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Original Article

Reading from an iPad or from a book in bed: the impact on human sleep. A randomized controlled crossover trial

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A R T I C L E I N F O

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A B S T R A C T

Objective: To objectively and subjectively compare whether reading a story for 30 min from an iPad or from a book in bed prior to sleep will differentially affect sleep.
Methods: Sixteen students (12 females, mean age 25.1 ± 2.9 years) underwent ambulatory (sleeping in their own beds at home) polysomnographic (PSG) recordings in a counterbalanced crossover design consisting of three PSG nights (one adaptation night, two test nights) and two different reading materials: read from an iPad or from a book. Illumination was measured during reading and Karolinska Sleepiness Scale was completed prior to turning the light off. Sleep diaries were kept to assess subjective sleep parameters from day to day.
Results: Illumination was higher in the iPad condition compared to the book condition (58.3 ± 6.9 vs 26.7 ± 8.0 lux, $p < 0.001$). Reading a story from an iPad decreased subjective sleepiness, delayed the EEG dynamics of slow wave activity by approximately 30 min, and reduced slow wave activity after sleep onset compared to reading from a book. No parameters of sleep state timing and sleep onset latency differed between the two reading conditions.
Conclusion: Although there was no direct effect on time spent in different sleep states and self-reported sleep onset latency, the use of an iPad which emits blue enriched light impinges acutely on sleepiness and EEG characteristics of sleep pressure. Hence, the use of commercially available tablets may have consequences in terms of alertness, circadian physiology, and sleep.

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1. Introduction

In the past few decades we have witnessed a sharp increase in the availability and use of electronic devices such as mobile phones, video game consoles, DVD players, television, audio players, computers, and tablets [1,2]. Along with this accessibility there has been an increase in media use among young people [3,4]. According to a study conducted by the Kaiser Family Foundation, children and youths, 8–18 years old, now use media for at least 7.5 h per day [4]. Much of the media consumption time (20%) is spent on mobile devices, such as cell phones, tablets, or hand-held videogame players [4], devices that have become more lightweight and portable making them easier to use, even in bed. Consistent with this, as many as 90–95% of people between the ages of 13 and 64 report the use of some type of electronic media such as television, computer, video game, or cell phone in the hour before bedtime at least once a week [5,6].

Such use has raised concerns as it may lead to insufficient sleep and sleep loss. Sleep is regulated by an interaction between three main factors: the homeostatic drive for sleep, the endogenous circadian system, and behavior. The homeostatic sleep drive rises progressively with time spent awake and declines during sleep. The classic marker of the homeostatic sleep drive has been slow wave activity in the delta range (1–4 Hz) in the course of non-rapid-eye-movement (NREM) sleep [7]. The circadian system regulates rhythmicity of our physiological functions, among others the sleep–wake rhythm, so that it normally adheres to a 24-h rhythm.

Light has been shown to shift the timing of the circadian clock. The retinal photoresponsive cell population (intrinsically

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photoresponsive retinal ganglion cells; ipRGC) contains the photopigment melanopsin, which absorbs a narrow band of wavelengths between 446 and 484 nm – ie, detects blue light. In addition to their connections to our circadian clock, ipRGC cells also project to waking and alerting active areas including the limbic system, striatum, and brainstem [8].

Many screens of electronic devices emit light where short blue wavelengths predominate compared to other light sources with the potential to elicit direct effect on human alertness, sleepiness, and circadian rhythmicity [9,10]. Epidemiological studies have shown associations between the use of electronic media just before bedtime and delayed bedtime [2,6,11,12], shortened sleep duration [12,13], and increased daytime tiredness [14]. An experimental study showed that bright light exposure with illuminance >6000 lux decreases sleep propensity, but with no effect on sleep consolidation or REM sleep [15]. In line with this, a recent study showed that adolescents exposed to 3-h evening LED screen illumination (~105 lux) reported higher sleepiness and had longer reaction times when wearing blue blocking glasses compared to clear lenses [16]. Blue-enriched polychromatic light at relatively low room light levels has further been shown to impact the homeostatic sleep drive by reducing slow wave activity during the first NREM sleep episode [17].

There is a paucity of experimentally and ecologically valid studies on the effects of electronic media just before bedtime and its effect on sleep. One recent study reported that reading from an electronic book for 4 h in the evening delayed sleep onset, reduced evening sleepiness, and delayed timing of the circadian clock (measured by melatonin) compared to reading from a printed book [18].

