BJPsych Advances (2021), vol. 27, 73–84 doi: 10.1192/bja.2020.47

ARTICLE

Let there be blue-depleted light: in-patient dark therapy, circadian rhythms and length of stay

Jan Scott, Knut Langsrud, Ingunn Ro Goulding & Havard Kallestad

SUMMARY

Light is the most important environmental influence (zeitgeber) on the synchronization of the circadian system in humans. Excess light exposure during the evening and night-time affects secretion of the hormone melatonin, which in turn modifies the temporal organization of circadian rhythms, including the sleep–wake cycle. As sleep disturbances are prominent in critically ill medical and psychiatric patients, researchers began to examine the impact of light exposure on clinical outcomes and length of hospitalization. In psychiatric inpatients, exposure to bright morning light or use of blue blocking glasses have proved useful interventions for mood disorders. Recently, knowledge about light and the circadian system has been applied to the design of inpatient facilities with dynamic lighting systems that change according to time of day. The installation of 'circadian lighting' alongside technologies for monitoring sleep–wake patterns could prove to be one of the most practical and beneficial innovations in inpatient psychiatric care for more than half a century.

LEARNING OBJECTIVES

After reading this article you be able to:

- demonstrate basic knowledge about the composition of light and the importance of intrinsically photosensitive retinal ganglion cells (ipRGCs)
- understand core components of the circadian system and the influence of light on the secretion of melatonin and entrainment of circadian rhythms
- demonstrate awareness of research about the impact of blue-depleted light on the sleep–wake cycle and the potential benefits of changing light exposure in psychiatric in-patient units.

KEYWORDS

In-patient treatment; sleep disorders; comorbidity; bipolar affective disorders; schizophrenia.

In human beings, light is essential for vision but also for non-image-forming processes associated with psychological and physiological well-being. Also, it appears that light influences recovery from a range of psychiatric and physical disorders (Castro 2011; Park 2018). This association was proposed many centuries ago, with documents written about asylums in Baghdad (circa 700 AD) suggesting that exposure to natural light and regular meals (ideally accompanied by a calming atmosphere and running water) were important elements of the therapeutic milieu (e.g. Tacchi 2017). Likewise, Florence Nightingale described light and the rhythm of night and day as two important factors in restoring physical health. Similar observations have been reported from 21st-century research undertaken in general hospital in-patient units, with studies indicating that exposure to daylight and views of the natural environment bolstered psychological coping and resilience, which in turn appeared to facilitate faster recovery after surgery (e.g. Ulrich 1984). Importantly, it has now been established that the interrelationship between light, sleep and health has an empirical biological basis (Czeisler 1999; Castro 2011; Goldstein 2014).

It is well-established that absorption of light by receptors in the eyes and skin influences several aspects of human health via downstream effects on circadian rhythms, mood, perception and chemical reactions within the body (e.g. the synthesis of vitamin D_3) (Joseph 2006). Also, we know that most people prefer daylight to electric lighting and that exposure to natural light improves visual acuity, enhances satisfaction with the perceived quality of living and working environments, and boosts subjective perceptions of health (Park 2018). Growing empirical evidence of significant associations between light exposure, mood and well-being has raised awareness of the notion that, as natural light is a key component of any 'healing environment', it may be possible to manipulate light exposure during clinical treatment for patient benefit (e.g. Beauchemin 1996; Park 2018; Scott 2019). In psychiatry, interest in these issues was fostered by growing awareness of seasonal subtypes of affective disorders and evidence that interventions that act on the circadian rhythm and sleep–wake cycle (collectively labelled 'chronotherapies') can

Jan Scott, MBBS, PhD, is a Professor of Psychiatry in the Institute of Neuroscience, University of Newcastle, UK, and the International Visiting Professor in Mental Health at the Norwegian University of Science and Technology (NTNU), Trondheim, Norway. She has a particular interest in mood disorders and undertakes research on motor activity and sleep–wake patterns in health and disease. **Knut Langsrud**, MD, is a psychiatrist and lead consultant of the acute in-patient unit at St Olavs University Hospital, Ostmarka, Norway. He founded the sleep clinic at Ostmarka and has published studies on sleep and circadian rhythms in severe mental disorders. He has a central role in all research activities related to the new psychiatric in-patient unit in Trondheim. **Ingunn Ro Goulding**, BA (Nursing), is a psychiatric nurse in the acute psychiatric unit at St Olavs University Hospital. She is a member of the staff group facilitating research and development in the new unit and took part in participant allocation and progress monitoring in the trial described in this article. **Havard Kallestad**, PhD, is a specialist in clinical psychology at St Olavs University Hospital and a researcher in the Department of Mental Health at NTNU. His research interest is in interventions aimed to improve sleep–wake disruptions in health and mental illness. He is the principal investigator of the NTNU research projects on light exposure in psychiatric units and co-designed the research infrastructure for the acute in-patient unit at St Olavs University Hospital with Dr Langsrud.
Correspondence Jan Scott. Email: jan.scott@newcastle.ac.uk

First received 26 Mar 2020
Final revision 9 Jun 2020
Accepted 23 Jun 2020

BOX 1 Light and its measurement

What is light?

- There are two forms of light: natural light (sunlight and fire) and artificial light.
- Sunlight is a form of electromagnetic radiation and is categorised by its wavelength into ultraviolet (UV) A, UVB, infrared and visible light. The actual wavelengths present vary over the day according to latitude, meteorological conditions and season. Visible light is essential for human vision and for regulating the circadian system (via retinal photoreceptors).
- Artificial light is a term that refers to any light source produced by electrical means, such as incandescent bulbs, fluorescent tubes and light-emitting diodes (LEDs). Compared with natural light, artificial light is composed of a more limited range of wavelengths, usually concentrated in a segment of the visible light spectrum. Artificial light is worse for colour perception, but the quantity, quality and intensity of light exposure can be controlled more easily than sunlight.

How is light measured?

