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Introduction

Caffeine is commonly used to alleviate the effects of sleep deprivation. A specific population that must perform while sleep deprived is the military. Many military operations require convoys to travel across flat desert terrain in order to accomplish various tasks. There are specific regulations as to the distance between vehicles that must be maintained, and speed at which vehicles can be driven within these convoys. Driving with a specific distance between, a slower speed and in an unattractive, repetitive landscape can become boring and monotonous. If a fatigued military truck driver is unable to stay alert on-duty the safety of the driver, the passengers and the rest of the convoy is at risk. This study serves to characterize the effects of sleep deprivation with dull tasks and examine the ability of caffeine to mitigate these effects. The Defense Automated Neurobehavioral Assessment (DANA) Rapid battery and a driver simulator were employed to measure the effectiveness of a multiple-dose caffeine administration paradigm to maintain vigilance during 2 nights of sleep deprivation. This poster focuses primarily on performance of the DANA tasks.

Methods

Participants and Design

Participation in this study was voluntary and informed consent was received from each subject. The study was proctored as a double-blind group design, in which 24 participants were randomly assigned into 6 groups of 4. There were two possible conditions to which the groups could be assigned: placebo or caffeine. Each group was randomly assigned to receive a caffeine or placebo administration.

Study subjects spent a total of 4 days and 3 nights in the sleep laboratory. Subjects were given a baseline sleep saturation from 10pm to 8am, which was followed by 49 hours of sleep deprivation/wakefulness. Caffeine was administered in 2-hour intervals—specifically at 0100, 0300, 0500, and 0700—on both nights of sleep deprivation. Performance results from the caffeine group were compared to results from the placebo group.

The primary task subjects participated in was a 40-minute driving simulator (SIM) designed to mimic the Australian outback. The simulator has seats mounted on motion actuators. This specific environment was chosen because the terrain is flat, repetitive and barren. The monotony in this simulation allows a more accurate examination of caffeine's ability to diminish the effects of sleep deprivation when performing a boring task.

After completing the driving simulation, each group performed a 5-minute PVT followed by the DANA Rapid. The DANA Rapid included a battery of three neurocognitive assessments to note: Simple Reaction Time (SRT), Procedural Reaction Time (PRT), and Go/No Go (GNG). There were a total of 18 administrations per subject and the last administration from Day 1 was used as the baseline. Placebo and caffeine groups were evaluated for statistical significance in reaction time needed to make correct responses and the number of response lapses for each test. A lapse for the SRT was >900ms; for PRT >2000ms and for GNG >1500ms. For the SIM task the number of crashes during each session was used as the primary variable for this presentation.

Measures

Defense Automated Neurobehavioral Assessment – Rapid (DANA) –Subjects completed the Rapid battery which consists of assessments of Simple Reaction Time (SRT), Procedural Reaction Time (PRT), and a Go-No-Go (GNG) task.

Driving simulator – Subjects completed a 40 minute driving simulation that was designed to reflect the environment in which on-duty military personnel are tasked to drive in. The simulator was a full motion platform with audio cues.

