Journal of Environmental Psychology 36 (2013) 270–279

Contents lists available at ScienceDirect

Journal of Environmental Psychology

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

Daytime light exposure and feelings of vitality: Results of a field study during regular weekdays

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ARTICLE INFO

Article history:
Available online 9 October 2013

Keywords:
Lighting
Vitality
Daytime
Well-being
Mental fatigue
Everyday settings

ABSTRACT

In the current study, we investigated daily light exposure and its relation with vitality in everyday settings on an hour-to-hour basis. The method consisted of experience sampling combined with continuous light measurement and a sleep diary during three consecutive days. Data collection was distributed over a full year. Results revealed substantial inter- and intra-individual differences in hourly light exposure. The amount of light experienced was significantly related to vitality, indicating that persons who were exposed to more light experienced more vitality, over and above the variance explained by person characteristics, time of day, activity patterns and sleep duration during the previous night. This relationship was more pronounced in the morning, during the darker months of the year and when participants had experienced relatively low vitality during the previous hour. Overall, the results provide support for acute effects of light exposure on feelings of vitality during daytime, even in everyday life.

1. Introduction

Light not only enables us to see the world around us, but is also important for our physical and psychological functioning. Exposure to light can affect human experiences, performance and physiology via both image-forming and non-image forming processes (Berson, 2003; Boyce, 2003; Hanifin & Brainard, 2007; Warthen & Provencio, 2012). Via the visual system, light enables us to extract and process relevant visual information required for performing visual tasks, and influences how we visually experience the environment. In addition to activation of the visual system, photoreceptors in the human retina signal light information to brain areas involved in the regulation of behavior, mood and physiology (Hattar, Liao, Takoa, Berson, & Yau, 2002; Vandewalle, Maquet, & Dijk, 2009). This non-image forming pathway affects the timing of physiological and psychological processes throughout the 24-h light–dark cycle, as well as a person's state of alertness and mood, physiological arousal and cognitive processing.

To date, most studies investigating acute alerting effects of light on human behavior and physiology have been performed in the late evening or at night. Laboratory studies have shown that nocturnal exposure to higher illuminance levels or light in the blue spectrum can result in increased feelings of alertness, more physiological arousal and better cognitive performance at night (e.g., Cajochen, Zeitzer, Czeisler, & Dijk, 2000; Campbell & Dawson, 1990; Lockley et al., 2006; Myers & Badia, 1993; Zeitzer, Dijk, Kronauer, Brown, & Czeisler, 2000). Similar beneficial effects of bright light or morning dawn-simulating light exposure during daytime have been demonstrated for individuals who had first experienced substantial light and/or sleep deprivation (Gabel et al., 2013; Phipps-Nelson, Redman, Dijk, & Rajaratman, 2003; Rüger, Gordijn, Beersma, de Vries, & Daan, 2006; Vandewalle et al., 2006). Moreover, a recent laboratory study suggested that exposure to white light with a higher illuminance level also had beneficial effects on alertness and vitality during daytime, even in the absence of sleep and light deprivation (Smolders, De Kort, & Cluitmans, 2012).

The extent to which the activating effects of light shown in the laboratory can translate to benefits in everyday life is relatively unknown. Only few studies have explored these effects in the field. Moreover, the process is complex as vitality and alertness may fluctuate with numerous other variables (e.g., activities, food intake, social context) that cannot be controlled outside the laboratory. In addition, light exposure throughout the day is very

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0272-4944/$ – see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.jenvp.2013.09.004

dynamic and research has shown that the experienced amount of light is, among other factors, dependent on whether a person is indoors or outdoors, on time of day and season, working hours and type of job, age and chronotype, suggesting both intra- and inter-individual differences in daily light exposure (Goulet, Mongrain, Desrosiers, Paquet, & Dumont, 2007; Guillemette, Hébert, Paquet, & Dumont, 1998; Hébert, Dumont, & Paquet, 1998; Hubalek, Brink, & Schierz, 2010; Martin, Hébert, Ledoux, Gaudreault, & Laberge, 2012; Sadikes, Messin, Senger, & Kripke, 1986; Scheuermaier, Laffan, & Duffy, 2010; Staples, Archer, Arber, & Skene, 2009; Thorne, Jones, Peters, Archer, & Dijk, 2009). So an important challenge for lighting research today is to establish the alerting and vitalizing potential of light in everyday life, over and above the rich set of stimuli already experienced there.

A few studies have revealed beneficial effects of prolonged exposure to blue-enriched or bright light among office employees in the field. For instance, two field studies have shown that exposure to blue-enriched light in office environments for several weeks improved subjective alertness, sleep quality and self-reported performance compared to lighting with a lower correlated color temperature (Mills, Tomkins, & Schlangen, 2007; Viola, James, Schlangen, & Dijk, 2008). Partonen and Lönnqvist (2000) revealed improved vitality after four weeks of repeated exposure to very high illuminance levels (~2500 lx at the eye) during the darker winter months in Finland.