- Light can be measured using radiometry or photometry. The former measures the entire visible and non-visible wavelength spectra, whereas the latter measures light according to the perception of brightness as seen by the human eye. This is quantified in lux units: for example, artificial light in a brightly lit office might reach 400 lux; a bright summer day often exceeds several thousand lux.
- The lux reported for a lamp often refers to the lux of light as measured at the surface of the lamp. For clinical purposes, it is more useful to know the level of incident light at the eye. For example, although a bright-light therapy (BLT) lamp may be marketed as providing 10 000 lux, this is the lux if it is used exactly as per instructions (e.g. at a distance not greater than ~30 cm, etc.).
- Recently, more refined approaches to the measurement and description of light have been promoted. These describe light intensity in terms of lux but weighted for the action spectrum of the different photopigments (e.g. melanopic lux). Thus, two light sources with different light spectra (e.g. blue and yellow) can have similar levels of photopic lux (often abbreviated to 'lux'), but different levels of melanopic lux. Variations in the latter mean that these light sources will have different effects on the circadian system.

also have profound effects on the mental state of individuals with mental disorders. Interest in the utility of chronotherapies for mental health has mainly focused on the benefits of morning bright-light therapy (BLT) (Parry 2003). However, the past 10–20 years has seen a growth in research on the clinical application of actual or virtual darkness to acute mental disorders such as mania (Gottlieb 2019). Furthermore, evidence of sleep–wake disturbances across a range of major mental disorders has led some experts to argue for the transdiagnostic application of chronotherapies (Kallestad 2012).

In this paper, we highlight key information about the phenomenon of light and how it is measured (see Box 1 for details). Then we provide a simple overview of the circadian system, briefly summarize some of the early clinical scientific evidence for the impact of light exposure on circadian rhythms and examine the links to physical and mental health. The paper then focuses on recent non-pharmacological developments in chronotherapies. Given that many reviews exist on this topic, we have chosen to focus on evidence regarding the effects of light exposure on clinical outcomes of hospital inpatients, especially the use of dark therapy for mood and other major mental disorders. We specifically highlight how changes to lighting systems in hospital units could improve sleep patterns of acutely ill inpatients and potentially modify the course and outcome of physical and mental disorders. In addition, we briefly note some of the challenges and opportunities of undertaking research in such settings. To meet journal requirements regarding space, we have not listed every reference on the topics and themes discussed in this article. Additional citations are available from the corresponding author.

Light and the circadian system

Box 1 briefly describes the two forms of light and how light is measured. Essential components of the circadian system are listed in Box 2 and important

BOX 2 The circadian system

Key components of the circadian system are:

- intrinsically photosensitive retinal ganglion cells (ipRCGs) that transmit information via the retinohypothalamic tract to the suprachiasmatic nucleus (SCN)
- a circadian pacemaker (also described as an internal oscillator or master clock) located in the SCN
- external oscillators (e.g. external stimuli such as light–dark cycles) that can entrain (reset) the internal oscillator, with light intensity, timing and spectrum being important disruptors of rhythms
- secretion of melatonin (a hormone that carries 'time' information) by the pineal gland
- local circadian oscillators in peripheral tissues

BJPsych Advances (2021), vol. 27, 73–84 doi: 10.1192/bja.2020.47

BOX 3 Light and the sleep–wake cycle

- Light is the most important zeitgeber of circadian rhythms (i.e. it is an environmental cue that entrains the circadian system).
- Light exposure in the morning, after the nadir of the core body temperature, will phase-advance circadian rhythms, whereas light exposure in the evening and night-time, before the nadir, will phase-delay circadian rhythms.
- Increased or decreased exposure to artificial light at night may significantly alter circadian rhythms. For instance:
  - exposure to light-emitting electronic devices for 4 consecutive nights may:
    - suppress melatonin secretion by 50% and delay melatonin onset by ~1.5 h
    - reduce the amount of rapid eye movement (REM) sleep
    - reduce alertness in the morning
  - avoiding artificial light exposure at night and remaining in darkness after sunset for 3 consecutive nights can advance the timing of melatonin onset and the sleep phase.

aspects of the effects of light on this system are summarised in Box 3.

This section offers a basic overview of the circadian system and the impact of light exposure on the synchronisation of circadian rhythms. Understanding this provides readers with useful insights into the underlying rationale for experimental manipulations of the circadian clock as utilised in chronotherapies (Benarroch 2008).

Light and the photoreceptors of the eye

The visual sensory system is comprised of image-forming photoreceptor cells of rods (for low-level light) and cones (for sharpness detail and colour vision). When a photon of light reaches the rods or cones it acts on light-sensitive pigments (photopigments called rhodopsins), and this generates a sequence of chemical events that create electrical impulses in the optic nerve, which converge in the visual cortex and are interpreted as vision (Castro 2011). However, it is now known that there is a third type of retinal photoreceptor in mammals called intrinsically photosensitive retinal ganglion cells (ipRGCs). The ipRGCs use the photo pigment melopsin to absorb light passing through the retina and generate electrical impulses that are transmitted via neurons to the suprachiasmatic nucleus (SCN) of the anterior hypothalamus (Lazzerini Ospri 2017; Fernandez 2018).

Research demonstrates that ipRCGs (which are independent of the rods and cones) mediate non-visual effects of light on a range of biological processes. The ipRGCs are particularly sensitive to the absorption of short-wavelength (blue) light but transmit information about all forms of the visible light spectrum through the retinohypothalamic tract to the SCN (Lazzerini Ospri 2017).

The circadian pacemaker and its connections

The SCN is often referred to as the circadian pacemaker (or ‘master clock’) because of its critical role in controlling and regulating circadian rhythms in mammals (Czeisler 1999; Reppert 2002). The SCN contains ~20 000 neurons that express a near-24-hour rhythm of electrical activity. Although the SCN cells can generate their own synchronised oscillations, they can be entrained (reset) by photic input (via ipRCGs) and non-photic input (from other brain regions). Hastings and colleagues (2019) explain that the efferent neural and humoral signals that are generated from the SCN play a critical role in coordinating the activity of circadian oscillators located in many different target organs and peripheral tissues of the body. Thus, the SCN maintains the internal temporal order underpinning physiological adaptation to the solar cycle (Hastings 2003). Importantly, SCN projections to the pineal gland modulate secretion of the hormone melatonin. Melatonin carries ‘time’ information, for example about the time of the day (a ‘clock’ function) and time of the year (a ‘calendar’ function), from the brain to all parts of the body (Benarroch 2008). Melatonin secretion begins at dark and the level of melatonin in the bloodstream plays an essential role in regulating the sleep–wake cycle (Foster 2005). Finally, connections between ipRGCs and the limbic system, striatum and the brain-stem may affect mood state, while connections between the thalamus, SCN, retina, visual and other cortical/subcortical areas suggest that the thalamus acts as a major interface between alertness and cognition (Fernandez 2018). The effects of light on these systems and the subsequent impacts may be of specific interest to psychiatry research and practice (Scott 2019).