Still, more studies are needed, especially with more naturally occurring electronic media exposure times. Against this backdrop we conducted a randomized controlled trial investigating the effect on sleep of reading a story (for about 30 min) in bed just before turning out the lights from an iPad compared to reading a story (for about 30 min) from a book in bed. We examined subjective measures of sleepiness before turning the lights out, polysomnographic recordings of sleep, and self-reported sleep onset latency the following morning. We explored whether the two conditions (book vs iPad) would lead to different whole night polysomnographic recordings (time in different sleep stages, total sleep time, nocturnal awakenings). In terms of specific hypotheses we expected reading from an iPad would result in (1) higher evening subjective alertness and (2) longer subjective and objective sleep onset latency. Moreover, we hypothesized that the dynamics of EEG the first 3 h after sleep onset would differ in the two reading conditions: (1) slow waves, indicators of sleep homeostasis, would be reduced and (2) theta and alpha activity would be higher in the iPad condition compared to the book condition during the first NREM sleep episode.

2. Methods

2.1. Ethical considerations

The study was approved by the Regional Committee for Medical and Health Research Ethics, Western Norway (2013/992) and conducted in line with the Declaration of Helsinki of 1964. All participants provided informed written consent to participate in the study.

2.2. Participants

Twenty volunteers were recruited to the study. All participants were familiar with tablets, were not extreme chronotypes, and were free from sleep, medical, and psychiatric disorders, as assessed by examination and questionnaires. No one smoked or used medications that could potentially influence sleep. One week prior to the study, the participants were instructed to keep a regular sleep–wake schedule (bedtimes and time of awakening within ±1 h of the self-selected hours of sleep), and they were requested to stay in bed for at least a time equal to their sleep need. Moreover, they were instructed to abstain from alcohol during the week prior to the experiment and to abstain from caffeine intake after 18:00 h on the recording nights. Four participants were excluded from the study due to period limb movements (PLM) during sleep (PLM index >15, one person), bruxism (one person), and technical issues with the polysomnographic (PSG) recording (two people). No participants had an apnea–hypopnea index >5/h. In total, 16 people were included in the study (12 females and four males; age ranged from 22 to 33 years, mean age was 25.1 years, SD = 2.9).

2.3. Design

A counterbalanced crossover design was used and included three nightly ambulatory (sleeping in their own beds at home) polysomnographic recordings: one adaptation night (to account for first night effects and to screen for sleep apnea and periodic limb movement disorder) and two experimental nights. On the two experimental nights, sensors for respiratory events and limb movements were omitted to minimize discomfort for the participants. The participants were randomly allocated to a balanced crossover design; they either read a story (for about 30 min) from a tablet (iPad, Model A1458, Apple, Inc.) in bed just before turning out the lights and then one week later read a story (for about 30 min) from a book just before turning out the lights or they were exposed to the conditions in the reversed order (first read a story from a book, then from a tablet one week later). The reading material comprised two different sets of stories. The stories were counterbalanced across media (tablet vs book) and across order (tablet first then book vs book first and then tablet). Hence, four orders of conditions were established, each with four participants. Randomization to the four orders was performed by an online randomization calculator (www.randomizer.org) and was stratified by gender, ensuring that three females and one male participated in each order. During the reading sessions in bed, participants were instructed to use ordinary reading light.

2.4. Sleep acquisition and analyses

PSG recordings (Titanium, Embla Systems Inc., Broomfield, CO, USA) were montaged according to the AASM Manual for the Scoring of Sleep and Associated Events [19]. Briefly, six EEGs, two electrooculograms (EOG), and one electromyogram (EMG; submentalis) were used all three nights. For the adaptation night, additional measurements were used to screen for any sleep disorders: EMG anterior tibialis, electrocardiogram (ECG), and respiration sensors (nasal cannula, thermistor, thoracic and abdominal respiratory inductance pletysmografi and pulsoximetry).

PSG recordings were analyzed according to AASM Manual for the Scoring of Sleep and Associated Events [19] by a registered polysomnographic technologist (RPSGT), blinded to the light conditions. Sleep parameters used for further calculations included measures of total sleep time, sleep efficiency, percentage amount of each sleep stage (N1, N2, N3, REM sleep), wake after sleep onset, arousal index, sleep onset latency (the time between lights off and sleep onset), latencies to N3, and REM sleep (the time between sleep onset and first epoch of N3 and REM sleep).

EEG spectrum analysis was conducted for the first 3 h after sleep onset using an offline Fast Fourier Transformation (FFT) applied on unfiltered EEG signals. Analysis was performed at 10-s intervals with Hamming Window and 75% overlap central derivation. EEG power spectra were calculated during NREM sleep in the frequency bands: delta 1 (0.50–1.99 Hz), delta 2 (2.00–3.99 Hz), theta (4.00–7.99 Hz),