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# ***Current State of Sleep-related Performance Optimization Interventions for the Esports Industry***

*Commentary*

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**Abstract:** The esports industry is rapidly expanding but despite industry growth, there are existing gaps in knowledge regarding holistic and pharmacological performance enhancement strategies. The current commentary focuses on the current state of performance intervention strategies that target sleep/wake and circadian timing systems. These performance intervention strategies are based on the current state of sleep/wake health and research portfolios of Army research laboratories. The intent is to provide a foundation for future research efforts directly targeting sleep/wake and circadian timing systems in order to optimize and enhance esports performance at both the individual and group levels.

## Scope of Significance

The esports industry is rapidly expanding. In 2020, the net worth of the industry exceeds \$1.5 billion. Asia and North America have the most esports athletes, by far compared to other regions of the world (Business Insider Intelligence, 2019). Professional esports athletes compete in national and international leagues, as well as receive endorsement from brands, in a similar way to traditional sports athletes. Despite industry growth, there are existing gaps in knowledge regarding the benefits of holistic and pharmacological performance enhancement strategies by means of coaxing both sleep/wake and circadian timing systems. These strategies are intended to be "battlefield ready," and thus add to the scope of risk factors identified and clinical evaluation and intervention strategies published previously (see Bonnar et al. 2019a, Bonnar et al. 2019b). Thus, the intent of this commentary is not focus on the rising concern and negative consequences of chronic video gaming on sleep physiological and psychological health (reviewed in Bonnar et al. 2019a, Bonnar et al. 2019b; Rudolf et al. 2020), but rather to present opportunities for leveraging existing "battlefield ready" sleep and/or circadian science & technologies that aim to optimize performance and simultaneously protect against physiological and psychological decline in esports athletes. Data to support the current state of affairs and potential sleep and/or circadian interventions derive from existing knowledge products and materiel solutions developed to optimize and enhance vigilance and neurobehavioral performance in Army research laboratories.

## Neural and Behavioral Phenotypes of Esports

Esports, much like traditional sports (e.g., football, basketball, and baseball), is the act of playing video games as an individual or on a team, in an organized, competitive environment (e.g., convention hall or sports arena). A recent survey of lifestyle habits in casual gamers ( $n = 1,066$ ; 91% male; 22 y.o.) estimated that the casual gamers plays 24 h of video games, on average, weekly (Rudolf et al. 2020). In more highly competitive cohorts such as our own esports athletes ( $n = 16$ ; 90% male; 27 y.o.), esports athletes play 60 h of video games, on average, weekly (10 h/day). Further, a recent review summarizing > 10 years of research on the neurobiology of video gaming (reviewed in Bavelier & Green, 2019) highlighted that performance predictions can be made from the extent of cortical/sub-cortical recruitment and activation of attentional/motor networks, including the anterior cingulate cortex (ACC) and dorsolateral prefrontal cortex (DLPFC; Basak et al. 2011; Bavelier et al. 2012), hippocampus (Gleich et al. 2017), striatum (Kuhn et al. 2011; Lorenz et al. 2015), and cerebellum (Basak et al. 2011) between recreational and elite esports athletes. A tertiary area of consideration is the fact that many battlefield scenario and strategy-based games of head-to-head team competition require athletes to adopt rotating shift work schedules. Our esports athletes adopt two 9 h shifts (0800 - 1700 EST; 1500 - 2400 EST). Depending on location of the competitor, esports athletes must sometimes compete from 0000 - 0900 h. These rotating shift work schedules, in turn, emphasize the continued need for both

monitoring and mitigating risk factors on the negative consequences of chronic video gaming on sleep physiological and psychological health as noted previously (reviewed in Bonnar et al. 2019a, Bonnar et al. 2019b; Rudolf et al. 2020). However, it is possible for esports athletes of strategy-based games to achieve adequate sleep and supplement with adequate exercise as assessed previously (Thomas et al. 2019). Thus, there is a critical need to utilize both holistic and pharmacological performance optimization and enhancement strategies that coax sleep/wake and circadian timing systems given the volume of sustained vigilance and attention required to play highly competitive video games, especially those requiring shift work strategies.

