Applied Ergonomics 70 (2018) 142–147

Contents lists available at ScienceDirect

Applied Ergonomics

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

Using coffee to compensate for poor sleep: Impact on vigilance and implications for workplace performance

Jason R. Anderson, Payton L. Hagerdorn, John Gunstad, Mary Beth Spitznagel*

Department of Psychological Sciences, Kent State University, Kent, OH, USA

ARTICLE INFO

Keywords:
Performance
Inhibitory control
Coffee
Sleep
Vigilance

ABSTRACT

Poor sleep negatively impacts vigilance and is associated with reduced well-being and work productivity. While many individuals depend on caffeine to counteract the cognitive consequences of poor sleep and restore optimal work performance, few studies have naturalistically evaluated this strategy. This study examined the effects of coffee on vigilance, comparing individuals based on recent sleep quality. Sixty-nine participants completed two randomized, counterbalanced trials consisting of 237 ml water or coffee (100 mg caffeine), followed by a continuous performance test assessing vigilance at 30, 90, and 120 min. While coffee improved and stabilized reaction time at all three assessments regardless of recent sleep history, its effects on omission and commission errors were seen only at 90 min; coffee increased commission errors and only partially reduced omission errors in individuals reporting poor sleep quality. The use of coffee to combat poor sleep may therefore be detrimental in situations requiring inhibitory control.

1. Introduction

Prior research implicates inadequate sleep as an international cause of reduced work productivity and increased economic burden. According to the National Sleep Foundation's (NSF) international bedroom poll (NSF, 2013), over 25% of adults report sleeping less than 7 h per night, the minimum sleep duration recommended for healthy adults (Consensus Conference Panel et al., 2015); this figure reaches 36%, 39%, and 51% in Germany, the United Kingdom, and the United States respectively (NSF, 2013). Studies estimating the economic burden of poor sleep and daytime sleepiness place annual reduced productivity costs in the billions for many Western countries (Culpepper, 2010; Daley et al., 2009; Hillman and Lack, 2013; Skaer and Sclar, 2010), with the costs of sleep-related presenteeism (i.e., attending work despite illness) reaching over $60 billion in the United States (Kessler et al., 2011). Over half of international bedroom poll participants reported sleeping less than needed on work days, and roughly 60% of these participants also reported reduced work productivity as a result (NSF, 2013). These claims are corroborated by other studies that demonstrate poor sleep is associated with greater daytime functional impairment, higher rates of occupational injury, and reduced workplace productivity (Rosekind and Gregory, 2010; Rosekind et al., 2010; Sarsour et al., 2011).

Two avenues through which poor sleep may impact work performance are the well-being of the individual worker and his or her ability to interact with the environment and other workers. Yoo et al. (2007) demonstrated that sleep deprivation leads to reduced connectivity between the medial prefrontal cortex and the amygdala, an essential connection for regulating emotional reactivity to negative stimuli. Subsequent research displays the effect of this reduced connectivity: inadequate sleep causes a bias toward the encoding of aversive stimuli and reduced attention toward neutral and positive stimuli (Gobin et al., 2015; Van der Helm and Walker, 2011), as well as greater depression and anxiety symptoms the following day (Kalmbach et al., 2017). Of critical importance for interacting with other workers, sleep loss impairs differentiation between friendly and threatening facial cues (Goldstein-Piekarski et al., 2015).

In addition to its emotional and interpersonal consequences, the cognitive impact of poor sleep may impede optimal interaction with the work environment, further reducing work productivity. Sleep deprivation leads to vigilance deficits, such as slower and more variable reaction time, more errors of omission (i.e., failures to respond to a stimulus; Goel et al., 2009), and fewer correct detections during vigilance tasks (Kilpeläinen et al., 2010). Deficits in inhibitory control – the

Abbreviations: NSF, National Sleep Foundation; PSQI, Pittsburgh Sleep Quality Index; NCA, National Coffee Association; USA, United States of America; DSM-IV-TR, Diagnostic and Statistical Manual of Mental Disorders IV Text Revision; SCPT, Standard Continuous Performance Test; ANAM4, Automated Neuropsychological Assessment Metrics–4; BMI, Body Mass Index; ANOVA, Analysis of Variance

* Corresponding author. Department of Psychological Sciences, Kent State University, 600 Hilltop Drive, Kent, OH 44242, USA.
E-mail address: mspitzna@kent.edu (M.B. Spitznagel).

https://doi.org/10.1016/j.apergo.2018.02.026
Received 6 March 2017; Received in revised form 2 January 2018; Accepted 27 February 2018

ability to voluntarily inhibit a response (Schall et al., 2017) – have also been reported following sleep deprivation (Drummond et al., 2006). Importantly, chronic short sleep duration, as opposed to total sleep deprivation, is sufficient to induce these deficits; Van Dongen et al. (2003) demonstrated that spending only 6 h in bed each night can, over time, produce cognitive deficits equivalent to those observed following two nights of total sleep deprivation.

Given the prevalence of short sleep duration (NSF, 2013), it is unsurprising that caffeine is the most widely used psychoactive drug (Roehrs and Roth, 2008). Researchers have proposed adenosine, a homeostatic sleep factor that accumulates in the brain during wakefulness (Stenberg, 2007), as a potential mechanism of the cognitive deficits observed following disrupted sleep (Van Dongen et al., 2010). Caffeine inhibits the effects of adenosine (McLellan et al., 2016), and recent work shows that caffeine restores decrements in reaction time (Einother and Giesbrecht, 2013; Souissi et al., 2014) and vigilance (Lorist and Snel, 2008) due to sleep deprivation. Other studies show that caffeine facilitates consistent performance following sleep deprivation, reducing errors related to lapses in attention (Dagan and Doljansky, 2006; Johnson et al., 2016; Philip et al., 2006).

