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Energy Drink vs. Coffee: The Effects on Levels of Alertness in Fatigued Individuals



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14. ABSTRACT Fatigue due to sleep loss has been shown to lessen cognitive performance, slow visual recognition, and impair mathematical reasoning. This is especially of concern in the aviation community, as both civil and military aviation operations often impose excess fatigue, and pilots are required to execute various complex activities and react to potential emergencies at any time during a flight. A prevalent fatigue countermeasure is the use of caffeine as a stimulant. Caffeine is commonly found in coffee, soft drinks, tea, gum, supplements, and energy drinks. Multiple studies have demonstrated the effectiveness of caffeine to increase alertness and improve cognitive performance in sleep-deprived individuals. Energy drinks contain caffeine and sugar, similar to a soft drink, but there are additional nonregulated ingredients that may be present. Manufacturers claim that the energy drinks can improve physical endurance and cognitive performance, but some health experts believe that any noticeable improvement is derived solely from the caffeine and sugar components. The purpose of this study was to lay the groundwork for investigating whether the additional components found in a common energy beverage will provide a higher degree of subjective and objective alertness in a fatigued individual over that provided by similar doses of caffeine and sugar alone. The study employed a double-blind, repeated measure design. Eight subjects were given subjective and objective cognitive testing prior to consuming Red Bull or coffee and 30 minutes after consuming the beverages in two sessions held 2 weeks apart. Data were analyzed using paired samples t-tests. The battery of tests given to the research participants demonstrated that both coffee and Red Bull have the ability to improve alertness in fatigued individuals. However, Red Bull had no statistically greater effects on objective cognitive performance in acutely fatigued individuals when compared to a control with the same amount of caffeine and sugar. Additionally, Red Bull had no statistically significant effects on subjective cognitive performance in acutely fatigued individuals when compared to a control with the same amount of caffeine and sugar. The only area that did demonstrate any statistical significance was the subjective feeling of the ability to concentrate. In that case, the coffee seemed to give a more profound effect. Given that the energy drink tested performed similarly to coffee, there is no evidence to support recommending the use of Red Bull in flying operations over the use of coffee, tea, or soda.					
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1.0 SUMMARY

Fatigue due to sleep loss has been shown to lessen cognitive performance, slow visual recognition, and impair mathematical reasoning. This is especially of concern in the aviation community, as both civil and military aviation operations often impose excess fatigue, and pilots are required to execute various complex activities and react to potential emergencies at any time during a flight. A prevalent fatigue countermeasure is the use of caffeine as a stimulant. Caffeine is commonly found in coffee, soft drinks, tea, gum, supplements, and energy drinks. Multiple studies have demonstrated the effectiveness of caffeine to increase alertness and improve cognitive performance in sleep-deprived individuals. Energy drinks contain caffeine and sugar, similar to a soft drink, but there are additional nonregulated ingredients that may be present. Manufacturers claim that the energy drinks can improve physical endurance and cognitive performance, but some health experts believe that any noticeable improvement is derived solely from the caffeine and sugar components. The purpose of this study was to lay the groundwork for investigating whether the additional components found in a common energy beverage will provide a higher degree of subjective and objective alertness in a fatigued individual over that provided by similar doses of caffeine and sugar alone. The study employed a double-blind, repeated measure design. Eight subjects were given subjective and objective cognitive testing prior to consuming Red Bull or coffee and 30 minutes after consuming the beverages in two sessions held 2 weeks apart. Data were analyzed using paired samples t-tests. The battery of tests given to the research participants demonstrated that both coffee and Red Bull have the ability to improve alertness in fatigued individuals. However, Red Bull had no statistically greater effects on objective cognitive performance in acutely fatigued individuals when compared to a control with the same amount of caffeine and sugar. Additionally, Red Bull had no statistically significant effects on subjective cognitive performance in acutely fatigued individuals when compared to a control with the same amount of caffeine and sugar. The only area that did demonstrate any statistical significance was the subjective feeling of the ability to concentrate. In that case, the coffee seemed to give a more profound effect. Given that the energy drink tested performed similarly to coffee, there is no evidence to support recommending the use of Red Bull in flying operations over the use of coffee, tea, or soda.