Light, the SCN and the sleep–wake cycle

Although the sleep–wake cycle is the most obvious example of a circadian rhythm in humans, many other physiological processes and behaviours show rhythmicity, including body temperature, release of hormones, metabolism and gene expression (Hastings 2019). Several environmental stimuli can entrain the SCN (and the sleep–wake cycle), but light is the most critical factor or zeitgeber

(Foster 2005). The role of light in resetting the phase of the SCN is partly a function of the timing, duration, intensity and wavelength of the exposure (which can range from regular light–dark cycles to seasonal 'photo-periods') (Czeisler 1999; Reppert 2002; Khalsa 2003). Bonmati-Carrion and colleagues (2014) comment that, in high-income countries, nights are excessively illuminated whereas, in contrast, more daytime hours are spent indoors. So, daytime light exposure equates to a much lower lux than under natural conditions, but there is excess light exposure during the evening and night-time, which leads to a reduced zeitgeber strength and a disorganisation of the circadian system (Box 3). Even a small change in the timing of the light exposure (e.g. 20 min of low-level artificial light at night) can cause perturbations in melatonin production and lead to a shift in the phase of circadian rhythms (Castro 2011). Furthermore, the impact will be observable in the next circadian cycle (with changes in sleep–wake patterns detectable in the following 24–36 h), whereas the effects on circadian physiology (such as temperature or melatonin levels) can be measured objectively immediately after the aberrant light exposure or even during the actual exposure (Wulff 2010).

Many biological processes show that maximal sensitivity to short-wavelength light and exposure to blue light during the daytime is important for maintaining well-being, alertness and cognitive performance during the day (Wahl 2019). In contrast, chronic exposure to blue light (even as part of traditional 'white' light) directly before bedtime may affect sleep quality and circadian phase and/or cycle duration (Wahl 2019). Interestingly, research indicates that the absence of blue light (so-called virtual darkness) is equivalent to actual darkness from the perspective of the human brain and synchronisation of circadian rhythms (Castro 2011; Scott 2019).

Brief comments about sleep–wake cycle disruptions and acute illness episodes

Craig & Mathieu (2018) highlight that any acute medical illness disrupts circadian rhythms, and evidence demonstrates associations with subsequent increases in morbidity and mortality. However, sleep–wake cycle disruptions are equally, if not more, apparent in mental disorders (Foster 2005). For instance, sleep–wake cycle disruptions are criterion symptoms for diagnosing unipolar and bipolar disorders; sleep abnormalities may be prodromal symptoms heralding the onset of mood, psychotic and/or other major mental disorders; and emerging data identify that circadian dysrhythmias may exacerbate e.g. suicidal behaviours (Rumble 2018; Scott 2019). Also, research by our own group demonstrates that day-to-day variability in sleep–wake cycles is associated with frequency of aggression or violent acts in transdiagnostic populations admitted to psychiatric intensive care units (Langsrud 2016, 2018).

Overall, experimental and clinical research has demonstrated a reciprocal relationship between stabilisation of sleep–wake/circadian disruptions and improvement in mental state across a range of mental disorders. These and other observations have promoted research into a range of chronotherapies that act on the circadian rhythm and/or regulation of the sleep–wake cycle in order to achieve a therapeutic effect on the mental state. As noted in Box 4, studies have examined the utility of melatonin agonists as an adjunctive pharmacological treatment in several mental disorders, while other research has explored, for example, in-patient provision of sleep deprivation (also called wake therapy). Comprehensive reviews are available on these topics (e.g. Parry 2003; Coogan 2011; Gottlieb 2019), so we do not repeat the findings here, but we now focus specifically on the influence of light exposure on physical and mental disorders. We then explore the clinical utility of interventions that modify exposure to light (and in turn regulate sleep–wake and circadian rhythms) with particular reference to in-patient settings.

BOX 4 The most widely used chronotherapies in psychiatry

- Melatonin and melatonin agonists
- Cognitive–behavioural therapy for insomnia (CBT-I)
- Bright-light therapy (BLT)
- Sleep deprivation (also called wake therapy)
- Blue-blocking glasses
- Dark therapy (see text for details)

This list represents therapies that are specifically identified as chronotherapies, so it does not include medications (such as antidepressants or mood stabilisers) or psychological therapies (such as interpersonal social rhythms therapy) that are primarily prescribed for specific Axis I diagnoses rather than as a chronotherapy.

For a discussion of combined chronotherapies see Humpston et al (2020).

Clinical research about light exposure and illness

Epidemiological studies, such as those undertaken with shift workers, repeatedly demonstrated that aberrant light exposure leads to prolonged chronodisruptions (Joseph 2006; Bonmati-Carrion 2014).

Furthermore, the resulting circadian dysrhythmias not only produce sleep disturbances but also are associated with an increased incidence of diabetes, obesity, heart disease, cognitive and affective impairment, premature ageing and some types of cancer (Foster 2005; Bonmati-Carrion 2014).

Sunny versus sunless wards

Although the negative impact of some types of light exposure has been well-publicised, a smaller body of research explores the potential health benefits of optimising light exposure in community and clinical settings. For example, a review by Park et al (2018) suggested that full-spectrum light exposure in hospital in-patients can be associated with increased levels of patient satisfaction, decreased levels of distress and improved physical capacity (by decreasing heart rate and systolic blood pressure, and increasing oxygen uptake). Such findings support evidence from earlier observational or cohort studies of medical patients, with several assessments of the impact of exposure to natural light on the clinical outcomes of patients admitted to intensive care units (ICU). In one study, Beauchemin & Hays (1998) noticed that beds in a cardiac intensive care unit (CICU) in Alberta, Canada, were oriented in such a way that four beds were north facing and virtually sunless (light exposure at 09.45 h registering 200–400 lux) and four were south facing and mainly bright (light exposure at 09.45 h registering 1200–1300 lux). They reviewed CICU admissions over 4 years and identified that individuals who experienced an acute myocardial infarct whose hospital beds were in bright rooms had better outcomes in terms of both shorter length of stay (LOS) and significantly lower mortality rates than those in dark rooms (8 *v.* 13%).

Undertaking randomised controlled trials (RCTs) with very acutely ill patients is problematic (not least, the assessment of capacity and ethics of obtaining informed consent), but some RCTs do exist. For example, an RCT of 89 patients admitted for cervical or lumbar spinal surgery found that the participants allocated to a brightly lit ward reported less distress or pain than those allocated to a dimly lit ward, and the former group needed 22% less analgesic medication per hour, which contributed to a significant reduction in the cost of care and treatment (Walch 2005). Nearly all the medical in-patient studies comment that the impact of light on the circadian system was an important mediator of the observed clinical outcomes (Scott 2019).

