Performance on the Defense Automated Neurobehavioral Assessment Battery (DANA) and simulated driving performance over 50h of continuous wakefulness: Correlation between Neurocognitive and Operational Performance (#2003).

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Background

Sleep deprivation and fatigue are major contributors to performance degradation in laboratory and operational settings[1-3]. In continuously operating work environments, performance decrements can have serious consequences. In fact, serious accidents and fatalities as a result of driving while sleepy are well documented[4]. Evaluating operational readiness requires understanding of available, relevant information with the means to detect and adjust for shortcomings. In studies of operational performance, additional, and often simple, tasks are also examined to assess neurocognitive performance. It can be generalized that some constructs measured by operational and neurocognitive tasks overlap, but the relationship and utility of using one to predict another under the condition of sleep deprivation has been lacking.

This study examined the relationship between neurocognitive and driving performance during 50h of sleep deprivation in subjects receiving caffeine or placebo. Performance over time was assessed and the relationships between performance metrics were sought in an effort to predict operational performance using a neurocognitive test.

Fig 1A. DANA and 1B. Military Energy Gum®

Methods

Participants

- Twenty-four healthy subjects (9 female) aged 18-31(22.5±2.9) yr, randomly assigned to caffeine (CAF, n=12) or placebo (PLA, n=12) groups.
- Low to moderate CAF users (<250mg CAF/day).
- Regular sleep wake patterns with an average total sleep time of 8.6±0.6h, verified with sleep diaries and activity monitors.

Measures

- Defense Automated Neurobehavioral Assessment (DANA) – Rapid The DANA (Fig 1A) is a 5 min neurocognitive battery consisting of three subtasks: simple reaction time (SRT), procedural reaction time (PRT) and a go-no-go (GNG) task.
- Primary variables were reaction time (RT), accuracy (ACC), Lapses (LAPS) and throughput (TP)
- Driving Simulator – The driving task simulated a monotonous drive at dusk thru the Australian outback (little scenery, few road cues) and the requirement to maintain speed at 80 kph. Each 40 min test was completed on a full motion platform with audio ques.
- Primary variables were speed maintenance (SM) lane deviations (LD) and crashes (CR).

Design/Procedure

- Participants had baseline sleep (10h TIB, Day 1/2), followed by 50h of sleep deprivation (beginning Day 2 at 0800) and one daytime recovery sleep period (9h TIB, Day 5).
- Participants chewed two pieces (100 mg CAF/piece) of Military Energy Gum® (Marketright Inc, Plano, IL, Fig 1B) or PLA at 0100, 0300, 0500, and 0700 on Days 3 & 4 during sleep deprivation.
- Throughout the study participants completed a range of neurobehavioral tests every 4 h.
- Between test periods participants refrained from physical activity (casual walking was allowed if participants were struggling to stay awake), but could do leisure activities (e.g., watch DVD's, play board/card games, etc.) in a shared lounge area.

Statistical Analyses

Mixed-model analysis (3-way) was used to analyze between group differences and change over time for DANA and driving performance (DRP). Fixed effects included group (CAF, PLA), gender, and time (15 test periods) with a random effect for subjects. Between-subject correlations (Pearson product-moment) were used to assess the relationship between average DANA and DRP variables over time by correlating mean performance variables (by group) at each of the 15 test periods. CAF & PLA correlations that were largest and similar in magnitude were used to identify the DANA metric that had the strongest relationship with driving performance (DANA RT, LAPS & TP; DRP LD & CR). Within-subject correlations (Pearson product-moment) were calculated for each individual over time to assess DANA and associated DRP change within each individual and within-subject correlations were summarized by direction and significance. A 'common' within-subject correlation for each group was calculated using analysis of covariance; largest PLA correlations were used to identify the strongest DANA and driving performance relationship. Lapse and crash data were analyzed after applying a Log10(x+1) transformation. Statistical significance was set at p = 0.05.

Results

- There were significant declines in all DANA subtask metrics and DRP metrics (time [p < .0001] and group x time interaction [p <.001]).
- Significant differences from baseline in DANA and DRP were observed at similar times (0300-0600, Day3) for PLA for all performance measures (Fig 2B, 3B).
- CAF performance declined with an increase in LD and SRT TP after 0300 Day4 (Fig 2A) while performance was maintained in CR and SRT LAPS (Fig 3A).
- Correlations for 24 pairs of DANA and DRP data were analyzed for each group.
- All CAF and PLA between-subject correlations were significant.
- Strongest between-subject correlations (Table 1): LD and SRT TP (Fig 4A); CR and SRT LAPS (Fig 4B).
- Within-subject correlations showed directional coherence in 82% - 100% of subjects and 35% - 75% were significant.
- All CAF and PLA common within-subject correlations were significant except CAF CR and PRT LAPS correlation.
- Strongest within-subject correlations: LD and SRT TP ($r_{caffeine}$ = -.60, p<.0001; $r_{placebo}$ = -.71, p<.0001); CR and PRT TP ($r_{caffeine}$ = -.32, p<.0001; $r_{placebo}$ = -.64, p<.0001).

Fig 2. Group Means Over Time in Lane Deviations and SRT Throughput for CAF (A) and PLA (B). Red arrows indicate CAF/PLA administration times.

