Applied Ergonomics 42 (2011) 256–260

Contents lists available at ScienceDirect

Applied Ergonomics

journal homepage: www.elsevier.com/locate/apergo

# Bright light effects on ultradian rhythms in performance on hemisphere-specific tasks

Irena Iskra-Golec [a,*], Lawrence Smith [b]

[a] Institute of Applied Psychology, Jagiellonian University, Os. Niepodległości 8/27, Lojasiewicza 4, 30-348 Krakow, Poland
[b] Institute of Psychological Sciences, University of Leeds, Leeds, UK

A R T I C L E I N F O

*Article history:*
Received 1 February 2010
Accepted 15 June 2010

*Keywords:*
Bright light
Ultradian rhythm
Cognitive performance

A B S T R A C T

Ultradian rhythms in indices of brain hemisphere activity and in cognitive performance have been found in numerous studies. Asymmetry of these rhythms with regard to phase and frequency have also been documented in some studies. There is some evidence that bright light can affect ultradian rhythms of arousal state and vigilance. A study on unilateral exposure to bright light has demonstrated more pronounced effects of bright light on the right hemisphere. The aim of this study was to examine whether daytime intermittent bright light could affect parameters of ultradian rhythms in performance speed on hemisphere-specific tasks, and whether the effect of bright light was symmetric for the rhythms in performance on hemisphere-specific tasks presented laterally. A counter-balanced, within-subject research design was applied. The performance of 15 participants on hemisphere-specific tasks exposed laterally was measured every 30 min starting at 08:00 h and ending at 20:30 h in intermittent bright light (IBL, pulses of 15 min of 4000 lux light regularly interspersed between 45 min of background light levels of 300 lux) and in ordinary room light (ORL) conditions (300 lux). Individual time series data were subjected to cosinor analysis. General linear model analyses (the factors were: level of processing, visual field, and the task) were performed on the rhythms' parameters. There was a substantial lengthening of the rhythms' periods in IBL conditions for performance speed on spatial tasks and an increase in amplitude of the rhythms of performance speed for spatial tasks in both visual fields and for verbal tasks in the left visual field in the IBL conditions when compared to the ORL conditions. The results showed that the schedule of light exposure affected ultradian rhythms of hemisphere-specific tasks differently and that the right hemisphere seems to be more "sensitive" to light than the left hemisphere.



## 1. Introduction

Kleitman's (1967) hypothesis of the basic rest activity cycle (BRAC) inspired research into 1.5 h-rhythms in human physiology and behavior. Ultradian rhythms have been demonstrated in a number of studies not only in physiological functions but in behavioral and cognitive processes as well. They have been demonstrated in the brain hemispheres' EEG activity (e.g., Tsuji and Kobayashi, 1988; Lavie, 1989; Ortega and Cabrera, 1990; Hayashi et al., 1994), sleep propensity (e.g., Lavie, 1991), gross motor activity (e.g., Globus et al., 1971, 1973; Grau et al., 1995), in perceptual performance (e.g., Lavie et al., 1974) motor performance (e.g., Gopher and Lavie, 1980), and in cognitive performance (e.g., Klein and Armitage, 1979). Moreover, cycles of several hours, so called 'slow ultradian rhythms' (e.g., Hayashi et al., 1994) and rhythms with very short periods (1–2, 4–7 and above 10 min) (e.g., Smith et al., 2003) have also been documented in addition to the 1.5 h rhythm corresponding to Kleitman's BRAC.

Additionally, asymmetric ultradian rhythms have been demonstrated in different indices of hemispheric activation (Shannahoff-Khalsa, 1993) as well as in some cognitive performance measures. This asymmetry concerns phase (e.g., Klein and Armitage, 1972; Meier-Koll, 1989, 1998) and frequency (Mender et al., 1997; Reinberg et al., 1997; Shub et al., 2001; Iskra-Golec, 2001). For example, Mender et al. (1997), Reinberg et al. (1997), and Shub et al. (2001) demonstrated ultradian rhythms with 8 h and 12 h periods in choice reaction time, while reacting separately with either the left or the right hand. Iskra-Golec (2001) found ultradian rhythms (12 h) in the shallow encoding speed of stimuli addressed to the left hemisphere and a period of around 8 h in the encoding speed of stimuli addressed to the right hemisphere.

Low amplitude and stability of ultradian rhythms (Lavie, 1989) make them susceptible to being masked by rhythms of higher

* Corresponding author. Tel.: +48 12 649 75 25.
*E-mail address:* upiskra@cyf-kr.edu.pl (I. Iskra-Golec).

0003-6870/$ – see front matter © 2010 Elsevier Ltd and The Ergonomics Society. All rights reserved.
doi:10.1016/j.apergo.2010.06.012

amplitudes (e.g., circadian rhythms) as well as other factors, e.g., high motivation (Hayashi et al., 1998). Thus, some studies failed to detect ultradian rhythms in performance (e.g., Kripke et al., 1985). Expression of ultradian rhythms seems to be facilitated by some environmental factors like constant conditions (Wever, 1992) and/or low environmental demands (Escera and Grau, 1994). Despite the existence of ultradian rhythms being documented in a number of studies their oscillator(s) and their external synchronizers have not yet been identified. Instead some hypotheses concerning both have been developed (Kobayashi et al., 1985; Shannahoff-Khalsa, 1991; Broughton, 1989, respectively). Thus, status of research on ultradian rhythms, with the focus on detection of these rhythms in a particular measure or a set of measures, resembles the status of early chronobiological research on circadian rhythms.