In psychiatry, theories regarding the origin of seasonal affective disorders, such as the circadian phase-shift hypothesis of winter depression, played an important role in stimulating research into light therapies (Lewy 2007). Like general medicine, the initial studies mainly comprised careful clinical observations of cohorts of patients admitted to psychiatric wards with hospital rooms that had different orientations and light exposure (e.g. they were east or west facing). For example, a retrospective study of hospital records by Beauchemin & Hays (1996) found that the LOS of patients with depression in sunny rooms was reduced by about 2.6 days (15%) compared with depressed patients in sunless rooms ($P < 0.05$). Open studies also indicated the benefits of bright light in unmedicated in-patients with depression (Wirz-Justice 1999). However, observational and open studies have largely been overtaken by prospective cohort studies, and by controlled trials and RCTs that actively manage the timing and duration of light exposure and (gradually) have established the minimum intensity of light (lux) required to achieve significant reductions in depressive symptoms.

Timing, duration and type of light

One of the first studies that alluded to the importance of the timing of light exposure was undertaken by Lewy et al (1998). Researchers noted that being exposed to bright daylight led to a significant decrease in symptoms within 2 weeks in in-patients with seasonal depressive disorders, whereas it took 4–6 weeks to show the equivalent benefit from antidepressants. However, the rapid improvement in symptoms was mainly associated with exposure to morning light, whereas afternoon or evening/night light had limited effects. Reviews and meta-analyses have identified that treatment effects in depression persist for longer with light illuminations >2000 lux (compared with artificial lighting or exposure <300 lux) and that morning BLT for about 2 h duration is more effective than BLT (of the same lux) for about 30 min (Parry 2003).

Some research suggests that spectral frequencies of light are associated with differential improvements in depressive symptoms, with inconsistent evidence that green light may be more beneficial than red light. However, the current consensus is that bright white light (often 10 000 lux at eye level and a distance of about 30 cm) for 30 min per day during the early morning (for up to 6 weeks) is likely to be most effective for depressive disorders. Evidence suggests that morning sunlight and/or BLT may be particularly useful for treating bipolar depression and/or reducing hospital LOS (Benedetti 2001), but a recent meta-analysis suggests that findings are inconsistent regarding any specific benefit for bipolar compared with unipolar depression (Takeshima 2020). Research is ongoing on the use of BLT for atypical depression, but there is emerging evidence of its utility in treatment-resistant disorders (Kragh 2018) and its use with adolescent in-patients (Holtmann 2018; Kirschbaum 2018).

Bright-light therapy beyond the mood disorders

The majority of studies of BLT focus on mood disorders, but there are suggestions that benefits may extend to other in-patient populations, such as individuals with eating disorders (although the timing of symptom response and persistence of treatment effects remain unknown) (Beauchamp 2016). Studies of BLT in psychotic disorders are scarce (Bellivier 2015), with most research focused on schizoaffective or puerperal disorders (Oren 2001; van Ravesteyn 2017). As evidence indicates that in-patients with schizophrenia experience significant sleep/circadian disruptions (~50% show severe circadian misalignment such as phase shifts, non-24-hour sleep–wake and melatonin cycles, etc.), it appears that intervention trials could be justified (e.g. Langsrud 2016; Scott 2019). Also, this research will allow examination of whether the therapeutic effect of light in mental disorders is mediated solely through an effect on the circadian system or, as suggested by some research, whether there is a direct effect of light on mental health (Fernandez 2018). As clinicians will be aware, these mediation studies will need to consider the effects of confounding by medications prescribed for in-patients with severe mental disorders (many of which have an impact on neurotransmitters and neuronal pathways linked to the circadian system).

From out-patient light therapy to in-patient dark therapy

Early research on the impact of natural light on hospital in-patients was quickly followed by out-patient studies using specifically designed equipment such as light boxes to deliver BLT to individual patients. The acceptability of BLT is partly due to principally favourable findings for efficacy in RCTs and meta-analyses, but also to its ease of delivery, positive views of BLT among consumers, limited evidence of side-effects and high levels of adherence. However, for in-patients personalised interventions such as the use of individual light boxes is only feasible or practical in selected units (Sheaves 2018). As an alternative, many facilities modify lighting systems in in-patient wards to aid delivery of light therapy, for example delivering BLT by bedside light-emitting diode (LED) lights (Okkels 2020) or changing the lighting system across the entire facility (Scott 2019).

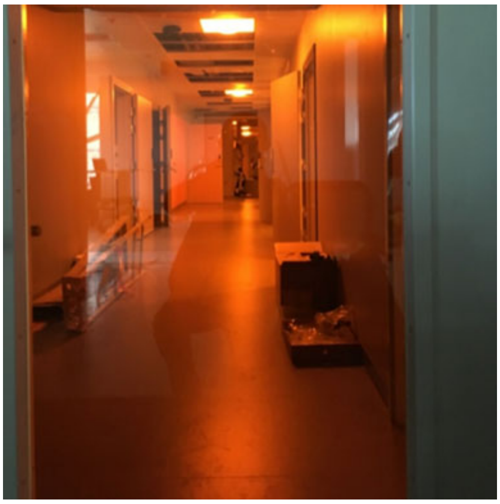
Dark therapies

Difficulties in delivering chronotherapy to acutely ill psychiatric patients is best exemplified by considering dark therapies. The interventions with published evidence of effectiveness are darkness therapy (spending 14 h in darkness per day) or the use of blue-blocking glasses with patients who are admitted to hospital for acute mania (Barbini 2005; Henriksen 2016). However, the research protocol required active engagement by the study participants, for example they were asked to repetitively engage in specified behaviours (resting in forced darkness from about 18.00 to 08.00 h) or use particular equipment (such as blue-blocking glasses) at specified times of the day (Scott 2019). Unsurprisingly, there are concerns about the level of adherence in individuals who are acutely unwell and about imposing personal responsibility on them regarding the timing of exposure to different intensities or spectra of light. Also, given the prevalence of sleep–wake cycle disturbances in in-patients with mental disorders, it is logical to consider the possibility of delivering ‘optimised’ or circadian lighting to transdiagnostic in-patient populations.

‘Circadian lighting’ in in-patient facilities: Scandinavian research and experience

In response to all the above considerations, clinical and research groups in Denmark (e.g. the Rigshospitalet in Copenhagen, Aabenraa and Aarhus University) and Norway (St Olavs Hospital in collaboration with the Norwegian University of Science and Technology in Trondheim) have designed in-patient facilities where changes in light exposure are regulated automatically and where programmable lighting conditions form an integral part of the therapeutic milieu. These new units are exploring the impact of environmental lighting on the sleep and clinical outcomes of psychiatric in-patients, and some are also examining how technological innovations might be employed to monitor any treatment benefits.