### **Sleep Extension Prior to Competition as a Fatigue Countermeasure**

It is clear that sleep restriction leads to slowed response speed, difficulty concentrating, and reductions in vigilance and alertness, which underlie or are a necessary component of performance capacity for virtually all cognitive tasks. Conversely, recovery sleep leads to the restoration of performance capacity. In recent years, it has been shown that individuals who sleep “normal amounts” are able to accrue sleep debt as a function of normal daily demands, described by Motomura et al. (2017) as “unrecognized sleep loss accumulated in the daily life”. In this study, sleep extension led to increases in frontal lobe cortical activation and regional interconnectivity (Motomura et al., 2017), suggesting enhanced capacity for top-down regulation of amygdalar activity, and thus improved mood. Extending sleep beyond habitual levels seems to be generally beneficial across multiple domains of cognition, emotional regulation, fatigue and mood; critical factors for esports athletes at individual and group-levels of performance.

Because improvements in performance can be short-lived, there is a need for inter-individualized sleep recommendations. For example, Ritland et al. (2019) showed that a few days of inter-individualized sleep extension led to improved motivation in collegiate tactical athletes, and that these improvements were sustained for even a few days after the athletes returned to their inter-individual habitual sleep amounts. Finally, sleep banking, or extended sleep prior to a subsequent period of restricted sleep has been shown to individual's cognitive performance and mood (Rupp et al. 2010, Arnal et al. 2015). In sum, sleep extension has been shown to be particularly beneficial following chronic sleep restriction or prior to sleep loss. The benefits of sleep extension tend to be more evident in the context of a greater-than-normal homeostatic sleep pressure (debt). Allowing esports athletes to sleep longer than habitually, and paying their accumulated sleep debt may therefore increase esports athletes short-term performance capacity, and enhance recruitment and activation of cortical/sub-cortical networks and motivational processes.

## Caffeine Dosing Strategies as a Fatigue Countermeasure

Another viable performance enhancement strategy tailoring to esports athletes would be to leverage existing wake- and sleep-promoting pharmacologies. One study of energy drink use in esports athletes noted minimal impact of caffeine derived from energy drink on actual performance (Thomas et al. 2019). Here, we advocate for a unique approach that has been successfully tested and evaluated and transitioned to a machine-learning based technology solution to the military. The approach rests on an inter-individualized caffeine dosing strategy used to sustain vigilance across sustained wakefulness and limited sleep opportunities (Vital-Lopez et al. 2018) and one that can additionally be used to predict future performance (Reifman et al. 2018). In general, 200 mg/12 h is regarded to be the optimal dose with minimal adverse effects in order to sustain vigilance with limited sleep opportunities (Hansen et al. 2019). Doses > 200 mg/12 h have no added benefit (Hansen et al. 2019). Ironically, the culture of esports is centered on chronic use of energy drinks containing > 200 mg caffeine/serving. It is critical to note that this caffeine dosing strategy to be used during high intensity training and competition differs from the daily practice of ceasing caffeine intake post-afternoon in order to avoid chronic sleep issues at night, notably because the half-life ~3 h (White et al. 2016).

Many esports athletes are sponsored by the energy drink industry. However, recent evidence from our research institution has identified that consuming > 2 energy drinks a day significantly increases likelihood of mental health problems, aggression, and fatigue (Toblin et al. 2018) in addition to a previous study in esports athletes minimal impact of caffeine derived from energy drink on actual performance (Thomas et al. 2019). Program evaluation of our esports athletes, however, revealed energy drinks are only used on a use-case basis for performance optimization under limited sleep. 50% of our athletes use energy drinks on an acute basis (< 5 times/month). 75% of our athletes consumed energy drinks two days/week/month, consuming no more than one drink/sitting. 75% primarily use for energy, secondary use for staying awake, and tertiary use for focus. 75% of athletes are chronic coffee drinkers, consuming > 1 cup/day.

