Caffeine is not a good model for sleep disruption when investigating next day cognitive performance and mood

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Summary: Partial sleep loss is common in society and can have detrimental effects on next day performance and mood. To assess the effects of poor sleep on mood and performance the following day caffeine was used with the aim of inducing poor sleep. Administration of 250 mg caffeine significantly reduced sleep efficiency and increased restlessness as measured by actiwatch. It was predicted that this poor sleep induced by caffeine would result in impairments in next day performance and reduced mood. Mood was unaffected, but surprisingly improvements were seen in a task of working memory compared to the placebo group. One possible explanation for this is that residual amounts of caffeine ameliorated the effects of poor sleep on performance the next day.

Introduction

Caffeine has been used previously as a model for inducing poor sleep with reductions in sleep efficiency (Carrier et al., 2007), total sleep time (Landolt et al., 1995) and increases in sleep onset latency (Paterson et al., 2007). The main action of caffeine is the antagonism of adenosine receptors. Adenosine is thought to be a major contributor to the homeostatic process of sleep regulation where levels build up during the day, inhibiting neurotransmitters responsible for mediating arousal.

Consequences of poor sleep

- Human errors: 20 - 25% crashes are sleep related
- Mood: over 90% patients with major depression report sleep problems
- Health: immune function, obesity & diabetes
- Social and occupational issues: loss of productivity & job satisfaction
- Economic factors: $92.5 - 107.5 billion in US

Aim: To use caffeine as a model for poor sleep to aid in finding cognitive tests that are sensitive enough to detect the effects of poor sleep in the normal population and in 'the field'.

Methods:

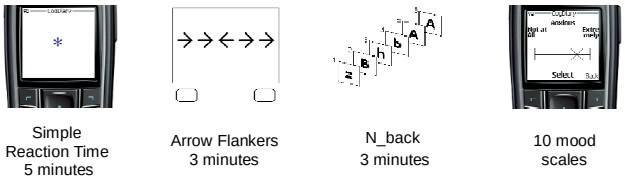
•Randomised, placebo controlled 2 week cross-over study with a no intervention, poor sleeper comparison group

•19 low caffeine consuming participants assessed as good sleepers and19 participants assessed as poor sleepers

•250 mg caffeine or placebo either one hour before bedtime or at 'light's out'.

•Sleep assessed by actiwatch and sleep diary

•Cognitive performance (attention, reaction time, impulse inhibition, working memory) and mood assessed on a dedicated mobile phone10 minutes after waking and in the afternoon to coincide with the 'post-lunch dip'.



Simple Reaction Time 5 minutes | Arrow Flankers 3 minutes | N_back 3 minutes | 10 mood scales

Figure 1. Cognitive test battery administered on a mobile phone

Results

1. Caffeine disrupted sleep objectively (sleep efficiency $F(1, 11) = 10.3$, $p = .007$; restlessness $F(1, 11) = 6.89$, $p = .022$) but not subjectively ($F(1, 15) = 0.82$, $p = .38$) with only a trend for reduced sleep quality on the first day ($F(1,15) = 4.28$, $p = .056$) in the caffeine group.
2. No significant differences in sleep onset latency.
3. No significant differences in mood (Energetic Arousal, Tense Arousal or 'cheerful').
4. No significant differences between caffeine and placebo groups on Simple Reaction Time or Arrow Flankers tasks.
5. Improvement in working memory (N_back task) for the caffeine group compared to placebo $F(1, 11) = 9.08$, $p = .012$.

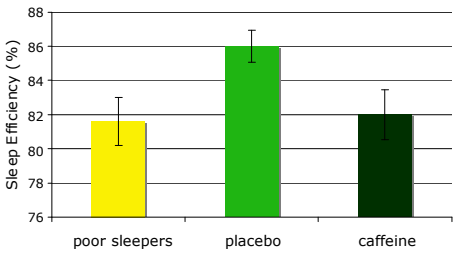


Figure 2. Sleep efficiency reduced by caffeine

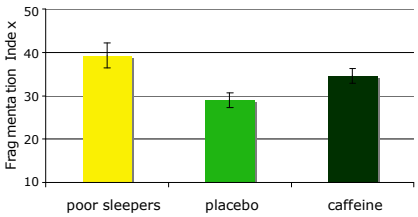


Figure 3. Restlessness increased by caffeine

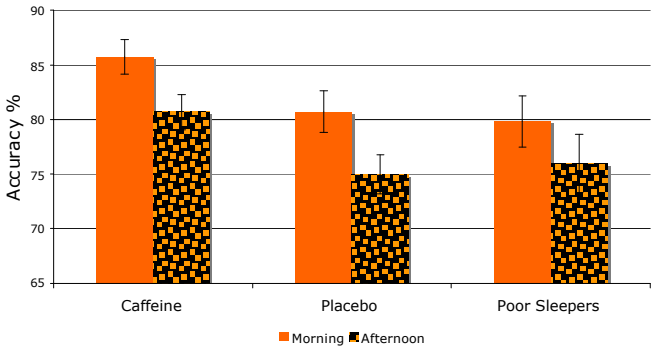


Figure 4. Improvement in accuracy on the working memory task after caffeine

Discussion

1. **Residual caffeine?** 0.2 - 0.5 mg/ml residual caffeine has been found in saliva after a similar dose and sleep opportunity as in this study (Carrier et al., 2007), although Brice and Smith (2001) found no strong associations between levels of caffeine in saliva and performance.

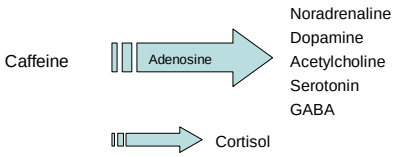


Figure 5. Secondary mechanisms affected by caffeine

Administration of caffeine the night before may have increased these levels of cortisol and neurotransmitters to above normal. Lovallo et al., (2005) found slightly elevated cortisol levels in the morning, roughly 13 hours after 600 mg caffeine administration, although the difference was not statistically different to placebo. Low doses of cortisol have been found to improve working memory performance (Lupien et al., 1999), which could help explain the improvements found on working memory compared to the placebo group.

2. **Learning effect?**

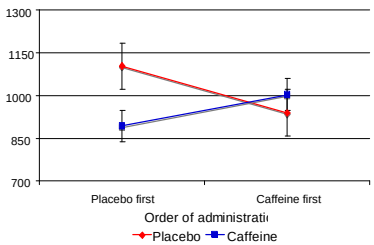


Figure 6. Treatment by order interaction on working memory task

Conclusion

Although administration of caffeine disrupted sleep measured objectively it is suggested that caffeine is not a good model for poor sleep when assessing next day performance and mood, possibly due to residual amounts of caffeine that ameliorated the effects of poor sleep on cognitive performance. In addition, overnight abstinence is not long enough for caffeine and its effects to be cleared from the body and brain and a longer period of caffeine abstinence should be used in studies that require caffeine free participants.

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