The focus on lighting and novel non-invasive methods for monitoring patient sleep represent a significant shift from previous eras (van den Berg 2005). Historically, acute psychiatric admission units have offered asylum and a place of safety, where ward routines and structured activities help to reduce arousal, regularise sleep–wake cycle patterns and improve self-esteem, and so on. However, the focus now is primarily on in-patient delivery of physical and pharmacological treatments that reduce symptoms and suicidality, enhance social functioning and sufficiently improve the individual’s mental state to allow a timely return to out-patient or community care (Scott 2019). Although



From 07:00 h to 18:00 h the ward has normal hospital lighting. From 18:00 h to 18:30 h there is a transition from normal to blue-depleted lighting. From 18:30 h to 06:50 h all light sources are blue-depleted. From 06:50 h to 07:00 h the lighting undergoes a transition to normal lighting.

FIG 1 Blue-depleted evening light in the new in-patient unit in Trondheim, Norway. The LED modules inside the light fittings contain a mix of red, green/white and blue diodes that can be programmed individually to emit different light intensities at different times of the day. To create evening blue-depleted lighting, only the green/white and red diodes emit light, and the blue diode is switched off. Blue-blocking window filters are also deployed in the evening, and all televisions have permanent blue-blocking filters.

recent guidance on the design and structure of new psychiatric units has emphasised the importance of the quality and fabric of the buildings and furnishings (e.g. Department of Health 2013), there is a lack of recognition that ordinary indoor hospital lighting is unsatisfactory for daily living and does not support stabilisation of sleep–wake patterns or circadian rhythms (indeed, it may worsen them). As Feifel (2008) points out, little or no attention has been given to the creation of a state-of-the-art in-patient milieu in psychiatry.

In laboratory studies, exposure to evening blue-depleted LED modules has been found to be less disruptive to the circadian system, to improve sleep and decrease arousal, although exposure to blue light during the day is important for a range of biological processes. Hence, the goal is not to create an environment that is devoid of blue light over 24 h. Rather, the aim is to create a lighting system that is programmed to produce blue-depleted evening light, which has an amber hue (Fig. 1). Ideally, this might be amalgamated with morning bright light (and/or change in the light spectrum and intensity throughout the unit during the course of the day) as this combined approach can increase zeitgeber strength, increase daytime wake time and strengthen the rest–activity rhythm (supplementary Appendix, available at https://doi.org/10.1192/bja.2020.47). However, some caution is needed regarding increasing the general daytime light intensity in units that regularly admit individuals presenting with acute mania. Furthermore, we await research to determine whether approaches will need further personalisation according to the circadian preference of each individual patient (chronotype).

As described in the publications from the Danish and Norwegian units, there are several options for introducing ‘circadian lighting’ (into existing or new-build units). In order of cost/complexity, these could include the following.

Simple individual interventions

Provide blue-light blocking screens that can be attached to the front of all electronic devices (especially mobile phones and electronic tablets). Also, if there is a clinical indication, consider providing blue-blocking glasses for patients to wear if they leave the unit in the evening (after about 18.30 h). If staffing levels and individual mental state allow, it is helpful if patients spend at least 30 min outdoors in daylight before about midday.

Basic unit-wide interventions

Ensure that television sets have permanent blue-blocking filters attached to the screen. Consider installing blue-blocking window filters that can be deployed in the evening and examine the need for (and/or feasibility of) installing external lights that block blue light in outdoor spaces used by patients from the facility.

Major innovation

As well as the individual interventions noted above, more sophisticated options might include installing programmable lighting systems in which all indoor light sources are blue-depleted during the evening and night-time (between about 18.30 h and 07.00 h). Ideally, the system should modify lighting across the entire unit, including corridors, etc. (Fig. 1), as partial systems (i.e. changes in patients' rooms only) appear to be less effective (Okkels 2020). From about 07.00 h to 18.00 h, individuals are exposed to ordinary indoor lighting (~3000 Kelvins (K) of colour temperature). Although the light intensity is preferably dimmed to about 20% (of the maximum) from 23.00 h to 06.50 h, the photopic lux (which is important for vision) of the light should remain constant (3000 K) throughout the 24-h cycle, i.e. it is only the melanopic lux (which is important for non-visual effects of light) that is lowered in the evening and at night-time. To further optimise circadian rhythmicity and mood, it is worthwhile considering the introduction of bright light in selected spaces such as the dining areas at breakfast time (≥10 000 lux) or other light interventions in individual patients' rooms.

Remote monitoring of sleep–wake-activity patterns

Any admission on an acute psychiatric unit is likely to include close monitoring of the patient across the 24-h cycle. Traditionally, direct observation has been employed to achieve this, especially repeated night-time observation of those who are severely unwell or at high risk of self-harm. Although nursing observation is the cheapest option, it is intrusive, time-consuming, largely inaccurate and potentially wakes the patient several times each night. These night-time intrusions have been shown to further worsen sleep and potentially increase the patient's sensitivity to light, noise or other disturbances (Park 2018). Moreover, these in-patients are likely to be exposed to increased lux at night-time (because lights are repeatedly switched on to enable observation), which is potentially countertherapeutic (Veale 2019). However, a system that requires no direct patient contact but allows staff to closely and continuously monitor individual patients uses ultra-wide-band radar technology that is built into the ceiling of patients' rooms. The system requires no direct patient involvement while offering real-time monitoring of sleep–wake state, movement and respiration. The system can detect movements of less than 1 mm and can be used with very high sensitivity and specificity for detecting sleep–wake state compared with polysomnography (Toften 2020). It avoids the use of any other remote approaches, such as visual observation by cameras, and is well-tolerated among patients. Our experience with about 4000 admissions to the acute psychiatric unit in Trondheim, is that only one patient reacted negatively to this remote observation.

Implementation of environmental interventions: questions to be resolved

The above developments have predominantly been introduced or are planned for introduction in specialist wards such as ICUs, neurorehabilitation and in-patient affective disorders units. Findings from this research has been encouraging, although a recent small-scale RCT (with a more limited approach to and control of light exposure) showed only modest effects on sleep quality and other parameters (Okkels 2020). Before expecting mainstream psychiatry to consider investing in these lighting (and monitoring) systems, it is necessary as a minimum to address the following clinical questions:

(a) Does stabilisation of sleep–wake cycle disturbances hasten symptomatic and/or functional recovery, reduce the use of any classes of medication (such as night sedation) and, critically, is there any impact on hospital LOS (as in-patient treatment is the costliest element of psychiatric care)?
(b) Which subgroups of patients benefit from exposure to these new lighting environments and which (if any) are adversely affected?
(c) What side-effects do patients experienced (over and above those associated with any disorder-specific treatments)?