2.0 INTRODUCTION

Fatigue due to sleep loss has been shown to lessen cognitive performance, slow visual recognition, and impair mathematical reasoning. Studies have shown that sleep-deprived individuals lose about 25 to 30% of their ability to perform useful cognitive activities with every 24-hour period of sleep loss [1]. This is especially of concern in the aviation community, as both civil and military aviation operations often impose excess fatigue, and pilots are required to execute various complex activities and react to potential emergencies at any time during a flight [2].

Required skills for airmen include gross and fine motor coordination, mental reasoning, multiple calculations, memorization, and visual cognition, all of which can be degraded by fatigue. A 30-hour period of sleep deprivation was shown to degrade basic piloting skills by over 40% [1]. This degradation can result in aircraft damage or loss, injury or death to passengers and crewmembers, or failed military missions [2]. In fact, fatigue has been associated with 87% of all U.S. Air Force mishaps between 1972 and 2000 [1].

Because of the adverse effects of fatigue on the safety of flight, attempting to properly manage fatigue has been a priority since the early days of aviation. Early methods were crude and mainly attempted to avoid flying in a fatigued state. Today, there are many advanced techniques and tools that airmen can use to combat fatigue, such as medication use, both pre-flight and during flight; proper nutrition; circadian rhythm shifting; strategic napping; exercise; and nutrition.

However, probably the most widely used fatigue countermeasure in airmen and other professions is the use of caffeine as a stimulant. While not regulated by the Food and Drug Administration, it is an important fatigue countermeasure. Caffeine is commonly found in coffee, soft drinks, tea, gum, supplements, and energy drinks. Multiple studies have demonstrated the effectiveness of caffeine to increase alertness and improve cognitive performance in sleep-deprived individuals. A study in 1990 showed clear evidence that a significant improvement of daytime alertness was noted in the subjects who consumed caffeine versus those who did not [3]. Another study completed in 2004 looking at the use of caffeine in fatigued individuals demonstrated a clear attenuation of the effects of sleep deprivation [4]. Finally, a study looking specifically at military operations concluded that caffeine use was an effective fatigue mitigation strategy to sustain psychomotor performance and vigilance [5]. The counter-fatigue effects of caffeine can be accentuated in those who do not regularly consume high levels of caffeine. The judicious use of caffeine is generally considered safe for civilian and military aviation operations, but overuse can cause elevated blood pressure, heart palpitations, stomach pains, and feelings of nervousness [1].

Most experts agree that the proper use of caffeine is for short-term cognitive arousal in a sleep-deprived setting. Caffeine is widely bioavailable and quickly enters the blood stream, affecting the central nervous system within 15 minutes. The stimulant effects last for approximately 4 to 5 hours, but can be longer in caffeine-sensitive individuals. Because tolerance can develop, aircrew should be encouraged to consume caffeine sparingly on nonflying days and reserve the stimulant effects for when they are needed the most [1].

A fairly recent trend in today's society is the regular consumption of energy drinks. These products contain caffeine and sugar, similar to a soft drink. However, there are additional nonregulated ingredients that may be present, including taurine, guarana, B-vitamins, ginseng, and L-carnitine. Manufacturers claim that the energy drinks can improve physical endurance and cognitive performance, but some health experts believe that any noticeable improvement is derived solely from the caffeine and sugar components [6]. Given the popularity of these products in today's society, many of our aircrew use them during aviation operations. Further study is warranted to demonstrate any added benefit provided by the unique components, as well as give guidance to flight surgeons on how they should advise the use of energy drinks in the cockpit.