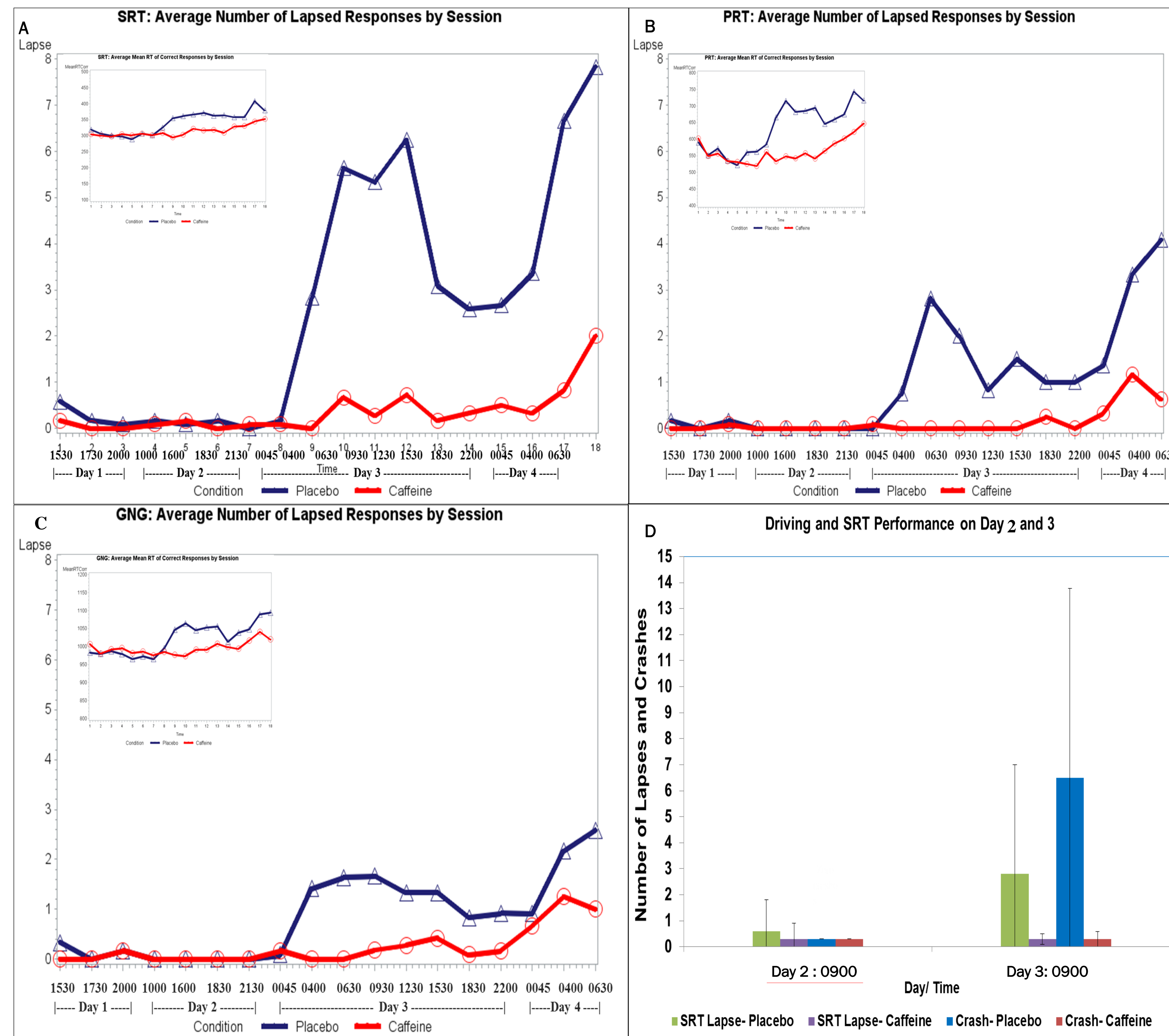


Figure A-D (to be read left to right)

- SRT among caffeine and placebo group are comparable until subjects are sleep deprived. The placebo condition jumps from 0 lapses in the 8th DANA administration to nearly 6 lapses in the 9th. The caffeine condition holds constant between the 8th and 9th administrations. From the 8th test administration through the 18th both conditions increase their number of lapses but the placebo group has more lapses than the caffeine at every administration.
- PRT is the same between placebo and caffeine conditions for the first two days. The placebo condition has 0 lapses at the 8th administration and 3 lapses by the 10th. The caffeine condition holds 0 lapses until the 14th administration where <1 lapse occurs. At every administration point during sleep deprivation the placebo group has more lapses than the caffeine group.
- GNG experienced the least obvious differences between conditions. While there is still an increase in lapses seen within the placebo condition compared to the caffeine condition, the differences are smaller. Between administrations 8 and 14 there is the greatest difference between conditions with placebo having 2 lapses in GNG at administration 10 and caffeine having 0 lapses at the same gathering point. At administration 16 placebo and caffeine groups are most similar during the sleep deprivation period, seeing 1 lapse each.
- Figure D takes measurements from two points-in-time to see if the number of SRT lapses gathered from the DANA Rapid correspond to the number of crashes seen in the driving simulation. At baseline, both conditions are performing with <1 lapse or crash. At day 3 the placebo condition has 3 lapses in SRT performance and 7 crashes in the driving simulation, while the caffeine condition still holds <1 lapse and crash. The placebo condition had a 6-fold increase in their number of lapses in SRT performance and a 7-fold increase in their number of crashes on day 3, as compared to baseline.

