1996). Only recently have four pilot studies examined aspects of adherence in light therapy in patients with SAD (Michalak, Hayes, Wilkinson, Hood, & Dowrick, 2002; Michalak, Murray, Wilkinson, Dowrick, & Lam, 2007) and patients with psoriasis (Yelverton, Balkrishnan, & Feldman, 2006; Yentzer et al., 2008). Two studies by Michalak and colleagues mounted elapsed time meters on light boxes to record the total time that light boxes had been switched on, while the other two studies used electronic light sensors to record the power status of the light units. The results of these studies showed that the lights were in general turned on when they should be. There is however one major limitation to using elapsed time meters or electronic light

sensors in measuring adherence to light treatments, this being that these devices only measure the time that a light unit has been activated, while neglecting to measure the actual light intensity that a participant receives during the treatment. Given the fact that light intensity is inversely proportional to the square of the distance from the light source to the observer (Dawson & Campbell, 1990), researchers would ideally like to know patients are in fact sitting in front of the light source at the instructed distance for the specific time duration. Furthermore, the fact that a light is switched on does not necessarily mean that the participant is even in the same room as the light.

The ideal way to measure light exposure would be with a light monitor worn next to the eye, but this is not practical. A wrist-worn actigraphy which monitors movement and light exposure may be a more informative device for monitoring adherence in light therapy. Previous studies have shown that it is a sensitive device for monitoring sleep/wake patterns in patients with sleep disorders (Ancoli-Israel et al., 2003; Dodd, Hare, & Arshad, 2008; Mehra et al., 2008; Morgenthaler et al., 2007), Attention-Deficit/Hyeractivity disorder (Dane, Schachar, & Tannock, 2000; Goodlin-Jones, Waters, & Anders, 2009; Owens et al., 2009) and Alzheimer's disease (D. Lee, Morgan, & Lindesay, 2007; McCurry, Pike, Vitiello, Logsdon, & Teri, 2008; Van Someren, 2007). While a few studies have mentioned the use of actigraphy and light sensors to monitor activity and daily light exposure (Dowling et al., 2005; Sloane et al., 2007; Thorne, Hampton, Morgan, Skene, & Arendt, 2008; Winkler et al., 2005), they have all neglected to report the results on the adherence to the light treatment.

## 1.11 Rationale

The effect of bright light exposure seems to benefit some healthy individuals with mild seasonality. A naturalistic study suggested that greater bright light exposure is associated with more positive social behaivour and better mood in individuals with mild seasonality (aan het Rot, Moskowitz et al., 2008). Most of the research literature conducted on bright light treatment had design weakness. Besides the fact that most studies generally lacked plausible placebos (Golden et al., 2005; Tuunainen et al., 2004), adherence to light treatment was seldom measured in published studies. However, as mentioned previously four recent trials using elapsed time meters and electronic light sensors suggested that lights were at least turned on at the appropriate times during home based light treatment (Michalak et al., 2002; Michalak et al., 2007; Yelverton et al., 2006; Yentzer et al., 2008). The present study described in this thesis examined the effect of bright light administration in winter on daily social behaviour and mood of healthy people with mild seasonality, concurrently looking at adherence to bright light administration by using Actiwatch, a wrist worn device equipped with an accelerometer and a light sensor.

**Hypotheses**

*Hypothesis 1.* Asking participants to wear an Actiwatch will provide more information on adherence to light treatment than other methods that have been used.

*Hypothesis 2.* Bright light administration will improve mood and decrease levels of quarrelsome behaviour.

# CHAPTER 2: METHODS

## 2.1 Participants

This study was approved by the Research Ethics Board of the McGill University Health Centre, Montreal. Participants were recruited from the community in Montreal, Canada (near latitude 45 º N) using advertisements in local newspapers and websites. Advertisements included the statements: "Looking for healthy men and women for a study comparing the effects of bright light and negative air ions on how individuals interact with others." People who phoned and expressed interest in the study were given a detailed explanation. If they were willing to participate and were mildly seasonal according to the Global Seasonality Scale they were invited for an interview in the lab. The Global Seasonality Score or GSS is one of the scales in the Seasonal Pattern Assessment Questionnaire (SPAQ) (Kasper et al., 1989b). The SPAQ is a widely used self-report screening instrument for seasonal mood and behaivour variations, it has 6 items that measure the intensity of seasonal variations in sleep length, social activity, mood, weight, appetite and energy level. Each item was scored from 0 (no change) to 4 (extremely marked change), for a total GSS range of 0 to 24. Higher scores indicated greater seasonal changes and mild seasonality was defined as having a GSS score from 6 to 11. The other scale evaluates the extent to which seasonal change is a problem.

The main inclusion criteria were a GSS score from 6 to 11 both at the initial telephone interview and during the interview in the lab screening, and working at least 30 hours per week excluding those working alone and past midnight. The requirement to work 30 hours with other people has been used in many previous studies of social interaction as it ensures that participants have social interactions with a variety

other people throughout the day. Exclusion criteria were current or past Axis I disorder according to DSM-IV, determined by the Structured Clinical Interview for DSM-IV, Non-Patient Edition (Spitzer, Williams, Gibbon, & First, 1995), or self-report of significant medical illness, use of psychotropic medication, pregnancy and lactation.

During the winters of 2007 and 2008, 44 men and 43 women met the inclusion criteria during the telephone screening and were invited to laboratory screening. Forty of these individuals were excluded. The most common reasons for exclusion were not having a GSS score between the range of 6 and 11 or having past history of mood disorders according to DSM-IV. A total of 47 individuals passed all screening requirements and began the study. Two women dropped out of the study due to job loss before the completion of the first study period and one woman dropped out after one week of participation due to an allergic reaction to the plastic wristband of the wrist-worn light and activity monitor (Actiwatch). Of the 44 participants who completed the study, one individual was excluded because she got pregnant during the second study period, one women was excluded because of technical problems with her Actiwatch, and three men and one woman did not comply with the event-contingent recording procedure (i.e., their event-contingent forms were not returned on a daily basis as required; see below). This left 38 participants whose data was analyzed.

**2.2 Procedure**

The study was first explained to the participants on the initial telephone interview and they were invited to the laboratory if they met the inclusion criteria. In the laboratory, the study was explained in detail and participants were shown the study treatments, a light box and a negative ion generator. Participants were told that both bright light and a

high level of negative ions are effective treatments for SAD patients and the purpose of this study was to test the effect of light and negative ions on social behaviour in healthy individuals. After providing written informed consent, participants were interviewed using the Structured Clinical Interview for DSM-IV, Non-Patient Edition (Spitzer et al., 1995) and completed two questionnaires: the complete SPAQ; and the Beck Depression Inventory (BDI) (Beck, Rush, Shaw, & Emery, 1979), one of the most commonly used instruments for assessing depression. The event-contingent procedure was then explained to participants. They were told they would be completing a 1-page record form for each interaction that lasted for at least 5 minutes every day for 42 days. A social interaction could occur in person, by telephone or via Internet chatting. Participants were provided with 10 record forms per day and were asked to complete the form as soon as possible after a social interaction occurred and to mail in each day's forms on the day following their completion. At the end of the first meeting, participants were given 21 stamped addressed envelopes with record forms, an Actiwatch, and a light box or a negative ion generator for the first 3 weeks of the study. They were told to wear the Actiwatch at all times except when showering or swimming. The Actiwatch is a wrist-worn device equipped with an accelerometer and a light sensor (Actiwatch-Light®, Respironics, Inc., Bend, OR USA) that was used to measure both motor activity and light levels every 2 minutes throughout the three week treatment periods. They were also asked about their expectations of the effectiveness of the two treatments.

Participants attended a second meeting at the end of the first three weeks. At this meeting their Actiwatch data was downloaded and reviewed. Participants were reminded to follow the study procedure and to wear the Actiwatch at all times especially during the

30 minutes treatment period in the morning. They were then given a newly programmed Actiwatch, record forms and a light box or negative ion generator for the second three weeks. Participants attended a final meeting at the end of the study to return the equipment and to complete final questionnaires. At this meeting, participants were asked about their perceptions concerning the accuracy of the recordings of their interactions, as well as the degree of difficulty they experienced in completing the forms and wearing the Actiwatch. Participants were furthermore asked whether and on what day they started to feel burdened by the study. Finally, they were paid $240 for taking part in the study.

**2.3 Treatment**

This was a cross-over study and the treatment order was counterbalanced. During the light treatment, participants were asked to sit in front of a light box while placing the arm with the Actiwatch on the table where the light box was situated, in order to measure the amount of light exposure from the light box. Participants could eat breakfast or read while sitting in front of the light box. During the negative ion treatment, participants were asked to remain in a room with a negative ion generator turned on. They were not however asked to remain seated in front of the generator. Both treatments were 30 minutes in duration and participants were asked to carry out the treatment within a half hour of waking for 21 days each in winter (during period of October to early March) with a 14 day wash out period in between. All measurements occurred after the time change in the fall and before the time change in the spring and not during the holiday season (December 20 to January 6) in order to avoid possible changes in mood and social behaviour associated with a time change and with the holiday season. The light box (BOXelite from Northern Light Technologies, Montreal, Canada) provided luminance of

10,000 lux at a distance of 43 cm from each participant's eyes, participants were asked to stay awake with their eyes open sitting in front of the light box. The negative ion generator (XJ-2100 Ionic Air Purifier from Heaven Fresh, Canada) had a flow rate of 4.2 x $10^{11}$ ions/sec, this rate was comparable to the low-density ionization rate of 1.7 x $10^{11}$ ions/sec, adopted as placebo treatment in previous studies (Goel & Etwaroo, 2006; Goel et al., 2005; Terman et al., 1998). The level of negative ions that has been shown to produce changes in mood is more than three orders of magnitude higher.