The Trondheim RCT and proof of principle trial

Most findings to date are derived from small-scale RCTs involving selected populations and/or cohort studies. However, to fully explore each of these propositions and to ensure adequate statistical power, it is necessary to undertake large-scale RCTs. Study design and assessment protocols are greatly assisted by ensuring early involvement of patient advocacy groups to advise on patient-preferred procedures and outcome measures. Likewise, some problems, such as recruitment of acutely ill patients, can be overcome by ethically approved approaches such as delayed consent procedures (Scott 2019). However, the major stumbling block to a large-scale trial of an environmental intervention has been the lack of any possibility of creating two units that differ only in the lighting system. The opening of the new psychiatric unit in Trondheim (with two wards of 20 beds with exactly the same layout, furnishings, facilities, staffing levels, etc.) therefore offers a unique opportunity to undertake a pragmatic effectiveness RCT with a sample size that is sufficient both to explore the possible reduction in LOS and to undertake subgroup analyses (e.g. to determine whether patients experiencing a manic episode benefit more than those experiencing psychosis). Essentially, about 500 trial participants have been randomised either to a ward employing the 'circadian lighting system' or to a ward employing normal hospital lighting. An additional feature of the research programme in Trondheim is that, with the cooperation of staff and professional

BJPsych Advances (2021), vol. 27, 73–84 doi: 10.1192/bja.2020.47

BOX 5 The Trondheim proof of principle trial of circadian lighting systems (see text for details)

Key elements of the trial protocol

- 12 healthy young adults were recruited to a brief randomised cross-over trial.
- Six individuals spent 5 days residing in the normal lighting environment, followed by 5 days in the blue-depleted evening light environment, whereas the other six started in the blue-depleted evening light environment, followed by the normal lighting environment.
- While resident at the unit, all participants were asked to follow a set daily routine (for this study population it focused only on regular mealtimes, bedtimes and rise times).

Brief summary of findings

- By the end of the trial, all participants showed a significant increase in sleep regularity (mean score on the sleep regularity index increased from 85% at baseline to 95%).
- Objective recordings (such as actigraphy) demonstrated that sleep–wake cycles became more stable simply from following a more regular routine in the normal lighting environment and compared with pre-trial sleep–wake patterns (outside the unit).
- Residing in the blue-depleted evening light environment was associated with the following additional benefits compared with residing in the normal lighting environment:
  - melatonin levels were less suppressed
  - the circadian rhythm was phase-advanced more
  - total sleep time was longer
  - rapid eye movement (REM) sleep was longer.
- Overall, residing for even 5 days in the blue-depleted evening light environment led to significant additional improvements on all key metrics associated with sleep and the circadian system (over and above those related to residing at the unit). Furthermore, there were no significant differences in reported side-effects (a slight excess of fatigue/tiredness in the blue-depleted light environment).

unions, we are examining whether there any negative effects on sleep–wake cycles or well-being of nurses and other staff and/or any changes in work performance. This is an important issue that has never been considered in any research into light exposure in medical or psychiatric wards.

As well as broad-based clinical outcomes, it will be important to undertake research into any effects on the circadian rhythm, sleep and neurocognitive arousal of individuals residing in a hospital unit (psychiatric or medical) providing evening blue-depleted light. Furthermore, from a basic science perspective, if individuals do show improvements in sleep–wake cycle, it would be important to demonstrate that this is linked to detectable changes in biology (e.g. melatonin secretion, objectively measured shifts in sleep phases, circadian rhythms). Undertaking such measurements in the sample recruited to the Trondheim RCT is not feasible (and detracts from the pragmatic focus, i.e. hospital LOS according to lighting exposure). So, to study any of these effects, we undertook a proof of principle study (trial protocol: ISRCTN12419665). As noted in Box 5, we concluded that it is possible to create a hospital in-patient environment that has a meaningful impact on the circadian system and sleep, without major side-effects or adverse effects. This has given us confidence to institute the lighting system in clinical practice.

Conclusions

Acute medical and psychiatric illnesses disrupt circadian rhythms, and lack of sleep further increases patients' vulnerability to unstable mood and disrupted cognition and motor activity (Park 2018). Naturalistic and observational studies have long demonstrated the potential benefits of manipulating light exposure for in-patients, and it is noteworthy that in the literature, the effectiveness of 'light-based' interventions has best been understood in relation to hospital LOS (Castro 2011). The findings of studies that employ various iterations of circadian lighting systems could influence the future design of hospital units offering care to patients with mental or physical disorders. The impact of this cannot be overstated for mental health research and practice, as there has been a lack of innovation in the design of in-patient psychiatric units, with limited changes in treatments, observation techniques or environments over the past 50 years (van den Berg 2005; Feifel 2008). An additional appeal of exploring the benefits of dynamic lighting systems for patients with mental disorders is that light and dark therapies are the only treatment interventions in psychiatry that can be proven to have directly evolved out of basic neurobiological research (Parry 2003). Hence, the underlying mechanisms of action can continue to be tested over time.

In summary, we highlight that there is a strong rationale for considering the impact of light exposure on individuals admitted to hospital with acute metal disorders. However, the modification of light exposure needs to take account of the fact that not all wavelengths of light are equally 'chronodisrupting' (Bonmati-Carrion 2014). Furthermore, the impact of certain wavelengths may vary over the course of 24 h. There is still a lack of knowledge regarding the quantity and quality of daylight needed for circadian entrainment and optimal

MCQ answers
1 e 2 b 3 b 4 d 5 d

physiological and psychological functioning (Munch 2020). Consequently, it is not yet established whether modifying indoor daylight by increasing the light intensity (e.g. to 500–1000 lux) and/or modifying the light spectrum have the same clinical effects as morning BLT, which is typically 10 000 lux. Similarly, it is not known how much reduction in exposure to the blue spectrum in the evening is necessary to achieve a clinical effect (e.g. reducing light levels to ≤20 melanopic lux may be sufficient for an effect on the circadian rhythm). There are also large differences in sensitivity to light between individuals and between patient groups, and some psychotropic medication may change light sensitivity (Gottlieb 2019). Because individuals in a psychiatric hospital unit are free to move around, light exposure is bound to vary, and we do not know how findings from laboratory studies will translate into such a context. These will be important questions to answer in the years to come.

Even if the introduction of a new in-patient lighting system is totally unfeasible, it is worthwhile considering simple interventions (changing light lux on laptops and tablets, using blue-blocking filters for mobile phones) to nullify the effects of nocturnal blue-light exposure (which is increasing owing to the proliferation of LEDs and electronic devices). As noted by Bonmati-Carrion and colleagues (2014), the development of lighting systems that preserve the melatonin rhythm could reduce some of the health risks associated with modern living, and could be especially important for individuals with or at risk of episodes of major mental disorders. The research challenge will be to identify who benefits most and to minimise any potential harms from these innovations.