Lapses for the SRT are responses >900ms; for PRT >2000ms and for GNG >1500ms.

*SRT, PRT and GNG defined under measures

Results

Repeated measures ANOVA (analysis of variance) were used in order to determine a difference in performance. Difference in performance was measured by evaluating mean reaction time of correct responses (DANA) and number of crashes between the placebo and caffeine groups (SIM). Additionally, logistic regressions were used on lapses responses in order to determine the odds ratio when given placebo compared to caffeine.

For the DANA subtests, the repeated measure ANOVA identified a statistically significant difference in mean reaction time between placebo and caffeine groups. For both SRT and PRT, subjects in the caffeine condition performed faster by 28 ms ($p=0.0433$) and 68 ms ($p=0.0216$), respectively (See Figs A & B). While the number of lapses responses was higher in the placebo group for the GNG, this was not significant (Fig C).

The logistic regression analysis showed significant results for all three subtests. Subjects were 4 times more likely to have a lapsed response for SRT, 5 times more likely for PRT, and 3 times more likely for GNG. Towards the end of the second night many of the subjects needed to be woken up to take the DANA.

Currently, only data from sessions 1 and 9 were available for analysis from the driving simulation. For the driving simulation, the repeated measures ANOVA resulted in a statistically significant difference in the number of crashes between placebo and caffeine groups ($p=0.0154$). As illustrated in Fig D the placebo group committed 3 more crashes (mean) as compared to the caffeine group. The logistic regression analysis was also significant with placebo subjects 23 times more likely to have crashed as compared to the caffeine group.

Summary/Discussion

Figures A-C compare placebo and caffeine groups by their respective number of lapses responses. Groups were analyzed by lapses rather than speed because lapses are an accepted indicator of when a task cannot be performed correctly. Speed analysis focuses on the amount of time it takes to make the correct response, but does not evaluate incorrect responses, which leaves a considerable amount of data unrepresented. There is a speed-accuracy tradeoff in human behavior where people will reduce speed in order to increase their accuracy. An analysis using lapses account for this adjustment, while a speed analysis does not.

Even though the effects of SRT and GNG are statistically significant, they may not be operationally significant since the subjects' performance declined by less than 50ms in the post treatment measures. However, this may be due to the use of only the correct responses for this measure. It is also possible that this small difference is due to the nature of going from a monotonous driving task to a different task that required an outside stimulus (i.e. being handed a device) which has an awakening quality to it. This non-significance could also be due to small sample size.

An increased number of lapses signals decreased attention during a task. There was a 6 fold increase in the number of lapses between days 1 and 3 in SRT performance for the placebo condition. If 3 lapses were seen during the SRT task (which runs for 2minutes) on day three, we could expect to see 60 lapses during the 40 minute driving simulation. The data gathered from sessions 1 and 9 suggests an increase in SRT performance lapses could indicate an increase in poor driving performance due to sleep deprivation. On day 3 the placebo condition saw a 7-fold increase in the number of crashes during the driving simulation, as compared to their baseline performance on day 1. While lapses in the DANA do not indicate crashes, they do indicate decreased performance. If data from subsequent sessions supports what we report here then performance on the DANA may be useful as an indicator of driving performance while sleep deprived.

It is important to note that some of the placebo subjects were experiencing micro sleep and required awakening at the end of the SIM task in order to complete the PVT and DANA. This arousal could have altered the number of lapses that would have otherwise been seen and may have had an impact on DANA performance. Also, there is a certain degree of intrapersonal variation within test subjects. Some subjects may have been more or less caffeine sensitive than others as well as their individual sensitivity to sleep deprivation. These differences may account for how the variation in performance observed here.