**2.4 Event-contingent recording**

During both treatment periods, participants reported on their social interactions and mood using an event-contingent recording method (Moskowitz, 1994). This recording method collects repeated measurements of interpersonal behaviour and affect as soon as they occur in the individuals' own environments over the course of two to three weeks, thereby reducing the recall bias of retrospective self-report. An event-contingent record form requested information about characteristics of a social interaction such as time, location (at work, home or other setting), and interaction partners (romantic partner, friend, acquaintance, supervisor, co-worker, supervisee, parent, other). In order to control for possible alcohol effects, the participant was also asked to record whether or not he or she has been drinking alcohol during or in the hour before the social interaction. Data was analyzed after excluding all interactions that occurred during or after alcohol ingestion.

*Behaviours.* There were 46 behaviour items developed by Moskowitz (1994) to measure 4 behaviour dimensions of agreeableness, quarrelsomeness, dominance, and submissiveness, which are described by the interpersonal circumplex model. Each

dimension had 12 items. Examples of items representing each of the behaviour are following: for agreeableness behaviour: “I listened attentively to the other,” “I exchanged pleasantries,” “I expressed affection with words or gestures,”; quarrelsome behaviour: “I made a sarcastic comment,” “I discredited what someone said,” “I gave incorrect information,”; dominance behaviour: “I gave information,” “I set goal(s) for the other(s) or for us,” “I spoke in a clear firm voice,”; and submissive behaviour: “I went along with the other(s),” “I gave in,” “I spoke only when I was spoken to.” See Moskowitz (1994) for a complete list of behaviour items.

Each record form included 3 behaviour items and there were 4 versions of form rotated daily to prevent participants from checking the same behaviours for every interaction. To control for response styles involving the tendency to check many or few items on the scale, ipsatized scores for each of the 4 behaviours were calculated using the following steps: (i) a score for each behaviour scale was calculated by dividing the number of behavioural items (between 0 and 3) participants had engaged in during the interaction by 3, which was the number of behavioural items on the list. (ii) An ipsatized score was then calculated by subtracting mean score of each behaviour scale from the participant’s score on each item. Ipsatized scores reflect the frequency with which agreeable, quarrelsome, dominant and submissive behaviours were marked, adjusted for the general rate of behaviour marking. Given that people normally mark quarrelsome and submissive behaviour less often, ipsatized scores for quarrelsome and submissive behaviours are on average lower than those for dominant and agreeable behaviours, and are frequently negative.

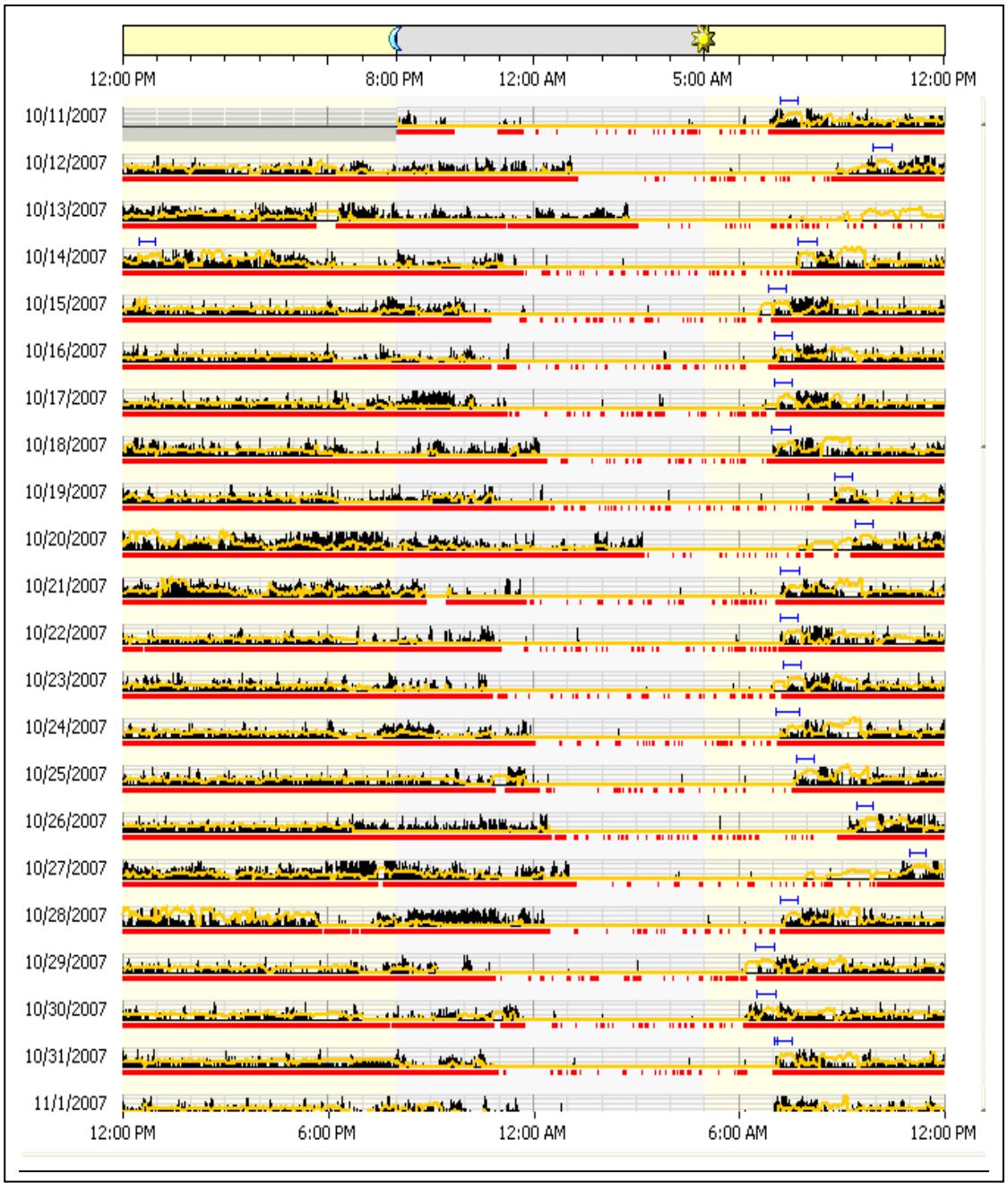
*Affect*. The event-contingent form also asked participants to rate how they felt during the interaction using a 0 to 6 scale on the positive affect items (i.e., happy, pleased, enjoyment/fun, and joyful) and negative affect items (i.e., worried/anxious, frustrated, angry/hostile, unhappy, and depressed/sad). Furthermore, participants were asked to indicate their pleasant or unpleasant feelings and degree of alertness by placing a single mark on a 9 ∞ 9 affect grid that measure valence and arousal (Russel et al 1989).

**2.5 Data analysis**

Data analysis occurred in two phases. The first was designed to obtain information about adherence to light treatment. Results downloaded from the Actiwatches were plotted using Actiware software (version 5.54.0003, Respironics, Inc.), as shown in Figures 1-3. The changes in light exposure and activity across time were compared with the participants' stated time of use of the light boxes as described in the result section.