Despite cultural stigma, there is huge potential for caffeine dosing strategies to be heavily utilized to sustain vigilance, particularly under limited sleep opportunities in esports athletes. Interestingly, a recent pharmacokinetic analysis of a 160 mg caffeine source consumed by males between the ages of 18 - 30 -- the primary demographic of the esports industry -- revealed no differences in plasma T<sub>max</sub> and half-life (t<sub>1/2</sub>) for coffee (instant, hot, and cold) and energy drinks (room temperature or cold; White et al. 2016): T<sub>max</sub> was ~ 70 min and t<sub>1/2</sub> was ~ 3 h, on average.

One promising alternative for maximizing caffeine optimization and enhancement of esports performance is use of caffeine gum (i.e., Military Energy Gum (MEG)) developed by our own research institution in order to support sustaining and high-tempo military operations. Studies with MEG are the foundation of the caffeine dosing strategies developed to predict future performance under sustained wakefulness and limited sleep opportunities (Vital-

Lopez et al. 2018; Reifman et al. 2019). The pharmacokinetic profile for one piece of 100 mg MEG was similar to coffee and energy drinks in Smith et al. 2016: T<sub>max</sub> of ~ 60 min and a t<sub>1/2</sub> of ~ 3 h (Kamimori et al. 2002). However, because one 100 mg piece of MEG can have the same pharmacokinetic impact as 160 mg of coffee or energy drink (40% less mg of caffeine administered) MEG may better mitigate caffeine tolerance developed with sustained caffeine consumption.

### **Hypnotic Strategies to Maximize Restorative Sleep**

Risk factors associated with chronic video gaming on sleep physiological and psychological health that can lead to sleep restriction has been noted previously (reviewed in Bonnar et al. 2019a, Bonnar et al. 2019b; Rudolf et al. 2020). Regarding sleep-promoting pharmacological interventions, existing hypnotics could be considered on a use-case basis. The half-lives of commonly prescribed hypnotics ranges from 12 h (lorazepam, 2 mg; suvorexant, 20 mg; alprazolam, 0.5 mg) to < 6 h (eszopiclone, 3 mg; zolpidem, 10 mg) and often lead to next-day drowsiness and impairment, especially if a full night of sleep is not achieved. The use of short-lived prescribed hypnotics may help esports athletes fall asleep, while reducing next-day drowsiness. For example, zaleplon which has a half-life of < 1 h, may be a viable performance enhancement strategy for esports athletes, particularly under multi-phasic sleep schedules and limited sleep opportunities dependent on competition schedule. However, it is critical to mention that hypnotic strategies to maximize restorative sleep should not be a first-line but rather last resort approach towards optimizing sleep in esports. Sleep hypnotics are controlled substances with side effects, including residual daytime grogginess, sleepiness, and lapses in vigilance (reviewed in Taylor et al. 2016). Appropriately timed melatonin dosing schedules (reviewed in Lewy et al. 2006) could also be effectively used to either progressively shift peak egaming performance to an optimal competition time or augment the ability to counteract wake-promoting signals and sleep after mid-night competition play. For more rapid shifts in peak egaming performance, blue-enriched light strategies coupled with caffeine supplementation should be considered (Burke et al. 2015).

### **Conclusions**

Our recommended performance optimization and enhancement interventions are rooted in inter-individualized schedules of sleep extension, caffeine dosing to sustain wakefulness, and hypnotic use to maximize the recuperative value of sleep developed over the past few decades at our research institution in order to support tactical athletes. We believe that our evidence-based interventions based on the current state of esports health and performance outcomes are the foundation for much larger programmatic evaluations of esports health and performance outcomes and supporting research & development initiatives aimed to optimize and enhance the esports industry at-large.

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