Note

Several in-patient units using circadian lighting systems are now in operation. Most of these have websites that describe the equipment being used or have written articles or manuals that give specific details of wavelengths of light that are required (or should be blocked) for maximum efficacy. Readers may wish to consult these other units. However, if readers are particularly interested in the work we are undertaking, we can provide more details about the Trondheim unit and the technical details regarding equipment. Also, site visits are possible for researchers or clinical groups looking to expand their use of these approaches and to discuss views and experiences of in-patient staff working in this new environment.

Acknowledgements

We thank the entire staff of the acute ward for participation. We would also like to thank the User Group at St Olavs Hospital, Ostmark, for their review and input to the research projects and their support throughout the process of constructing the new unit in Trondheim.

Author contributions

All authors agreed the preliminary learning objectives and J.S. wrote a preliminary draft of the article. This drew on the protocol and research publications by the group. All authors contributed to redrafting of the article and contributed MCQs or commented on the statements and items included. All authors agreed the final submitted version of the manuscript.

Supplementary material

Supplementary material is available online at https://doi.org/10.1192/bja.2020.47.

Funding

The research described in this article is supported by grants from the Norwegian University of Science and Technology and St Olavs Hospital.

Declaration of interest

None.

ICMJE forms are in the supplementary material, available online at https://doi.org/10.1192/bja.2020.47.

References

Barbini B, Benedetti F, Colombo C, et al (2005) Dark therapy for mania: a pilot study. *Bipolar Disorders*, **7**: 98–101.

Beauchamp M, Lundgren J (2016) A systematic review of bright light therapy for eating disorders. *Prim Care Companion CNS Disorders*, **18**(5): 10.4088/PCC.16r02008.

Beauchemin K, Hays P (1996) Sunny hospital rooms expedite recovery from severe and refractory depressions. *Journal of Affective Disorders*, **40**: 49–51.

Beauchemin K, Hays P (1998) Dying in the dark: sunshine, gender and outcomes in myocardial infarction. *Journal of the Royal Society of Medicine*, **91**: 352–4.

Bellivier F, Geoffroy P, Etain B, et al (2015) Sleep- and circadian rhythm-associated pathways as therapeutic targets in bipolar disorder. *Expert Opin Ther Targets*, **19**: 747–63.

Benarroch E (2008) Suprachiasmatic nucleus and melatonin. *Neurology*, **71**: 594–98.

Benedetti F, Colombo C, Barbini B, et al (2001) Morning sunlight reduces length of hospitalization in bipolar depression. *Journal of Affective Disorders*, **62**: 221–3.

Bonmati-Carrion M, Arguelles-Prieto R, Martinez-Madrid M, et al (2014) Protecting the melatonin rhythm through circadian healthy light exposure. *International Journal of Molecular Sciences*, **15**: 23448–500.

Castro R, Angus D, Rosengart M (2011) The effect of light on critical illness. *Critical Care*, **15**: 218–30.

Coogan A, Thome J (2011) Chronotherapeutics and psychiatry: setting the clock to relieve the symptoms. *world Journal of Biological Psychiatry*, **12** (suppl 1): 40–3.

Craig T, Mathieu S (2018) CANDLE: the critical analysis of the nocturnal distribution of light exposure. A prospective pilot study quantifying the nocturnal light intensity on a critical care unit. *Journal of Intensive Care and Society*, **19**: 196–200.

Czeisler C (1999) Stability, precision, and near-24-hour period of the human circadian pacemaker. *Science*, **284**: 2177–81.

Department of Health (2013) *Health Building Note 03-01: Adult Acute Mental Health Units*. Department of Health.

Feifel D (2008) Transforming the psychiatric in-patient unit from short-term pseudo-asylum care to state-of-the-art treatment setting. *Psychiatry (Edgmont)*, **5**(9): 47–50.

Fernandez D, Fogerson P, Lazzerini Ospri L, et al (2018) Light affects mood and learning through distinct retina–brain pathways. *Cell*, **175**(1): 71–84.e18.

Foster R, Wulff K (2005) The rhythm of rest and excess. *Nature Reviews Neuroscience*, **6**: 407–14.

Goldstein A, Walker M (2014) The role of sleep in emotional brain function. *Annual Review of Clinical Psychology*, **10**: 679–708.

Gottlieb J, Benedetti F, Geoffroy P, et al (2019) The chronotherapeutic treatment of bipolar disorders: a systematic review and practice recommendations from the ISBD task force on chronotherapy and chronobiology. *Bipolar Disorders*, **21**: 741–73.

Hastings M, Reddy A, Maywood E (2003) A clockwork web: circadian timing in brain and periphery, in health and disease. *Nature Reviews. Neuroscience*, **4**: 649–661.

Hastings M, Maywood E, Brancaccio M (2019) The mammalian circadian timing system and the suprachiasmatic nucleus as its pacemaker. *Biology*, **8**: 13–21.

Henriksen T, Skrede S, Fasmer O, et al (2016) Blue-blocking glasses as additive treatment for mania: a randomized placebo-controlled trial. *Bipolar Disorders*, **18**: 221–32.

Holtmann M, Mokros L, Kirschbaum-Lesch I, et al (2018) Adolescent depression: study protocol for a randomized, controlled, double-blind multicenter parallel group trial of Bright Light Therapy in a naturalistic inpatient setting (DeLight). *Trials*, **19**(1): 568.

Humpston C, Benedetti F, Serfaty M, et al (2020) Chronotherapy for the rapid treatment of depression: a meta-analysis. *Journal of Affective Disorders*, **261**: 91–102.

Joseph A (2006) *The Impact of Light on Outcomes in Healthcare Settings (Issue Paper #2)*. Center for Health Design.

Kallestad H, Hansen B, Langsrud K, et al (2012) Impact of sleep disturbance on patients in treatment for mental disorders. *BMC Psychiatry*, **12**: 179.

Khalsa S, Jewett M, Cajochen C, et al (2003) A phase response curve to single bright light pulses in human subjects. *Journal of Physiologica*, **549**: 945–52.

Kirschbaum I, Straub J, Gest S, et al (2018) Short-term effects of wake- and bright light therapy on sleep in depressed youth. *Chronobiology International*, **35**: 101–10.

Kragh M, Larsen E, Martiny K, et al (2018) Predictors of response to combined wake and light therapy in treatment-resistant in-patients with depression. *Chronobiology International*, **35**: 1209–20.