Energy drinks are highly ubiquitous in today's society. A survey completed in 2007 looking at the pattern of energy drink consumption among college students revealed that over one-half of the participants admitted to using more than one energy drink per month. The main reasons cited for their use were "insufficient sleep (67%), to increase energy (65%), and to drink with alcohol while partying (54%)" [7]. A more recent study shows that 35% of 18- to 24-year-old men drink them regularly, up from 19% in 2003. Furthermore, this survey showed that sales of these drinks have increased by more than 100% in the past 5 years [8]. Given that the manufacturers make claims that are, at best, highly anecdotal with no apparent research, efforts should be made to categorize any noticeable effects and begin to provide guidance for

establishing the role of these products in the flying community. The purpose of this study was to lay the groundwork for investigating whether the additional components found in a common energy beverage will provide a higher degree of subjective and objective alertness in a fatigued individual over that provided by similar doses of caffeine and sugar alone.

3.0 METHODS

The study protocol was reviewed and approved in advance by the U.S. Air Force School of Medicine Institutional Review Board. Each study volunteer provided informed written consent before participating. Volunteers received no monetary compensation for participation, although costs associated with overnight stays during the testing sessions were reimbursed.

3.1 Subjects

There were eight volunteers who participated in the study (five male, three female). Their ages ranged from 18 to 47 years old (mean 38.3 years). Potential subjects were medically screened by a physician for disqualifying health conditions and potential medication interactions. All were nonsmokers, even though this was not part of the exclusion criteria.

3.2 Procedure

Research volunteers were asked to awake the morning of the testing sessions at a usual hour. They were restricted from using caffeine after noon and taking a mid-day nap. At the natural circadian drop, each subject was given subjective and objective cognitive testing prior to consuming one of two commercial products, either Red Bull as the energy drink or coffee. Commercially procured coffee was used to control for the caffeine and sugar that is contained in the energy drink. After 30 minutes, each subject repeated the subjective and cognitive testing.

The Karolinska sleepiness scale (KSS) was used for subjective testing [9]. This test asks subjects to assign how sleepy they feel on scale of 1 to 9, with 1 corresponding to a feeling of being very awake and 9 corresponding to fighting sleep.

Another subjective test that was accomplished was the visual analog scale (VAS). The subjects were shown a solid bar on a personal digital assistant (PDA) and were asked to rate the value on the bar of each of eight separate fatigue-related feelings: concentration, anxiety, energy level, confidence, irritability, jitteriness, sleepiness, and talkativeness [10].

Objective cognitive testing was accomplished using the 5-minute psychomotor vigilance task (PVT). In this test a subject hits a key in response to a visual stimulus on a dedicated PDA. The time it takes for this to be accomplished is measured, and longer reaction times correlate to heavy states of fatigue [11,12]. Many of the past fatigue studies used the PVT as a measure of cognitive functioning in fatigued individuals.

3.3 Study Design

This study employed a double-blind, repeated measure design. Each subject received both test samples in a randomized order over the course of two separate testing sessions. These sessions were held 2 weeks apart to prevent additive effects of acute fatigue.

3.4 Statistical Analysis

Since each individual was acting as his or her own control, data were analyzed using paired samples t-tests. For all analyses, an alpha-level of less than or equal to 0.05 was used to represent statistical significance.

4.0 RESULTS

4.1 Subjective Testing

The first test of subjective cognitive alertness was the KSS. Figure 1 shows the change in value from baseline for each subject during each session. The average change in KSS value for coffee was -1.25, while the average change in KSS value for Red Bull was -2. However, this was not a statistical difference, as the paired t-test resulted in a p-value of 0.1114.