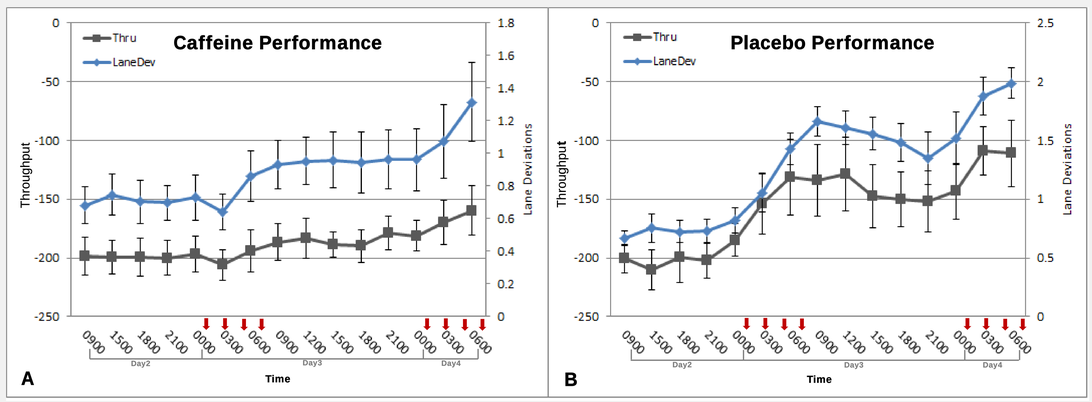

Fig 3. Group Means Over Time in Crashes and SRT Lapses for CAF (A) and PLA (B). Red arrows indicate CAF/PLA administration times.

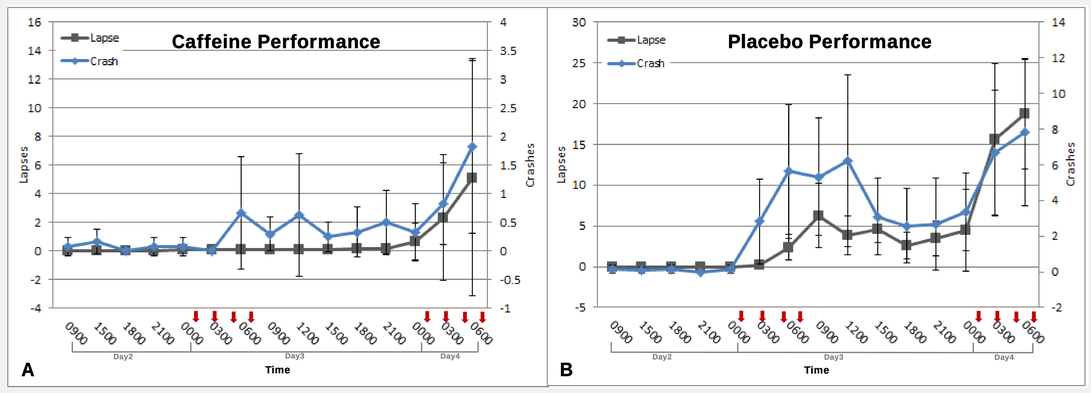

Fig 4. Between-subject correlation plots for Lane Deviations and SRT Throughput (A) and Crashes and SRT Lapses (B). Red circles are mean CAF performance and blue squares are mean PLA performance.

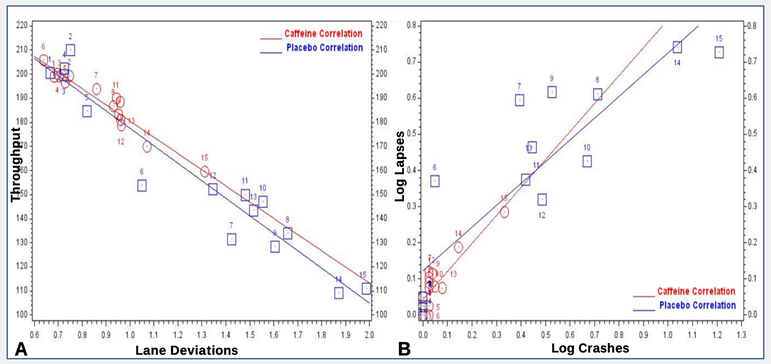

Table 1. Strongest between-subject (and corresponding within-subject) correlations for Driving and DANA performance in CAF and PLA groups. Additional correlations between DP and DANA metric are available upon request. *p<.05

	Lane Deviations & SRT Throughput		Crashes & SRT Lapses	
	Between-subject	Within-subject	Between-subject	Within-subject
Caffeine	-0.97*	-0.60*	0.88*	0.21*
Placebo	-0.96*	-0.71*	0.89*	0.59*

Summary

- The onset of DANA and driving performance decrements appeared to be similarly impacted by sleep deprivation after 0300 (20 hr awake) in the placebo group and end of the study in the caffeine group.
- The strength of the between-subject correlations demonstrate that the DANA can be used as an indicator of average driving (i.e., operational) performance.
- DANA SRT had the strongest relationships with driving measures in both groups.
- Lane deviations had the strongest between- and within-subject correlations with SRT throughput: decreases in throughput (correct responses rate with respect to reaction time) was related to increases in driver swerving.
- Crashes had the strongest between-subject relationship with SRT lapses: as the number of lapses increased, so did the average number of crashes. Within-subject correlations for crashes had a stronger relationship with PRT throughput.
- The magnitude and directional coherence of within-subject correlations support that DANA and driving performance relationships hold true for an individual.
- Within-subject correlations were not as strong as between-subject correlations most likely a result of interindividual difference (e.g., sensitivity/insensitivity to caffeine/sleep loss, etc.).
- Caffeine within-subject correlations with crashes were low because the majority of subjects given caffeine did not crash.
- Overall, the consistency, magnitude, and statistical significance of between- and within-subject correlations demonstrates the aptitude of DANA's ability to predict driving performance (average and individual) during sleep deprivation.

References

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