In addition to these effects of long-term exposure (order of weeks), several field studies have measured individuals' light exposure patterns and investigated its relationship with mood, social behavior, sleep quality and circadian phase of their rest–activity cycle on a day-to-day basis. Hubalek et al. (2010), for example, employed wearable light meters worn close to the eye in a naturalistic study (see Hubalek, Zöschg, & Schierz, 2006) and demonstrated that light exposure during the day can have a significant and positive effect on subjective sleep quality, but that it was not related to self-reported mood assessed at the end of day. Moreover, Figueiro and Rea (2010a; 2010b) showed that reduced exposure to light in the blue spectrum in the morning or exposure to light with a higher portion in the blue part of the spectrum in the evening may result in a delayed onset of sleep among adolescents in daily situations. A field study by Martinez-Nicolas, Ortiz-Tudela, Madrid, and Rol (2011) showed a relation between persons' light exposure, timing and quality of sleep and skin temperature, suggesting a link between the intensity and variability of a person's light exposure throughout the 24-h day and the amplitude and phase of his or her circadian rhythm. Moreover, Aan het Rot, Moskowitz, and Young (2008) showed that the duration of exposure to bright light during the morning, afternoon or evening was related to the amount of positive social interactions experienced among persons suffering from mildly seasonal affective disorder.

Yet, little is known about the relationship between persons' experienced light intensity levels and their momentary affective state throughout the day, i.e., acute effects. In the current field study, we explore the relation between daytime light exposure and feelings of vitality among healthy day-active persons on an hourly basis in everyday situations. Vitality refers to the positive feeling of having energy or resources available to the self (Ryan & Deci, 2008; Ryan & Frederick, 1997). Experiences of vitality are central to mental well-being, health and performance, and important for success in various realms of life including one's career, health, and quality of the social network (e.g., see Heatherton & Wagner, 2010). Vitality generally correlates closely with self-reported alertness and an item probing alertness is often included in vitality scales. Research has shown time-dependent and inter-individual variations in vitality as a function of, among others, persons' chronotype and general health (e.g., Ryan & Frederick, 1997; Thayer, 1989; Thayer, Takahashi, & Pauli, 1988). We therefore investigated the relationship of light exposure with vitality throughout the day correcting for inter- and intra-personal differences in experiences of vitality. More specifically, this study investigates whether light exposure would significantly predict vitality over and above the daily dynamics of vitality as a function of person characteristics, time of day, activity patterns and sleep duration during the previous night. Even though the relationship with vitality is the main focus of the current study, relationships between light exposure and feelings of tension, positive affect and negative affect were also investigated.

Based on earlier laboratory studies showing acute activating effects of light, we expected to see a positive relationship between the amount of light participants experienced and their level of vitality. In other words, we hypothesized that participants would feel more vital when they had experienced relatively more light. We had, however, no clear hypotheses concerning the relationship between light exposure with tension, positive and negative affect as – in contrast to potential activating effects - earlier findings on affective improvements under bright light have been inconsistent (e.g., Baron, Rea, & Daniels, 1992; Daurat et al., 1993; Hubalek et al., 2010; Kaida, Takahashi, & Otsuka, 2007; Partonen & Lönnqvist, 2000; Smolders et al., 2012). As earlier laboratory-based experiments have revealed time and mental status-dependent effects during daytime (e.g., Smolders et al., 2012; Vandewalle et al., 2006), we also investigate whether the relationship between light exposure and vitality is equally strong throughout the day, or whether instead it depends on time of day, or on previous vitality level. Moreover, we investigate potential seasonal variations and explore the role of light in the blue spectrum in the relationship between light and vitality.

2. Method

The method employed in this study was experience sampling, combined with continuous measurement of light exposure with a wearable device, a morning and evening diary and an online questionnaire.

2.1. Participants

Forty-two healthy persons participated in this field study, of which 10 participated twice, resulting in 52 sessions. Participants consisted mainly of office employees and students. Of these participants, 20 were male and 22 were female (mean age 25 years, $SD = 8.1$, range: 19–56). The participants all lived, worked, and/or went to university in the Eindhoven region (51° 44′ N, 5° 48′ E), the Netherlands. None of them had specific expertise in lighting. Up to two persons participated each week, rendering data on a wide range of light exposures, activities and settings. If a person participated twice, there were at least three months in between the two sessions. The study started in October 2010 and ran a full year until October 2011. Fourteen sessions took place during spring, 10 during summer, 12 during autumn and 16 during winter.

2.2. Measures

2.2.1. Light exposure

Light exposure at the eye was measured with a device, called Daysimeter (developed by RPI's Lighting Research Center, supplied by LumenTech Innovations), worn at eye level. The Daysimeter has two optical sensors to measure light exposure: one sensor corrected for the spectral sensitivity of the visual (photopic) system and one sensor that detects short wavelength light based on the spectral sensitivity of the circadian system determined by