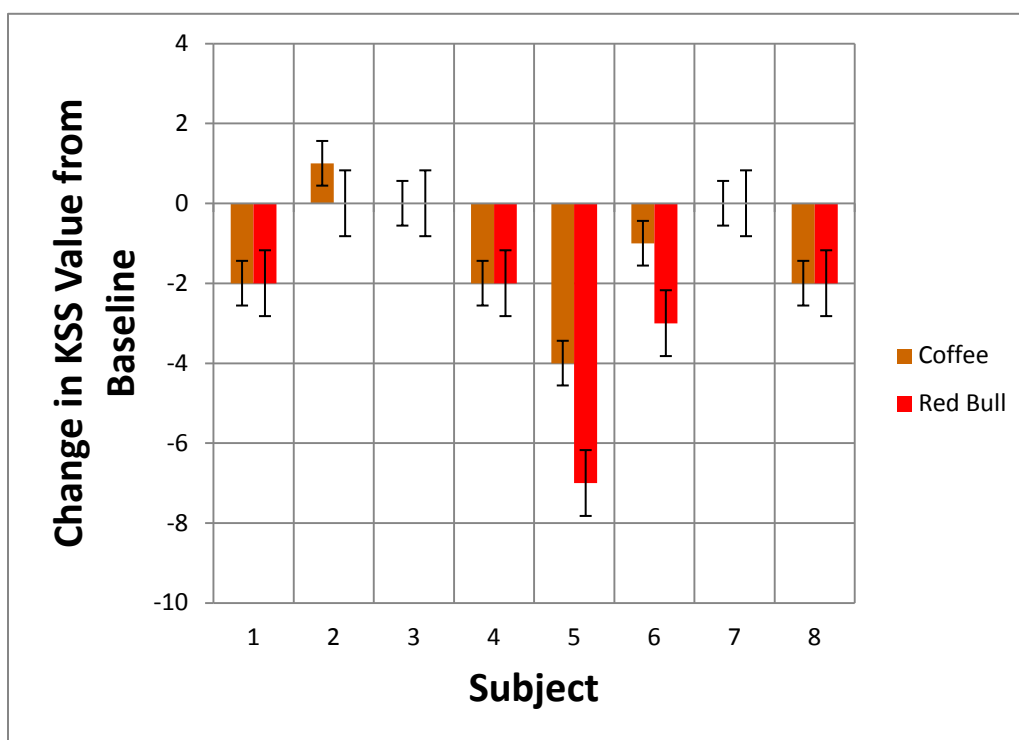


Figure 1. Change in KSS Value from Baseline for Each Subject

The second test for subjective cognitive alertness was the VAS. The VAS looked at eight separate feelings that the research subjects were asked to rate at the time of testing. Each of these sections was evaluated individually.

Figure 2 shows the change in VAS values from baseline for concentration. The average change in VAS value for coffee was 8.375, while the average change in VAS value for Red Bull was -0.5. This test did show a level of statistical difference, as the paired t-test resulted in a p-value of 0.0000.