Langsrud K, Vaaler A, Kallestad H, et al (2016) Sleep patterns as a predictor for length of stay in a psychiatric intensive care unit. *Psychiatry Research*, **237**: 252–6.

Langsrud K, Kallestad H, Vaaler A, et al (2018) Sleep at night and association to aggressive behaviour in patients in a psychiatric intensive care unit. *Psychiatry Research*, **263**: 275–9.

Lazzerini Ospri L, Prusky G, Hattar S (2017) Mood, the circadian system, and melanopsin retinal ganglion cells. *Annual Review of Neuroscience*, **40**: 539–56.

Lewy A, Bauer V, Cutler N, et al (1998) Morning vs. evening light treatment of patients with winter depression. *Archives of General Psychiatry*, **55**: 890–6.

Lewy A, Rough J, Songer J, et al (2007) The phase shift hypothesis for the circadian component of winter depression. *Dialogues in Clinical Neuroscience*, **9**: 291–300.

Munch M, Wirtz-Justice A, Brown S, et al (2020) The role of daylight for humans: gaps in current knowledge. *Clocks & Sleep*, **2**: 61–85.

Okkels N, Jensen LG, Skovshoved LC, et al (2020) Lighting as an aid for recovery in hospitalized psychiatric patients: a randomized controlled effectiveness trial. *Nordic Journal of Psychiatry*, **74**: 105–14.

Oren DA, Cubells JF, Litsch S (2001) Bright light therapy for schizoaffective disorder. *American Journal of Psychiatry*, **158**: 2086–7.

Park M, Chai C, Lee H, et al (2018) The effects of natural daylight on length of hospital stay. *Environ Health Insights*, **12**: 1178630218812817.

Parry B, Maurer E (2003) Light treatment of mood disorders. *Dialogues in Clinical Neuroscience*, **5**: 353–65.

Reppert S, Weaver D (2002) Coordination of circadian timing in mammals. *Nature*, **418**: 935–41.

Rumble M, Dickson D, McCall W (2018) The relationship of person-specific eveningness chronotype, greater seasonality, and less rhythmicity to suicidal behavior: a literature review. *Journal of Affective Disorders*, **227**: 721–30.

Scott J, Langsrud K, Vethe D, et al (2019) A pragmatic effectiveness randomized controlled trial of the duration of psychiatric hospitalization in a trans-diagnostic sample of patients with acute mental illness admitted to a ward with either blue-depleted evening lighting or normal lighting conditions. *Trials*, **20**(1): 472.

Sheaves B, Freeman D, Isham L, et al (2018) Stabilising sleep for patients admitted at acute crisis to a psychiatric hospital (OWLS): an assessor-blind pilot randomised controlled trial. *Psychological Medicine*, **48**: 1694–704.

Tacchi MJ, Scott J (2017) *Depression: A Very Short Introduction*. Oxford University Press.

Takeshima M, Utsumi T, Aoki Y, et al (2020) Efficacy and safety of bright light therapy for manic and depressive symptoms in patients with bipolar disorder: a systematic review and meta-analysis. *Psychiatry and Clinical Neuroscience*, **74**: 247–56.

Toften S, Pallesen S, Hrozanova M, et al (2020) Validation of sleep stage classification using non-contact radar technology and machine learning. *Sleep Medicine* [Preproof] 6 Mar. Available from: https://doi.org/10.1016/j.sleep.2020.02.022.

Ulrich R (1984) View through a window may influence recovery from surgery. *Science*, **224**: 420–1.

van den Berg A (2005) *Health Impacts of Healing Environments: A Review of Evidence for Benefits of Nature, Daylight, Fresh Air, and Quiet in Healthcare Settings*. University Hospital Groningen (http://agnesvandenberg.nl/healingenvironments.pdf).

van Ravesteyn L, Lambregtse-van den Berg M, Hoogendijk W, et al (2017) Interventions to treat mental disorders during pregnancy: a systematic review and multiple treatment meta-analysis. *PLoS One*, **12**(3): e0173397.

Veale D (2019) Against the stream: intermittent nurse observations of in-patients at night serve no purpose and cause sleep deprivation. *BJPsych Bull*, **43**: 174–6.

Wahl S, Engelhardt M, Schaupp P, et al (2019) The inner clock: blue light sets the human rhythm. *Journal of Biophotonics*, **12**(12): e201900102.

Walch J, Rabin B, Day R, et al (2005) The effect of sunlight on post-operative analgesic medication usage: a prospective study of patients undergoing spinal surgery. *Psychosomatic Medicine*, **67**: 156–63.

Wirz-Justice A, Graw P, Roosli H, et al (1999) An open trial of light therapy in hospitalised major depression. *Journal of Affective Disorders*, **52**: 291–2.

Wulff K, Gatti S, Wettstein J, et al (2010) Sleep and circadian rhythm disruption in psychiatric and neurodegenerative disease. *Nature Reviews Neuroscience*, **11**: 589–99.

MCQs

Select the single best option for each question stem

1 Regarding photoreceptor cells in the eye:

a it was recently discovered that there are four types of photoreceptor in the eye
b cones are essential for vision in low-level light
c ipRGCs is an abbreviation of interpersonally sensitive retinal ganglion cells
d ipRGCs are image-forming photoreceptors
e ipRCGs directly mediate the effects of light on the circadian pacemaker via the retinohypothalamic tract.

2 Regarding the circadian system:

a the suprachiasmatic nucleus is the external oscillator of the circadian system
b melatonin carries ‘time’ information from the pineal gland to other tissues and organs
c a minimum of 60–90 min exposure to low-level light is necessary to suppress melatonin production
d biological processes show low sensitivity to blue light
e the absence of red light is the equivalent of darkness from the perspective of the human brain.

3 Research in individuals residing for 5 consecutive days in a blue-depleted evening light environment (compared with normal lighting) is likely to show:

a more phase delay in circadian rhythms
b less suppression of melatonin secretion
c reduced rapid eye movement (REM) sleep
d reduced total sleep time
e evening headaches.

4 Morning bright-light therapy (BLT) in psychiatry:

a is only an add-on treatment for sleep–wake disturbances
b is a treatment for mania
c is used for suppression of melatonin levels for patients with sleep–wake disturbances
d has a direct effect on mental state in addition to effects on sleep–wake disturbances
e is used to improve advanced sleep–wake phase disorder.

5 Dark therapy in psychiatry:

a is only an add-on treatment for sleep–wake disturbances
b is a treatment for depression
c is used for suppression of melatonin levels for patients with sleep–wake disturbances
d is a treatment for mania
e is used to improve advance circadian rhythm problems.

BJPsych Advances (2021), vol. 27, 73–84 doi: 10.1192/bja.2020.47