**FIGURE 1**

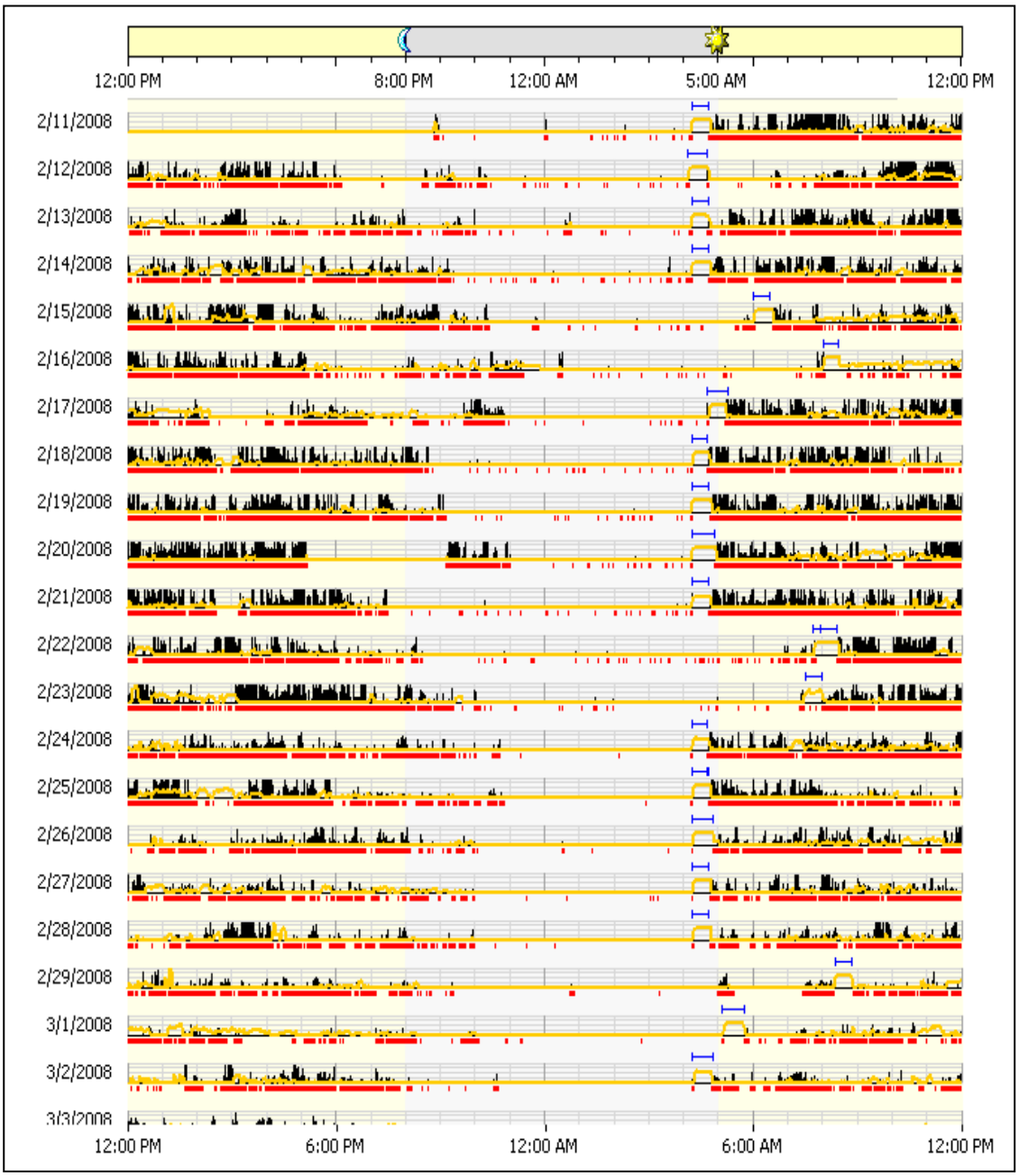
**Example of an Actogram from Group 1**




Black vertical lines represent motor activity, and yellow horizontal lines represent lux measurement. The red bar at the bottom means that there is detectable activity. Periods with no red bar indicate no detectable activity. Periods where there is a red bar and no black vertical lines indicate low activity levels that do not show in the black vertical lines. Smaller irregular red bars for extended intervals indicate sleep. Blue horizontal marker indicates self-report treatment period.

**FIGURE 2**

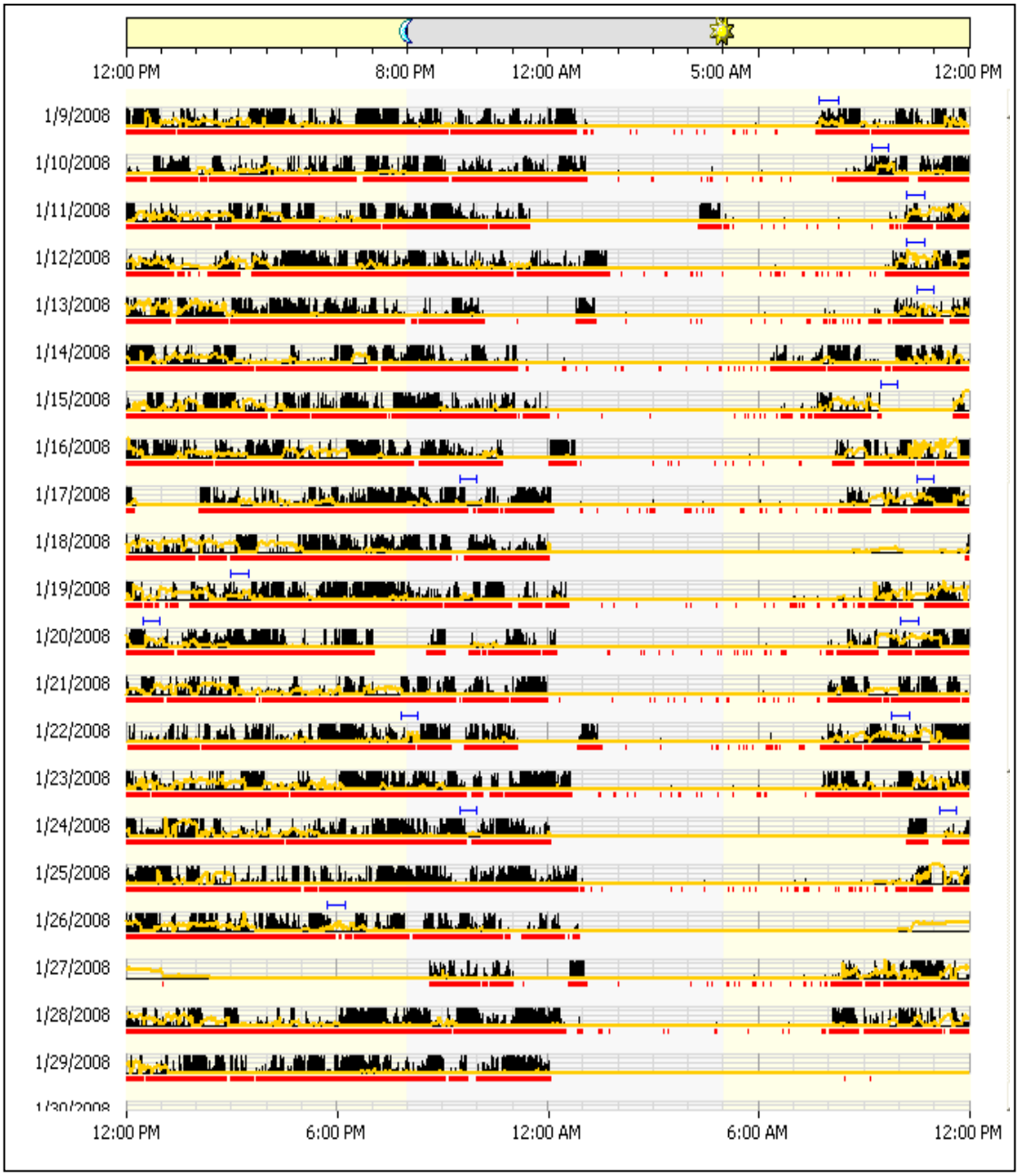
**Example of an Actogram from Group 2**




Black vertical lines represent motor activity, and yellow horizontal lines represent lux measurement. The red bar at the bottom means that there is detectable activity. Periods with no red bar indicate no detectable activity. Periods where there is a red bar and no black vertical lines indicate low activity levels that do not show in the black vertical lines. Smaller irregular red bars for extended intervals indicate sleep. Blue horizontal marker indicates self-report treatment period.

## FIGURE 3

### Example of an Actogram from Group 3




Black vertical lines represent motor activity, and yellow horizontal lines represent lux measurement. The red bar at the bottom means that there is detectable activity. Periods with no red bar indicate no detectable activity. Periods where there is a red bar and no black vertical lines indicate low activity levels that do not show in the black vertical lines. Smaller irregular red bars for extended intervals indicate sleep. Blue horizontal marker indicates self-report treatment period.

In the second phase of the data analysis, results on social behaviour and mood obtained during social interactions were analyzed to see if there were differences during the two phases of the study when there was exposure either to the light box or to negative ions. As the number of social interaction record forms varied per condition, per day, and per person, statistical analyses were performed using multilevel models with maximum likelihood estimation (PROC MIXED in SAS version 9.2) which permits the analysis of unbalanced data. Each model included a random intercept and unstructured covariance structure. The degrees of freedom for F-tests were determined by dividing the residual degrees of freedom into between-subjects and within-subjects portions (Singer, 1998). There were three predictors: condition, order and sex. Condition (placebo vs. light administration) was a within-subject factor. Order (placebo first vs. light administration first) and gender (men vs. women) were the between-subjects factors. As preliminary analyses showed no interaction of gender with condition or order; gender was not included in further analyses.

The effect size correlation was calculated for each significant effect of light using the formula $r = [F/(F + df)]^{1/2}$ (Rosnow & Rosenthal, 1996) and Cohen's d values were calculated from the effect size correlation, $r^2 = d^2 / (d^2 + 4)$.

All data were analyzed after exclusion of all interactions that occurred within an hour of alcohol ingestion. Previous work demonstrated that alcohol ingestion before or during a social interaction altered social behaviour (aan het Rot, Russell et al., 2008). Furthermore, social interaction forms were further excluded if they were recorded on days when the light box or negative ion generator were not used based on self-report or days when self-reported light administration time did not match with the Actiwatch data.