In conclusion, even after two nights of sleep deprivation, caffeine maintained performance on the DANA tasks and simulator driving performance as compared to placebo.

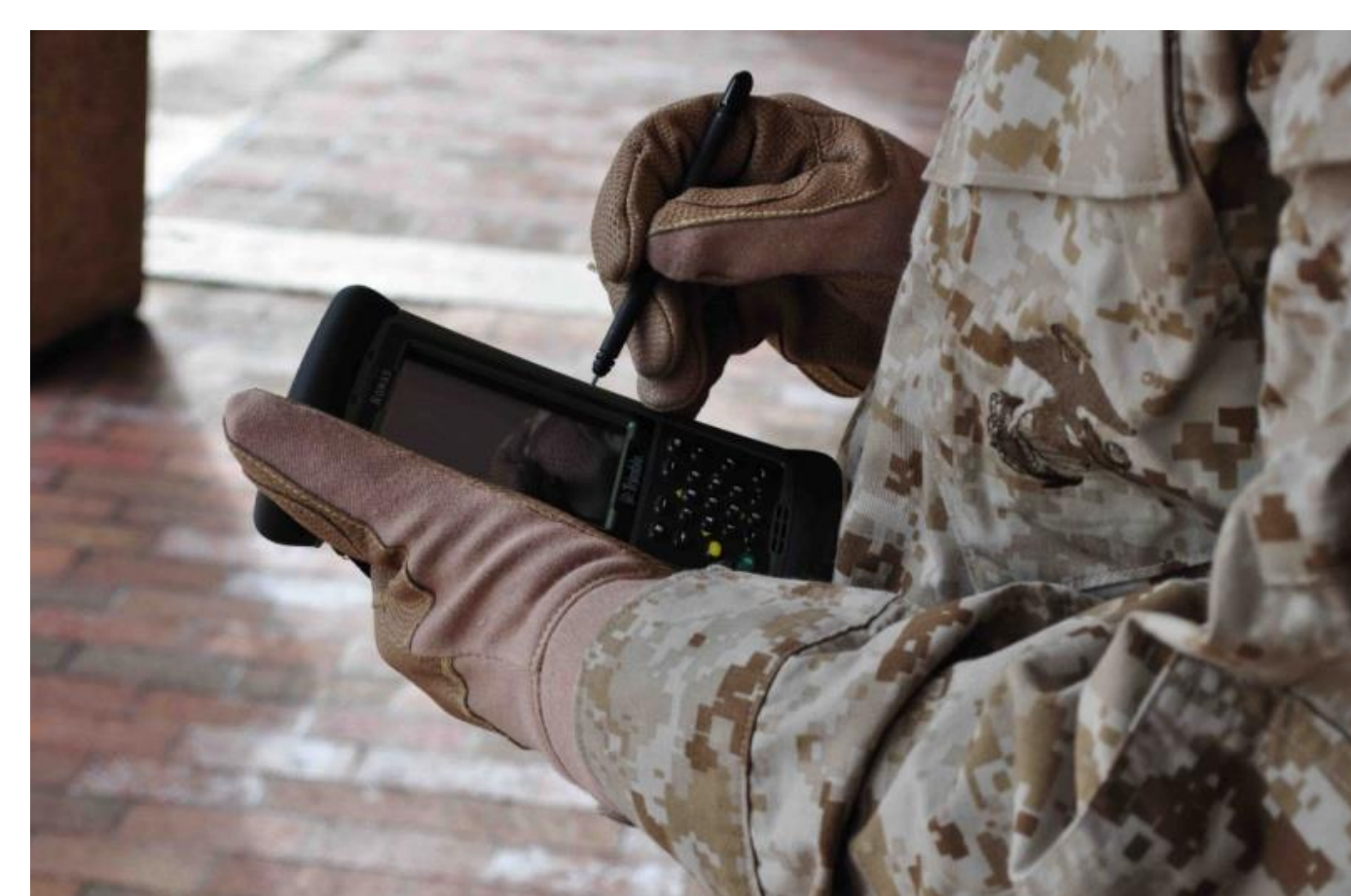


Figure E
An example of a soldier completing the DANA Rapid Battery