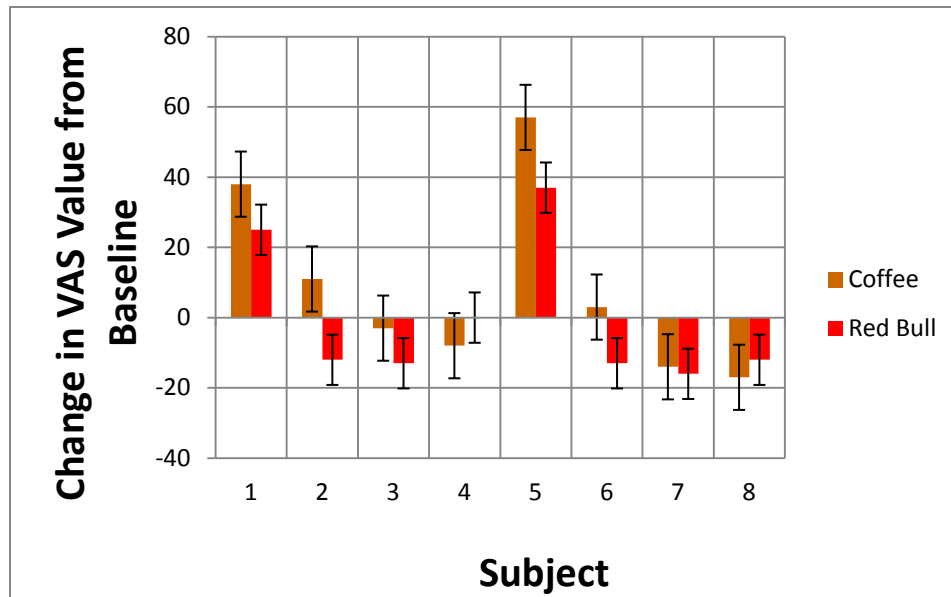


Figure 2. Change in VAS Value from Baseline for Concentration

Figure 3 shows the change in VAS values from baseline for feeling anxious. The average change in VAS value for coffee was 6.125, while the average change in VAS value for Red Bull was 9.125. This test did not show a level of statistical difference, as the paired t-test resulted in a p-value of 0.7196.

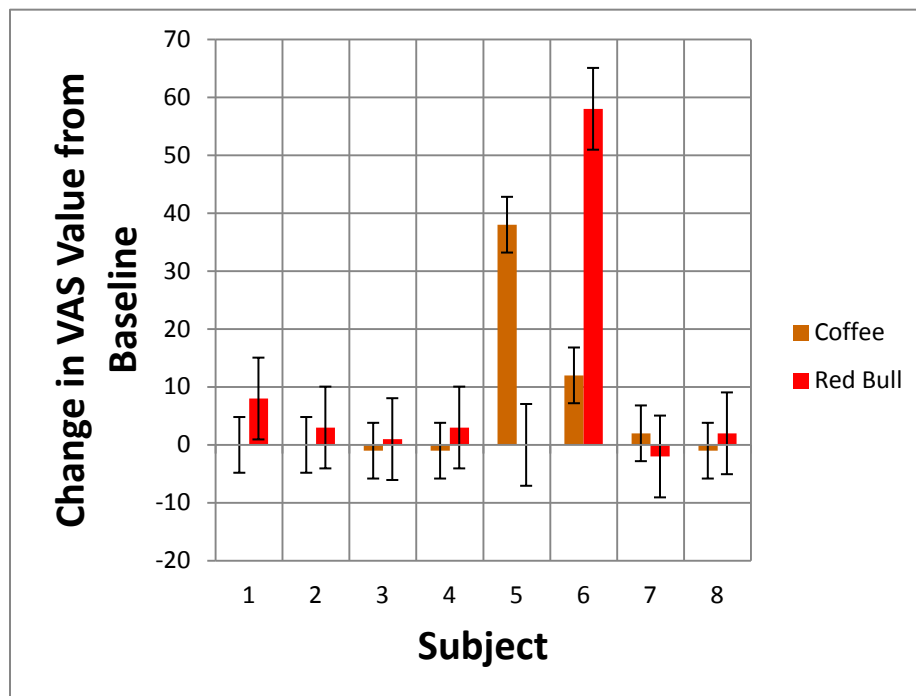


Figure 3. Change in VAS Value from Baseline for Feeling Anxious

Figure 4 shows the change in VAS values from baseline for how energetic the test subject felt. The average change in VAS value for coffee was 7.5, while the average change in VAS value for Red Bull was -20.5. This test did not show a level of statistical difference, as the paired t-test resulted in a p-value of 0.3821.