# CHAPTER 3: RESULTS

## 3.1 Adherence with light administration

Twenty-three of the participants (designated group 1) showed changes in activity and light exposure that were consistent with adherence to the light administration protocol. An example is shown in Figure 1. The records for these participants exhibited the following characteristics: (i) increase in light exposure (>1000 lux) during their reported time sitting in front of the light, (ii) an irregular pattern of light exposure; as would be expected if the participant were moving his or her arm so that the Actiwatch was at times below the surface on which the lamp was placed while at other times exposed to the light but at varying angles, and (iii) moderate movement as would be expected for someone moving their arms while sitting. Participants in this group demonstrated these characteristics in their Actiwatch record for more than half of the 21 day light exposure period (mean 18 days, range 13 – 21 days).

Eight of the participants (group 2) had an Actiwatch record with two characteristics during more than 12 days during the light administration period: (i) uniform high light exposure, and (ii) no movement or a very low level of movement consistent with, for example, someone moving the Actiwatch slightly on a surface where it was placed. An example is given in Figure 2. Tests in the lab by one of the researchers revealed that it was not possible to sit sufficiently still during 30 minutes that no movements were detected on the Actiwatch. The pattern seen with these participants was that seen when the Actiwatch was removed from the experimenter's wrist and placed on the surface where the light was situated. While it is possible that participants in this group did sit in front of the lamp during a 30 minute period each morning after taking off the

Actiwatch, there was no evidence from the Actiwatch record that they adhered to the light administration protocol.

Another 7 of the participants (group 3) had an Actiwatch record that showed no evidence of enhanced light exposure or a regular moderate level of activity during the time they reported sitting in front of the lamp, or reported that they failed to use the light box in the morning for more than half of the 21 day light administration period (mean 16 days, range 12 - 21 days). An example is given in Figure 3. As with group 2 there was no evidence from the Actiwatch record to support adherence to the protocol for the majority of days during the light administration period.

**3.2 Descriptive characteristics of participants**

There were no group differences on the baseline measures of GSS, BDI and expectation ratings (Table 1). Table 1 also records some of the participants' feeling and expectations about the study. They did not find it particularly difficult to fill in the forms or to wear the Actiwatch, and had confidence in the accuracy of the forms they filled out. However, before the end of the study most participants started to feel that the study was a burden. Before the study 74% of the participants in group 1 expected both treatments to have an equal positive effect, but by the end of the study a majority (56%) thought light was the better treatment. Event-level means and standard errors for affect and interpersonal behaviour for the three groups are shown in Table 2.

## TABLE 1

## Basic descriptive characteristics of participants

| | Group 1 (n=23) | Group 2 (n=8) | Group3 (n=7) |
|---|---|---|---|
| **Men** | 6 (26%) | 4 (50%) | 5 (63%) |
| **Women** | 17 (74%) | 4 (50%) | 3 (37%) |
| **Age in years** | 36 ±13 | 30 ±7 | 34 ± 8 |
| **Global Seasonality Score (lab)** | 8.6 ± 2 | 9.1 ± 2 | 8.3 ± 1.5 |
| **Beck Depression Inventory pre-study** | 2.3 ± 3 | 1.3 ± 2 | 3.9 ± 6 |
| **Beck Depression Inventory post-study** | 2.8 ± 5 | 1.3 ± 2 | 1.1 ± 2 |
| **Total number of record forms** | 5796 | 1784 | 1570 |
| **Number of record forms after exclusion forms completed within 1 h of alcohol ingestion** | 5398 | 1648 | 1460 |
| **Number of record forms after exclusion forms completed on days of no adherence *** | 5186 | 1607 | 1395 |
| **Difficulty recording interactions †** | 2.4 ± 1 | 2.8 ± 1 | 2.1 ± 1 |
| **Accuracy of recording of interactions †** | 4.9 ± 0.9 | 5.1 ± 0.6 | 4.9 ± 0.8 |
| **Difficulty wearing light meter †** | 2.2 ± 1 | 2.8 ± 1 | 2.1 ± 1 |
| **The day (out of 42 days in total) that participants begin to feel burdened by the study** | 31 ± 13 | 22 ± 8 | 32 ± 10 |
| **Expectation before study ‡** | | | |
| **-Light exposure** | 5 (22%) | 3 (38%) | 1 (13%) |
| **-Negative ion generator** | 1 (4.3%) | 0 | 0 |
| **-Neither** | 17 (74%) | 5 (63%) | 7 (88%) |
| **Expectation after study ‡** | | | |
| **-Light exposure** | 13 (57%) | 2 (25%) | 3 (38%) |
| **-Negative ion generator** | 0 | 2 (25%) | 1 (13%) |
| **-Neither** | 10 (43%) | 4 (50%) | 4 (50%) |

Values are means ± standard errors

*Group 1: Records removed on days of no adherence was determined by self-report data and days when self-report light exposure time did not match with the Actiwatch data. Group 2&3: Records removed was determined by self-report days when the light box or negative ion generator were not used.

† Difficulty and accuracy of light and social interaction measurements assessments were based on a 6-point scale; where 1 was labeled "no difficulty" or "not at all accurately" and 6 was labeled "great difficulty" or "very accurately".

‡ Participants were asked "Did you expect to experience better mood or more positive social interactions with (1) Lamp (2) Negative ion generator or (3) Neither

## TABLE 2

## Group differences in social interaction variables

| | Group 1 (n=23) | | Group 2 (n=8) | | Group3 (n=7) | |
|---|---|---|---|---|---|---|
| | **Light** | **Negative ions** | **Light** | **Negative ions** | **Light** | **Negative ions** |
| **Dominant behaviour (ipsatized frequency x 100)** | 7.6±1.1 | 7.8±1.1 | 8.2±1.7 | 5.8±1.7 | 8.9±1.5 | 9.8±1.5 |
| **Submissive behaviour (ipsatized frequency x 100) †** | -6.1±1.2* | -4.8±1.2 | -7.3±1.7 | -5.2±1.7 | -6.7±2.2 | -8.1±2.2 |
| **Quarrelsome behaviour (ipsatized frequency x 100)†** | -16.9±1.2** | -18.7±1.2 | -14.2±2.1 | -13.9±2.1 | -14.7±2.3* | -19.8±2.3 |
| **Agreeable behaviour (ipsatized frequency x 100)** | 15.5±1.3 | 15.7±1.3 | 13.3±1.7 | 13.2±1.7 | 12.6±3.5* | 18.2±3.5 |
| **Positive affect (averaged item score)** | 2.2 ±0.2 | 2.2±0.2 | 2.2±0.2 | 2.2±0.2 | 2.6±0.2* | 2.3±0.2 |
| **Negative affect (averaged item score)** | 0.4±0.1 | 0.4±0.1 | 0.2±0.04 | 0.2±0.04 | 0.2±0.05 | 0.2±0.05 |
| **Affect valence (grid score)** | 7.8±0.2 | 7.6±0.2 | 8.2±0.4 | 7.9±0.4 | 7.9±0.4 | 7.9±0.4 |
| **Affect arousal (grid score)** | 7.0±0.2 | 6.9±0.2 | 6.9±0.2 | 6.9±0.2 | 7.1±0.3 | 7.2±0.3 |
| **Perceptions of agreeableness (grid score)** | 8.1±0.2 | 8.1±0.2 | 8.7±0.5 | 8.5±0.5 | 8.2±0.4 | 8.4±0.4 |
| **Perceptions of dominance (grid score)** | 7.3±0.2 | 7.3±0.2 | 7.3±0.2 | 7.3±0.2 | 7.5±0.5 | 7.7±0.5 |

Data are presented as estimated least squares means ± SEM. *$p < 0.05$ **$p < 0.01$ for light relative to negative ions

† People normally marked quarrelsome and submissive behaviours less often; therefore the ipsatized scores for these two behaviours were negative (see section 2.4).

For group 1, data were analyzed after the exclusion of all data collected within one hour of alcohol ingestion (398 record forms or 6.9% of the interactions). The number of these social interactions that occurred during light administration (195 record forms) and those that occurred during placebo treatment (203 record forms) was not significantly different, $\chi^2 (1) = 0.97$, $p > 0.05$. Furthermore, social interactions recorded on days when the light box or negative ion generator were not used based on self-report and days when self-reported light administration time did not match with the Actiwatch data resulted in exclusion of additional 212 record forms or 5.9% of interaction forms. The number of social interaction forms that were excluded was significantly greater during the light period (160 record forms) than the placebo period (52 record forms), $\chi^2 (1) = 50.53$, $p < 0.01$. A total of 5186 record forms remained for the data analyses.

For group 2 and group 3, data were also analyzed after the exclusion of all forms collected within one hour of alcohol ingestion. For group 2, 136 record forms or 7.62% of the interactions were excluded. The number of these interactions that occurred during light administration (66 record forms) and those that occurred during placebo treatment (70 forms) was not significantly different, $\chi^2 (1) = 0.47$, $p > 0.05$. For group 3, 110 record forms or 7.01% of the interactions were excluded, and the number of these interactions that occurred during light phase (51 forms) and those that occurred during placebo phase (59 forms) was not significantly different, $\chi^2 (1) = 0.81$, $p > 0.05$.

For groups 2 and 3, social interactions recorded on days when no light box or negative ion generator were used, based on self-report, were excluded, but no record forms were removed when their self-reported administration time did not match with the Actiwatch data given that the Actiwatch data could not reliably determine the bright light

exposure at the eye. In group 2 Actiwatch data was consistent with adherence to the light protocol on an average of 1 day of the 21 day study period (range 0 – 4 days), and while for group 3 the average was 5 days of the 21 day light period (range 0 – 11 days).