The studies on ultradian rhythms rarely demonstrate the effects of exogenous manipulation on these rhythms in the search for cues to help understand their mechanisms and identify their oscillator (s) and synchronizers. It has been shown, however, that a single pulse of bright light can affect ultradian rhythms in arousal (Tsuji et al., 1999) and vigilance level (Tsuji et al., 2003). Ultradian periodicity of arousal state was dispersed in non-bright light conditions while in bright light conditions it became more stable with periods of 10-, 3-, and 1.5-h (Tsuji et al., 1999). In another study (Tsuji et al., 2003) a single pulse of bright light in the morning resulted in the phase advance of the body temperature rhythm in some subjects and in the phase delay in others. In the cases of a phase advance in the body temperature rhythm, the ultradian periodicity of performance measures remained stable at periods of around 2.0 h and 12.0 h. The ultradian periodicity of performance measures was rather dispersed in the cases where there was a temperature rhythm phase delay.

Studies of light effects (bright light or light of different wavelengths) concentrate mainly on the alerting or circadian effects of light. It has been demonstrated in a number of studies that the effect of light on the human circadian system depends on the timing, intensity, duration, pattern, wavelength and history of exposure. A recent study (Cajochen et al., 2008) suggests that there might be a hemispheric asymmetry in the alerting effects of light.

This study was a secondary analysis of part of the data from a larger study reported elsewhere (Iskra-Golec and Smith, 2008). The earlier study showed bright light effects on the daily course of performance speed on spatial tasks (with the interaction between measurement time and light conditions approaching significance) and lack of such effects in the case of verbal tasks. This finding as well as the research mentioned earlier in this section reporting, (a) hemispheric asymmetry of ultradian performance rhythms with regard to phase and frequency, (b) the stabilizing effect of bright light on the periodicity of ultradian rhythms, and (c) the recent finding suggesting a hemispheric asymmetry in the alerting effect of light, provide the rationale for the following hypotheses examined in this study:

1. There is a significant effect of daytime intermittent bright light on the parameters of ultradian rhythms of performance speed on hemisphere-specific tasks presented laterally.
2. There are different effects of bright light on the rhythms of performance speed on hemisphere-specific tasks presented laterally.

## 2. Methods

### 2.1. Participants

The participants in the larger study reported elsewhere (Iskra-Golec and Smith, 2008) were 20 right-handed student volunteers (15 female, 5 male). Participants were recruited for the study by advertisements on the university's intranet. They underwent pre-study screening (interviews) to ensure that they had a normal sleep–wake cycle (habitual bedtime $23 \pm 1$ h and wake time: $07.00 \pm 1$ h), normal or corrected vision, and were healthy and free from medical and psychiatric disorders (GHQ-12, Goldberg and Williams, 1988). All participants were required to maintain their regular 8 h sleep schedule for two weeks before the experiment and to record their bed and wake times each day in sleep diaries. Each participant signed a written informed consent form providing information on the study, and each was paid for her participation. The experimental protocol was approved by the Ethics Committee of the Institute of Psychological Sciences, University of Leeds. The research methods meet the ethical standards of the journal (Portaluppi et al., 2008).

For the purpose of the present study the performance data of male volunteers were excluded from the analysis since ultradian rhythms were not detected in the performance data of two subjects and in two others, non-significant ultradian rhythms were detected. Performance data obtained from 15 female students ($n = 15$) aged between 21 and 24 yr (mean 22.2 yr, SD = 1.31) were subjected to further analysis for this study after cosinor analysis revealed significant ultradian oscillations.

### 2.2. Protocol

A repeated measure within subject study design was applied. A semi-constant routine with limited exposure to major time cues was applied. The protocol comprised eight experimental sessions of 13 h duration (07:30 h–20:30 h); four in ordinary room light conditions (ORL) and four in intermittent bright light (IBL) conditions. IBL condition sessions and ORL condition sessions were carried out simultaneously, one in the bright light laboratory and the other one in the department computer room on four consecutive Saturdays in winter (January and February). Both rooms were comparable with regard to experimental conditions apart from the light level during the IBL exposure. All participants were studied for the first time on the first two Saturdays in the sequence. For each experimental session 10 randomly selected participants were studied: five in IBL conditions and the other five in ORL conditions. Two weeks later each group of five participants was studied in the alternative lighting conditions to those experienced in the first session. This way 20 participants were studied in both light conditions with a two-week interval between the sessions. For the purpose of this study the data for 15 participants (as noted in the Participants section above) from 6 sessions (3 in IBL conditions and 3 in ORL conditions) were subjected to further analysis.

The Bright Light laboratory was equipped with a ceiling-mounted, computer controlled light system with seven channels. Each channel consisted of 3–4 ft. × 2 ft. bays (luminaries) with four fluorescent tubes. In both bright and ordinary room light conditions, Polylux XL F36W/835 fluorescent tubes were used. They had a light output of 3350 lumens, a color rendering index of 0.85, and a color temperature of 3500 K. The bright lighting system was controlled by variable ballasts, allowing variable intensities of light exposure at different periods. In the dim lighting condition the lights were regulated by standard non-variable ballasts. The system allowed the light intensity to be increased from a minimum illumination of 100–200 lux up to 5000 lux. The procedure of IBL exposure consisted of six, 15-min pulses of BL of 4000 lux intensity (as measured, while seated, at eye level on the horizontal plane) at hourly intervals starting from 11:00 h. Between the 4000 lux light pulses in the IBL condition as well as during the ORL conditions the level of light was typical for office light levels (i.e., 300 lux).