While previous work has shown that caffeine may alleviate vigilance deficits precipitated by sleep loss, most studies have examined this phenomenon in the context of laboratory-controlled sleep deprivation, focusing solely on caffeine. However, most of the caffeine consumed in the United Kingdom (Fitt et al., 2013) and United States (Fulgoni et al., 2015) is in the form of coffee, and the majority of adults in Western societies drink coffee on a daily basis (Lopez-Garcia et al., 2014; USA NCA, 2016). Many individuals report using coffee in an attempt to enhance cognitive function (Franke et al., 2014), likely due to its presumed benefits for attention and to combat the cognitive sequelae of poor sleep. As coffee contains other compounds besides caffeine (Baspinar et al., 2017), studying the cognitive effects of coffee itself may better generalize to common habits in Western societies, and determine whether coffee consumption is an effective strategy for salvaging work performance following inadequate sleep.

The present study examined the effects of coffee on cognitive function, comparing individuals reporting recent history of poor sleep quality to those reporting good sleep quality. Based on past research, it was hypothesized that coffee would improve vigilance in individuals with poor sleep quality, possibly restoring vigilance to that of individuals with good sleep quality.

2. Materials and methods

2.1. Participants

Sixty-nine healthy young adults were recruited from the campus of a large Midwestern University via flyer. Each participant completed two randomized, counterbalanced beverage trials of either 237 ml (8oz; chosen to reflect a standard serving size) water or coffee (100 mg caffeine; Green Mountain Coffee, Nantucket Blend) following an overnight fast. Exclusion criteria for the study included diabetes or other metabolic disorder (due to the potential impact on cognitive function; Moheet et al., 2015), history of moderate to severe head injury (i.e., loss of consciousness > 10 min), past or present diagnosis of a neurologic disease, severe psychiatric illness, learning disorder or developmental disability, alcohol or drug dependence (all DSM-IV-TR defined), or sensory impairment that could interfere with cognitive testing (i.e., unable to appropriately interact with test stimuli). Exclusion criteria were assessed through telephone screening prior to the first laboratory visit.

2.2. Measures

2.2.1. Cognitive function

Cognitive function was measured via the Standard Continuous Performance Test (SCPT) from the Automated Neuropsychological Assessment Metrics–4 (ANAM4; www.vistalifesciences.com), a repeatable, computerized cognitive battery with alternate forms. Participants were shown a target letter at the beginning of the task and instructed to respond as quickly as possible whenever the target letter appeared on the computer screen, while refraining from responding to any other letter. Outcome variables included errors of commission (response to non-target letters; inhibitory control), errors of omission (failure to respond to the target letter; vigilance), reaction time, and reaction time variability (i.e., standard deviation of reaction time within each SCPT administration). Continuous performance tests are sensitive to sleep loss in other samples (Gruber et al., 2011; Joo et al., 2012), have been used in conjunction with the psychomotor vigilance task to examine the cognitive impact of sleep deprivation (Van Enkhuizen et al., 2017), and are considered valid measures of sustained attention and inhibitory control in clinical assessment (Riccio et al., 2002).

2.2.2. Sleep quality

Sleep quality was measured via the Pittsburgh Sleep Quality Index (PSQI), a 19-item self-report questionnaire that assesses a number of sleep quality domains, such as sleep duration, frequency of sleep disturbance, and sleep disorder symptomatology over the past month. Higher scores indicate poorer sleep quality. The current study distinguished participants as having either good (global PSQI score ≤ 5) or poor sleep quality (global PSQI > 5) according to the empirically established cutoff (Buysse et al., 1989).

2.2.3. Regular daily caffeine intake

Average daily caffeine intake was assessed via the Block 2000 Brief Food Frequency Questionnaire (www.nutritionquest.com). This instrument contains approximately 70 items, and allows for the assessment of dietary caffeine intake from food. It is possible that a portion of the observed cognitive benefits of caffeine are due to the reversal of caffeine withdrawal (Snel and Lorist, 2011). Thus, caffeine intake (daily mg intake) was assessed as a potential covariate.

2.2.4. Demographic questionnaire

Participants self-reported demographic characteristics, including age, gender, and race/ethnicity.

2.3. Procedures

All study procedures were approved by the local institutional review board. Following provision of written informed consent, participants completed two separate morning sessions following an overnight fast and 24 h of alcohol and exercise abstinence. Sessions were counterbalanced, separated with a minimum washout period of at least 48 h, and completed within 2 weeks. Height and weight were assessed at the start of the initial session. Each session began with consumption of either 237 ml water or coffee. ANAM4 testing was completed 30, 90, and 120 min after beverage consumption, with pre-test practice sessions administered at each time point to reduce potential practice effects (Beglinger et al., 2005). Time points were chosen to capture the rise, peak, and fall in blood concentration of caffeine, which peaks between 30 and 60 min post-consumption (Snel and Lorist, 2011) and remains at highest concentration levels for roughly 1 h (Koppelstaetter et al., 2010). The 90-min assessment thus captures peak caffeine concentration, while the 30- and 120-min assessments occurred during the rise and fall in concentration respectively. Participants completed self-report measures or sat quietly during breaks between cognitive testing.

2.4. Statistical analyses

Previous work examining the effect of the interaction between caffeine and sleep deprivation on cognitive function (Bonnet and