For group 2, 1.88% or 31 interaction forms were excluded on days when the treatment device was not used according to self report; all 31 excluded forms were recorded during the light administration period and no form was excluded from the placebo period, $\chi^2$ (1) = 29.66, $p < 0.01$. A total of 1607 forms remained for the data analyses. For group 3, 4.45% of interaction forms were excluded based on self-report of non-adherence. The number of forms excluded due to missed light or placebo administration was significantly greater during the light period (56 record forms) than the placebo period (9 record forms), $\chi^2$ (1) = 33.98, $p < 0.01$. A total of 1395 record forms remained for the data analyses.

### 3.3 Analysis results of group 1

#### Effects of light on interpersonal behaviour

*Quarrelsome behaviour.* Quarrelsome behaviour was analyzed with two main effects (condition, order) and their two-way interactions. The effect of condition was significant, $F_{(1,22)} = 13.61$, $p < 0.0001$. There was no significant main effect or interaction effect involving order. Quarrelsome behaviour was greater under the light condition (mean ± SE; -16.95 ± 1.17) than under placebo (-18.71 ± 1.17). The treatment effect size for quarrelsome behaviour was large with an *r* value of 0.62 and a Cohen's *d* of 1.57.

Based on previous work by Moskowitz and colleagues quarrelsome behaviour could be moderated by interpersonal context (Moskowitz, 1994; Moskowitz et al., 2001). We therefore conducted multilevel analyses with quarrelsome behaviour as the dependent

variable and order, an interpersonal contextual variable (setting: interaction at home or at work, and relationship status: with a romantic partner, friend, or acquaintance), and the interaction of condition and the interpersonal contextual variable as predictors. We found a significant interaction of condition and partner's relationship status (romantic partner, friend, acquaintance), $F_{(2,21)} = 7.95$, $p < 0.05$. Level of quarrelsomeness was higher when individuals were interacting with romantic partner under light (-10.59 ± 1.82) than placebo (-15.37 ± 2.14). The difference between light and placebo was significant ($t_{21} = 3.73$, $p < 0.01$ by Tukey test), and the effect size when individuals were interacting with their romantic partner moderated the effect of light on quarrelsome behaviour was large with an $r$ value of 0.63 and a Cohen's $d$ of 1.63.

*Submissive behaviour.* Submissive behaviour was analyzed the same way as quarrelsome behaviour and revealed a significant effect for condition, $F_{(1,22)} = 4.55$, $p < 0.05$. Light decreased submissive behaviour (light vs. placebo: -6.12 ± 1.20 vs. -4.84 ± 1.20) with a medium effect size ($r = 0.41$, Cohen's $d = 0.91$). There were no significant interaction effects with order or the contextual variables.

*Dominant and Agreeable behaviour.* The analyses for dominant and agreeable behaviour revealed no significant effects.

**Effects of light on affect**

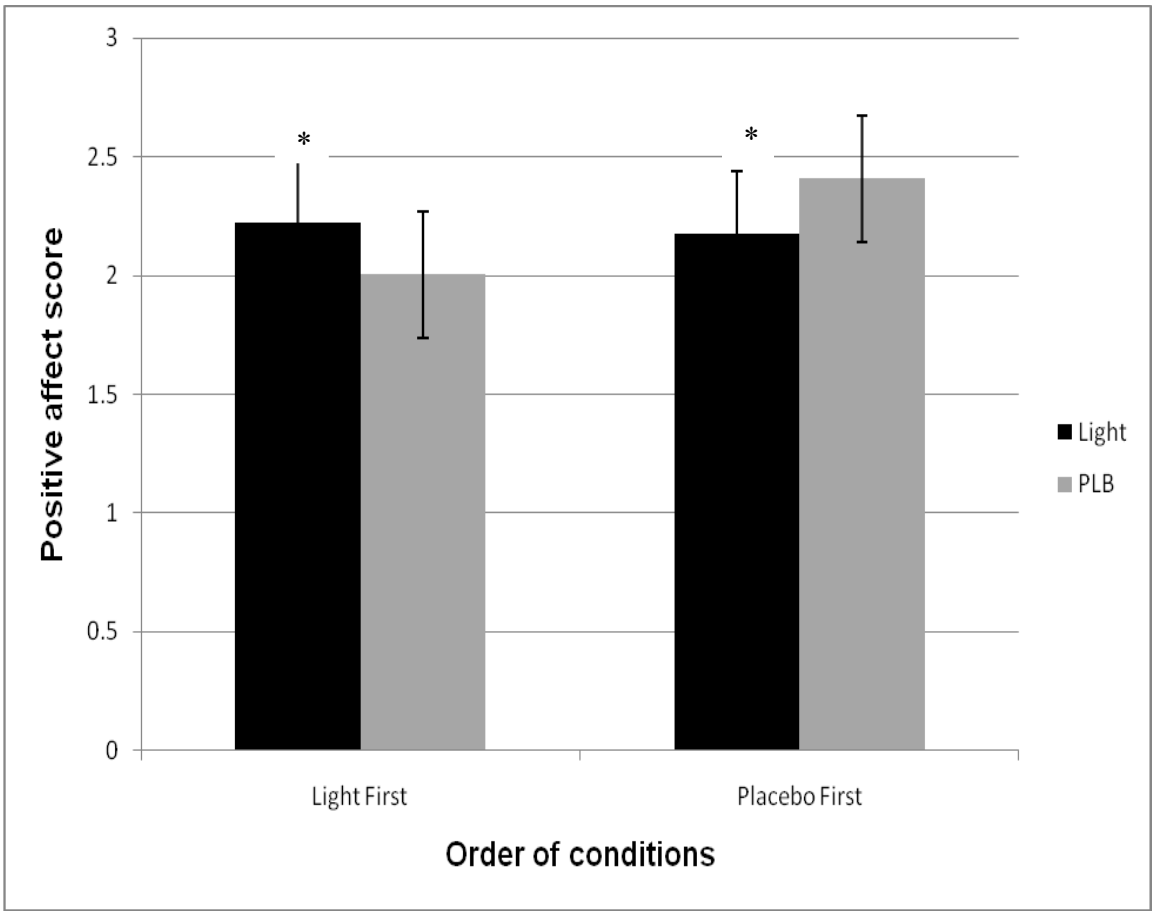
*Positive Affect.* There were no main effects for condition and order, but there was a significant condition and order interaction for positive affect, $F_{(1,21)} = 53.93$, $p < 0.001$, with no significant main effect of light or order. Positive affect was greater on light (2.22 ± 0.27) than on placebo (2.00 ± 0.27) when light was given first ($t_{21} = -5.24$, $p < 0.001$ by Tukey test). The treatment size for positive affect in those who received light first was

large with an *r* value of 0.75 and a Cohen's *d* of 2.29. When placebo was given first positive affect was greater on placebo (2.41 ± 0.26) than on light (2.18 ± 0.26) ($t_{21}$ = 5.15, $p < 0.001$ by Tukey test; Fig. 4). Cohen's *d* for positive affect in those who received placebo first was 2.29 with an *r* value of 0.75.

There was a significant interaction of condition and partner's relationship status (romantic partner, friend, acquaintance), $F_{(2,21)} = 13.95$, $p < 0.01$. Level of positive affect was lower when individuals were interacting with romantic partner under light (2.24 ± 0.24) than placebo (2.58 ± 0.24). The difference between light and placebo was significant ($t_{21} = 4.96$, $p < 0.001$ by Tukey test). Moreover, when placebo was received first positive affect was higher when participants were interacting with romantic partner under placebo (2.95 ± 0.33) than under light (2.18 ± 0.33) ($t_{21} = 7.93$, $p < 0.0001$ by Tukey test; Fig. 5). However, when light was given first positive affect was higher on light (2.30 ± 0.34) than on placebo (2.20 ± 0.34) ($t_{21} = -1.11$, $p > 0.05$ by Tukey test; Fig. 5).