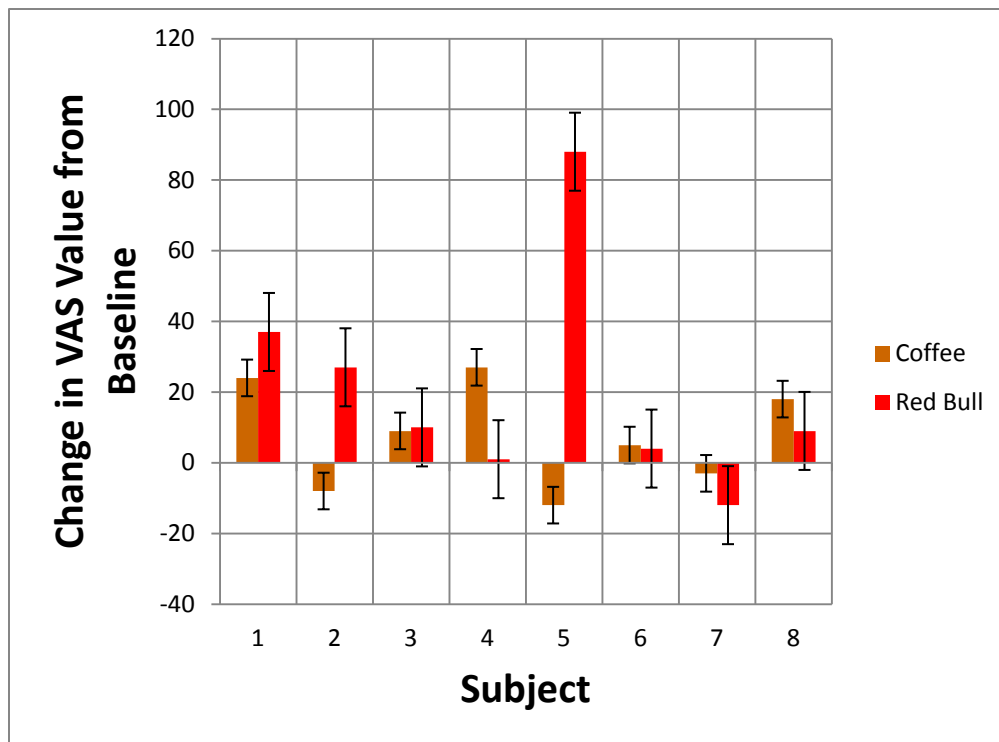


Figure 4. Change in VAS Value from Baseline for Feeling Energetic

Figure 5 shows the change in VAS values from baseline for confidence. The average change in VAS value for coffee was -5.25, while the average change in VAS value for Red Bull was -05.75. This test did not show a level of statistical difference, as the paired t-test resulted in a p-value of 0.9549.

Figure 6 shows the change in VAS values from baseline for irritability. The average change in VAS value for coffee was -5.875, while the average change in VAS value for Red Bull was 1.375. This test did not show a level of statistical difference but did approach significance, as the paired t-test resulted in a p-value of 0.0904.