**FIGURE 4**

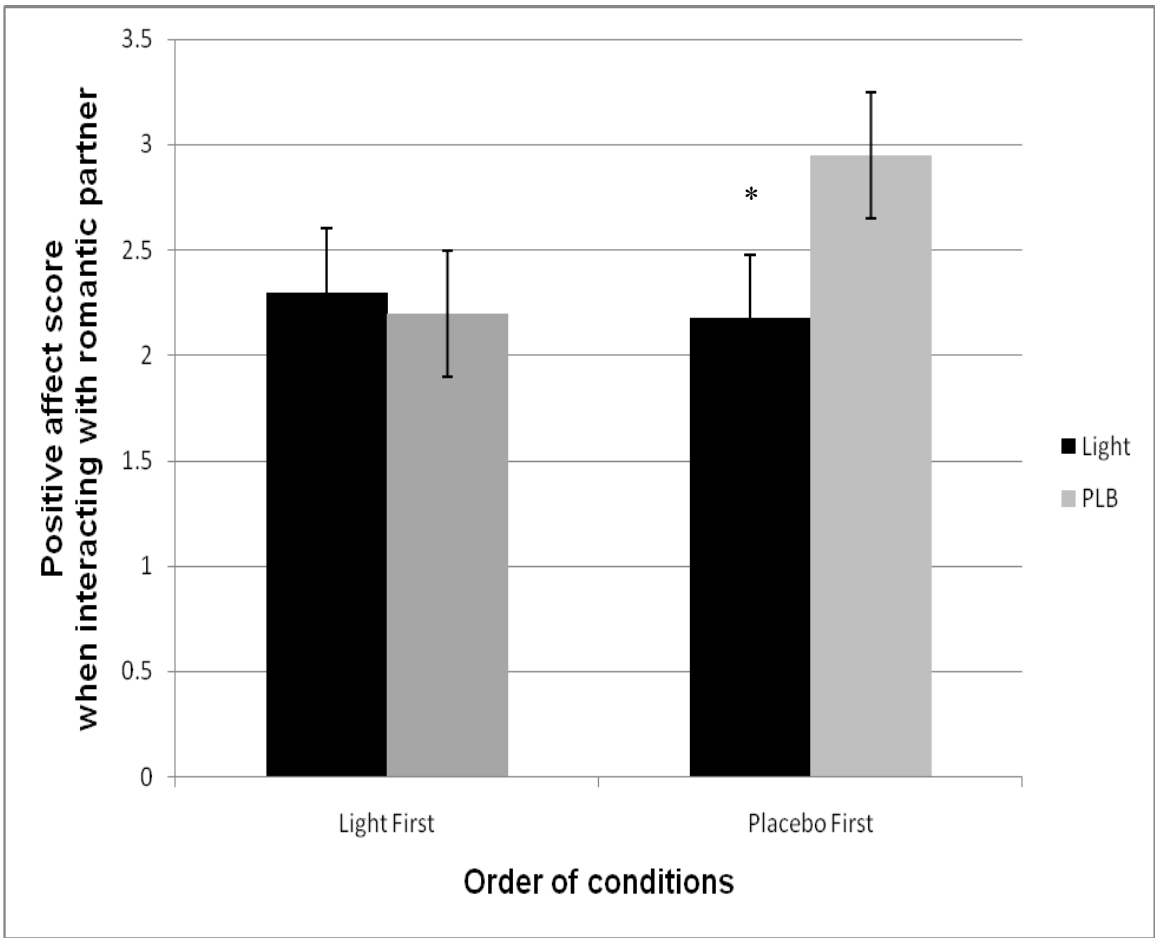
**Positive affect during light and placebo conditions in Group 1**




Values are estimated least squares means ± standard errors.
Light increased positive affect in participants who received light first ($p < 0.001$).
Placebo increased positive affect in participants who received placebo first ($p < 0.001$).

**FIGURE 5**

**Positive affect when individuals were interacting with the romantic partner during light and placebo conditions in Group 1**



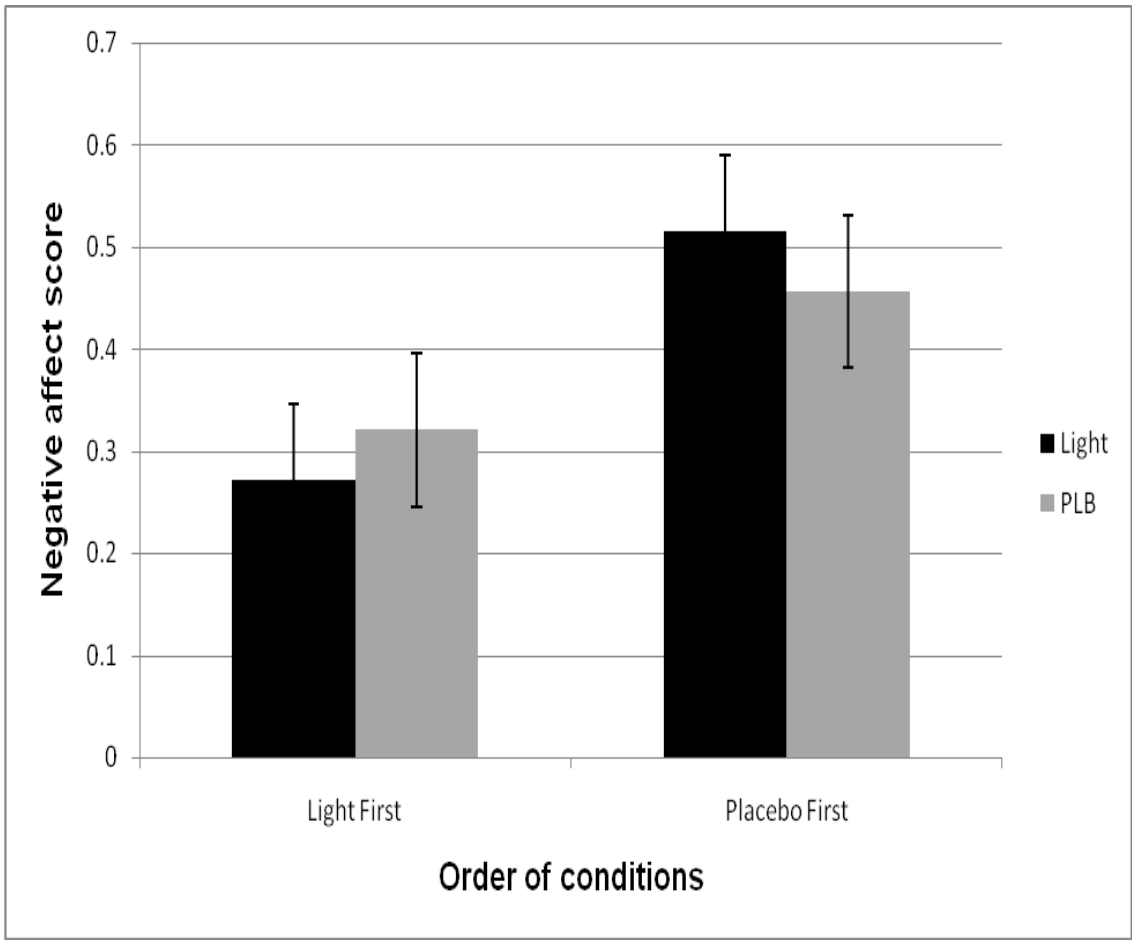

Values are estimated least squares means ± standard errors.
When light was received first, light increased positive affect when participants were interacting with their romantic partner ($p > 0.05$).
When placebo was received first, placebo increased positive affect in participants when interacting with romantic partner ($p < 0.001$).

*Negative Affect.* There were no main effects for condition and order for negative affect**,** but there was a significant interaction with condition and order, $F_{(1,21)} = 8.75$, $p < 0.05$. Negative affect was greater during the light condition ($0.52 \pm 0.073$) than during the placebo condition ($0.46 \pm 0.073$) when placebo was given first ($t_{21} = 2.19$, $p > 0.05$, by Tukey test; Fig. 6). When light was received first there was no significant difference on negative affect score between the two conditions ($p = .59$). There were no significant interaction effects with the contextual variables ($F_{(2,21)} = 1.73$, $p > 0.05$).

*Affect valence and affect arousal.* The analyses for affect valence and affect arousal revealed no significant effects.

**FIGURE 6**

**Negative affect during light and placebo conditions in Group 1**




Values are estimated least squares means ± standard errors.
Light increased negative affect in participants who received placebo first ($p > 0.05$, by Tukey test).

### 3.4 Analysis results of group 2

#### Effects of light on interpersonal behaviour

The analyses for dominant, submissive, agreeable, and quarrelsome behaviour revealed no significant effects.

#### Effects of light on affect

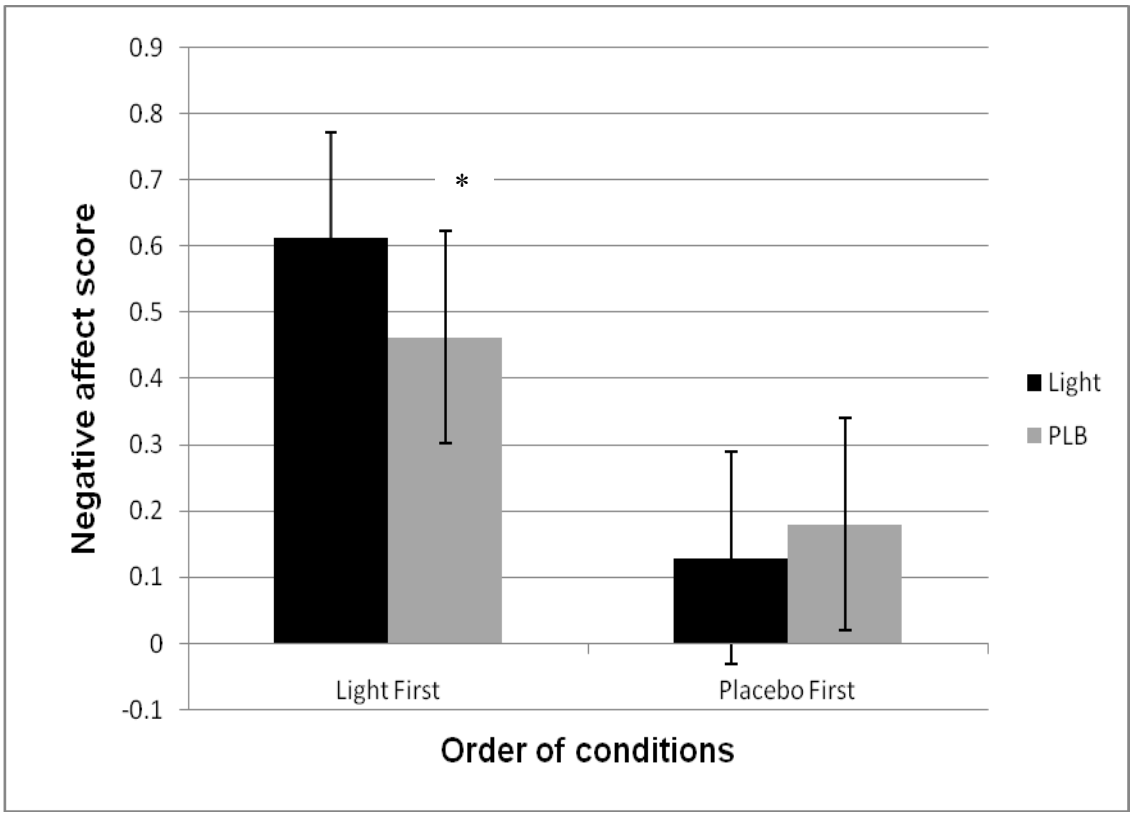
*Positive and negative Affect.* There were no main effects, but there was a significant condition by order interaction for positive affect, $F_{(1,6)} = 8.52$, $p < 0.05$. Post-hoc analyses did not reveal a significant difference between the light and placebo conditions in either order.

For negative affect, there were no significant main effect of light or order, but there was a significant interaction with condition and order, $F_{(1,6)} = 21.93$, $p < 0.01$. Negative affect was greater on light ($0.64 \pm 0.18$) than on placebo ($0.46 \pm 0.18$) when light was given first ($t_6 = 4.58$, $p < 0.05$, by Tukey test; Fig. 7). When placebo was received first, there was no significant difference in negative affect between the two conditions ($p = 0.27$).

*Affect valence and affect arousal.* The analyses for affect valence and affect arousal revealed no significant effects.

**FIGURE 7**

**Negative affect during light and placebo conditions in Group 2**




Values are estimated least squares means ± standard errors.
Light increased negative affect in participants who received light first ($p < 0.05$, by Tukey test).

### 3.5 Analysis results of group 3

**Effects of light on interpersonal behaviour**

*Quarrelsome behaviour.* Quarrelsome behaviour was analyzed with two main effects (condition, order) and their 2-way interactions. The effect of condition was significant, $F_{(1,5)} = 19.66$, $p < 0.01$, and there was no significant interaction with order. Quarrelsome behaviour was higher under light condition (mean ± SE; -14.71 ± 2.30) than under placebo (-19.76 ± 2.30). The treatment effect size for quarrelsome behaviour was large with an $r$ value of 0.89 and a Cohen's $d$ of 8.

*Agreeable behaivour.* Agreeable behaviour was analyzed the same way as quarrelsome behaviour and revealed a significant effect for condition, $F_{(1,5)} = 17.34$, $p < 0.01$. Light decreased agreeable behaviour (light vs. placebo: 12.63 ± 3.49 vs. 18.20 ± 3.48) with a large effect size ($r = 0.88$, Cohen's $d = 3.72$). No significant interaction with order.

*Dominant and submissive behaviour.* The analyses for dominant and submissive behaviour revealed no significant effects.

**Effects of light on affect**

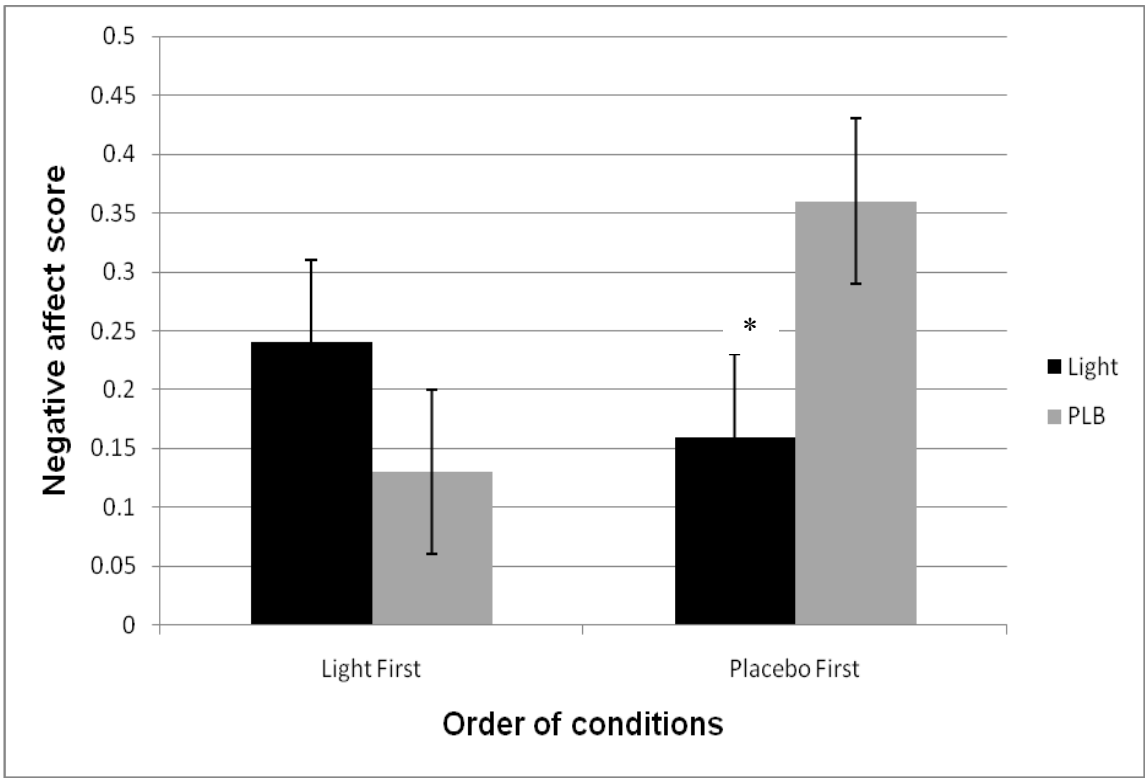
*Positive Affect.* There was a significant effect for condition, $F_{(1,5)} = 16.59$, $p < 0.01$, and there were no effects involving order. Positive affect was greater under light condition (mean ± SE; 2.37 ± 0.36) than under placebo (2.08 ± 0.36). The treatment effect size for positive affect was large with an $r$ value of 0.88 and a Cohen's $d$ of 3.64.

*Negative Affect.* For the negative affect, there was no significant main effect of light or order, but there was a significant interaction of condition by order, $F_{(1,4)} = 41.15$, $p < 0.01$. Negative affect was greater on light (0.24 ± 0.071) than on placebo (0.13 ±

0.069) when light was given first ($t_4 = 3.61$, $p > 0.05$, by Tukey test). When placebo was given first, negative affect was greater on placebo (0.36 ± 0.072) than on light (0.16 ± 0.071) ($t_4 = -5.34$, $p < 0.05$ by Tukey test; Fig. 8). Cohen's *d* for positive affect in those who received placebo first was 5.17 with an *r* value of 0.94.

**FIGURE 8**

**Negative affect during light and placebo conditions in Group 3**




Values are estimated least squares means ± standard errors.
Light decreased negative affect in participants who received placeb first ($p < 0.05$, by Tukey test).

## CHAPTER 4: DISCUSSION

This study examined the effects of bright light on social interaction and mood in mildly seasonal individuals, over three weeks of morning bright light administration and three weeks of low-density negative ions. Participants recorded their mood and behaviours using an event-contingent method and wore an actigraphy with a light sensor to monitor their adherence to home based bright light exposure. Our study was the first known research trial to demonstrate different behaviour patterns of adherence to bright light administration. In our results, we found that a majority (61%) of the participants demonstrated characteristics, from the Actiwatch data, that suggested adherence to the light administration protocol (group 1). We found two groups of the participants who showed no such evidence for adherence (groups 2 and 3). Among those who showed no evidence of adherence, we found 20% of the participants (group 2) demonstrated a specific motor activity and lux pattern during the time of daily morning bright light administration, and that this pattern existed at least 17 out of the 21 day bright light administration. Their Actiwatch data showed unchanging lux measurements along with sustained absence of motor activity. This specific pattern would most likely occur when the Actiwatch was removed by the participant and placed directly in front of the light box. The pattern contrasted greatly with that of group 1 which showed steady motor activity with increased but fluctuating lux measurements presumably due to their hand movements. While it is possible that participants in group 2 did sit in front of the lamp during a 30 minute period each morning after taking off the Actiwatch, there was no evidence that they did adhere to the light administration protocol. The lack of any difference in social behaviour or mood when the participants in group 2 were assigned to

light and negative ions is consistent with the idea that they did not adhere to the protocol to any appreciable extent. The lack of change could also be attributed to the small group size (n = 8) and the resulting lack of power to detect change.