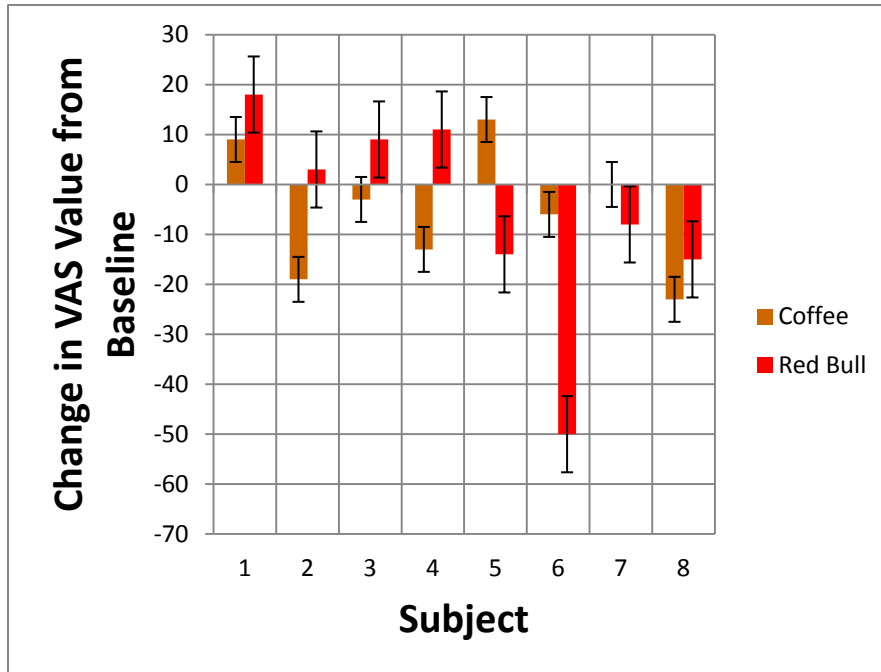


Figure 5. Change in VAS Value from Baseline for Feeling Confident

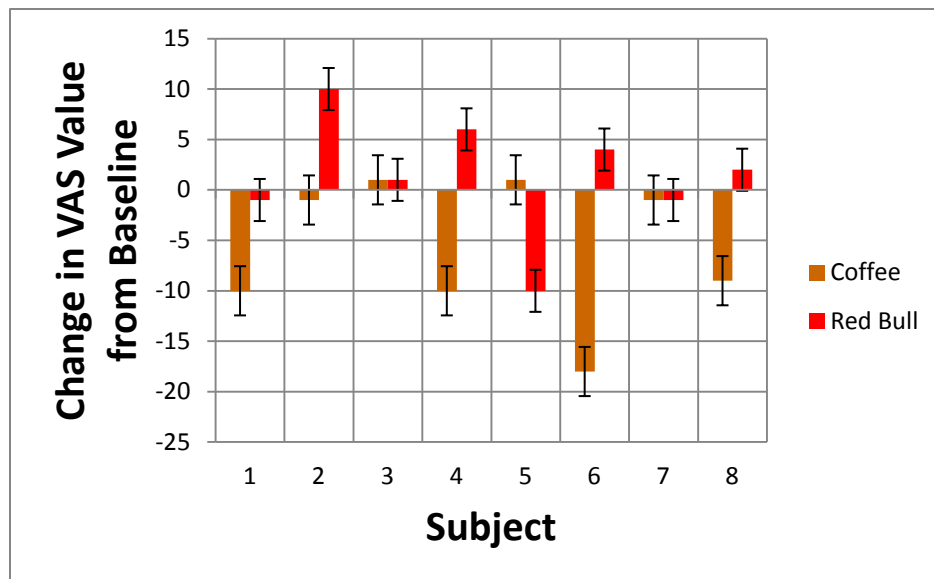


Figure 6. Change in VAS Value from Baseline for Feeling Irritable

Figure 7 shows the change in VAS values from baseline for feelings of jitteriness. The average change in VAS value for coffee was 3.375, while the average change in VAS value for Red Bull was 8.875. This test did not show a level of statistical difference, as the paired t-test resulted in a p-value of 0.4935.