We identified another 18% of the participants whose Actiwatch data did not show any evidence that they adhered to the bright light protocol on the majority of days during the 21 day light period (group 3). Nonetheless, as discussed below, these participants, like those in group 1, did show an increased in quarrelsome behaviours when assigned to light relative to negative ions. Therefore, they may have adhered to the protocol even though this was not apparent from the Actiwatch record. This suggests that the Actiwatch record may be able to detect some participants who do not adhere to a light administration protocol (e.g. those in group 2), but may give false negatives on the results of non-adherence (those in group 3). While the Actiwatch results suggested that it is superior to methods used previously (e.g. asking about adherence, or determining the times during which the light box is switched on), it is not an ideal method. Nonetheless, the fact that Actiwatch results provided some evidence that 61% of the participants (group 1) did adhere to the protocol most of the time indicates that Actiwatch data can be useful.

Our participants were not suffering from any disorder and their motivation for adhering to the protocol is not known, although given that the exhibited seasonality they may have expected to benefit from light administration. Nevertheless, our results were comparable to the adherence literatures published on both psychiatric treatments and community based programs. Cramer and Rosenheck (1998) reviewed the compliance literature of individuals with mental and physical disorders; they found the adherence

rates were 58% and 65% among patients receiving antipsychotics and antidepressants. Another meta-analysis reviewed over 569 studies excluding samples of alcoholic, drug-abusing, homeless, or institutionalized patients, they found adherence rates among patients with various disease conditions (HIV, Arthritis, Caner, etc) receiving intervention that requires behavioural modification such as diet, health behaviour and exercise were 59.3%, 69.7% and 72% respectively (DiMatteo, 2004). Moreover, the two groups of participants who failed to adhere to bright light administration protocol fit the description of the two types of five types of noncompliance to prescription drugs described by Fishman et al. (2000), undercompliance (only partial use of medication), and drug holiday (those who abruptly stop taking their medication for a few days).

This study tested the hypothesis that bright light administration would improve mood and social behaivour in the winter in people with mild seasonality. This hypothesis was based on a number of studies that reported that bright light improved various aspects of mood and behaviour in people with some degree of seasonality (Avery, Kizer et al., 2001; Kasper et al., 1990; Kasper et al., 1989a*;* Partonen & Lonnqvist, 2000) and healthy people in whom seasonality was not determined (Kasper, et al., 1990; Kasper, et al., 1989a; Avery, Kizer, et al., 2001; Partonen & Lonnqvist, 2000; Kohsaka, et al., 1999). Contrary to our hypothesis, in group 1 three weeks of morning bright light administration caused a significant increased in quarrelsome behaivour in healthy people with mild seasonality, along with a decrease in submissiveness, but no change in affect. Although these results are not consistent with the previous studies mentioned above, they are consistent with a smaller number of earlier studies that found bright light treatment did not benefit healthy people with or without sensitivity to seasonal changes (Genhart et al.,

1993; Kasper et al., 1990; Kasper et al., 1989a*;* Rosenthal et al., 1987). Genhart et al. (1993) found that one week of bright light treatment at 2500 lux worsened mood and increased irritability, anxiousness and agitation compared to placebo control (300 lux) in healthy elderly women without seasonality. In addition, 15% of the participants dropped out of the study trial due to increased irritability. This finding was supported by a cross-over trial of bright morning light (>2500 lux) and placebo evening light (less than 10 lux), where they found 32% of patients with late luteal phase dysphoric disorder (LLPDD) reported experiencing increased agitation from morning bright light treatment and not from placebo light condition (< 10 lux) (Parry et al., 1993). Elevated levels of irritability, agitation, and anxiety along with other side effects such as headache, nausea and eyestrain have been well documented by various studies (Kogan & Guilford, 1998; Levitt et al., 1993; Oren, Shannon, Carpenter, & Rosenthal, 1991; Terman & Terman, 2005). Irritability is the mental state associated with quarrelsomeness, so our results are consistent with those mentioned above.

The decline in submissiveness due to light administration in group 1 was presumably associated with increased quarrelsomeness. It is possible for someone to be both submissive and quarrelsome, as in passive aggressiveness (e.g. as indicated by an item on the quarrelsome scale "I withheld useful information"). However, the activating effect of light, seen in the studies cited above as agitation, may have caused the quarrelsomeness to be more active and therefore less submissive.

In group 3, during light treatment, relative to negative ions, the participants were significantly more quarrelsome, less agreeable but had more positive affect. Although the increase in quarrelsomeness is like that in group 1, suggesting that group 3, like group

1, probably did adhere to treatment to a significant extent. There are important differences between the results in groups 1 and 3 in that group 3 did not show a change in submissiveness but did show decreased agreeableness. Furthermore, there was an improvement of mood with light treatment in group 3, which is surprising given the more negative social behaviour. This result is not easily explained. However, given the small size of group 3 (n = 7) the results of that group cannot be accepted with any confidence.

In the present study, treatment improved positive affect in group 1 but only during the first treatment regardless of whether the first treatment was bright light or low-density negative ions. Similar results were found in group 3. One possibility is that participants had positive expectation of the treatment in the first study period related to the novelty of the experience, and when this expectation effect had worn off during the second treatment period, positive affect score was significantly lowered during the bright light condition. This is consistent with the fact that, before the start of the study, almost three quarters of the participants in group 1 expected both treatments to work. During the study participants started feeling burdened by their participation and in addition by the end of the study less than half the participants thought both treatments had worked (Table 1). Both of these findings are consistent with an expectation effect that declined during the study. The order effect we found is similar to that reported by Genhart et al. (1993) who found that participants' ratings of positive affect rose following the first week of light treatment, relative to baseline, regardless of whether they were treated with bright or dim light. Previous studies found bright light administration improved subjective mood, vitality and quality of life in healthy people. Two of these studies (Avery, Kizer et al., 2001; Kasper et al., 1989a) used a parallel design where participants were randomly

allocated to either bright light or placebo condition, and two other studies used a cross-over design (Kohsaka et al., 1999; Partonen & Lonnqvist, 2000) but they did not report finding an order effect. The important conclusion is our results did not show that bright light improved positive affect in healthy individuals with mild seasonality.

In conclusion, this study demonstrated that bright light administered in the morning for three weeks did not improve mood in the healthy, working mildly seasonal individuals and actually had an adverse effect on social behaviour by increasing quarrelsomeness. This conclusion applies only to those participants whose Actiwatch data suggested that they demonstrated good adherence to light treatment. It is not clear whether the change in social behaviour we found was a direct result of the light treatment or associated with how the light was administered. During light administration, unlike during exposure to negative ions, participants had to sit in front of the light. Given all participants worked at least 30 hours per week sitting in front of the light for 30 minutes each morning may have disrupted their normal morning routine, when they were getting ready to go to work, more than being confined to a room with a negative ion generator that could easily be moved from room to room. Possibly a disruption of the normal morning routine would contribute to the greater quarrelsomeness. Thus, it is not clear whether the increased quarrelsomeness is a biological effect of the light or a psychosocial effect of how the light was administered.

**4.1 Limitations and implications**

An important limitation of the present study is that we did not impose the same degree of behavioural restrictions during the placebo condition, by asking participants to sit in front of the low-density negative ion generator as during the bright light condition.

A second limitation is that using the Actiwatch to obtain some measure of adherence to treatment, while better than methods used previously, is far from ideal. Furthermore, there was no measure of adherence to negative ion treatment. A third limitation is that we did not monitor sleep during either study conditions. Previous studies shown bright light can have a powerful effect on sleep. This can influence the participants' overall well-being and might affect treatment outcome (Ancoli-Israel et al., 2003; Benedetti et al., 2005; Dumont & Beaulieu, 2007). While the Actiwatch data gave some indication of sleep duration it could not distinguish between someone lying quietly in bed with minimal movement but awake and someone sleeping. A fourth limitation is the relatively small sample size.

This study has three main implications. The first is that a significant number of participants, those in group 2, may not only have failed to adhere to treatment, but may have behaved in a way that would deceive the researchers about their adherence, that is taking their Actiwatch off their wrist and putting it on a surface in front of the light box. Given that past studies with light administration at home did not have any adequate measure of adherence the results of such studies must be assessed with caution. The second implication is that better methods of testing adherence are needed. One possibility is to use a webcam in the home of the participant during treatment periods. However, this would be rather cumbersome and expensive to implement. A third implication is that the effect of light on mood and behaviour remains uncertain given the widely divergent results of different studies. Much more research will be needed to define what factors influence the results of light studies and to determine to what extent

the effects of light that have been reported are due to biological effect of light or psychosocial effects of the method used to administer light.

**4.2 Summary**

The findings of the present study indicate that there is a need for much better methods to measure adherence to home based bright light exposure. We found that while a majority (61%) of our participants show evidence consistent with adherence to treatment, the remaining 40% demonstrated no such evidence. Given that adherence to light treatment is usually not measured during light administration, and that the most common method for determining adherence is based simply upon the time during which the light is turned on, our results suggest that results in the literature with home-based light administration must be accepted only with caution, and indicate the need for better methods for determining adherence to the protocol in light studies. The results also indicate that in healthy, working individuals with mild seasonality light administration may not improve mood and may actually have adverse effects on social behaviour. Future research needs to identify the circumstances in which light administration is beneficial and the circumstances in which it is contraindicated.

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