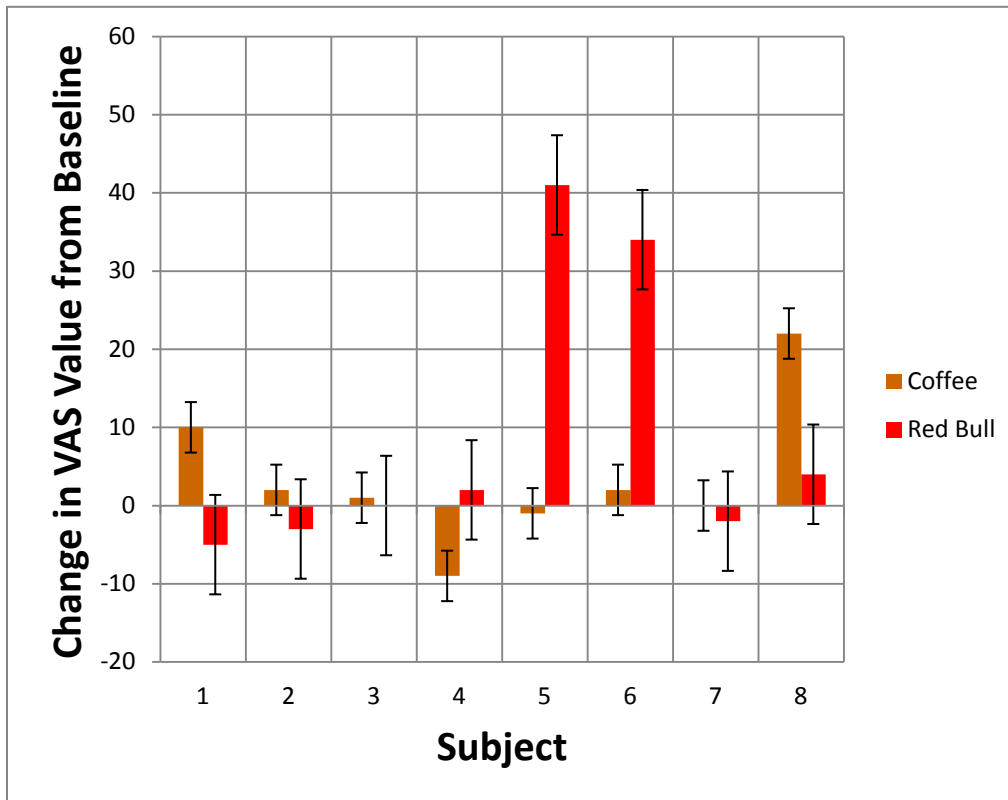


Figure 7. Change in VAS Value from Baseline for Feeling Jittery/Nervous

Figure 8 shows the change in VAS values from baseline for feelings of sleepiness. The average change in VAS value for coffee was -15, while the average change in VAS value for Red Bull was -14.625. This test did not show a level of statistical difference, as the paired t-test resulted in a p-value of 0.9411.

Figure 9 shows the change in VAS values from baseline for feelings of talkativeness. The average change in VAS value for coffee was -9.375, while the average change in VAS value for Red Bull was 13. This test did not show a level of statistical difference, as the paired t-test resulted in a p-value of 0.2866.

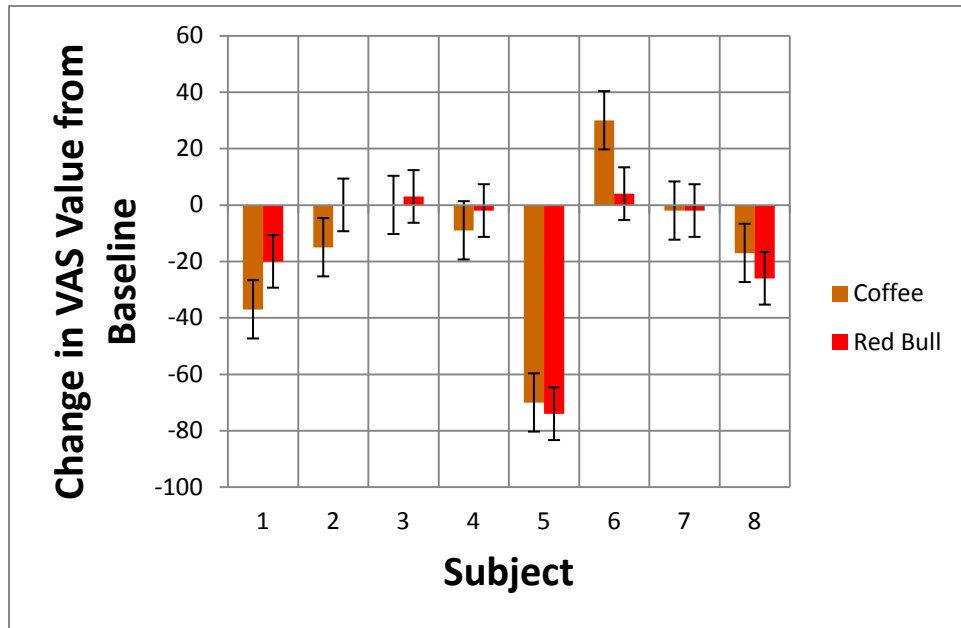


Figure 8. Change in VAS Value from Baseline for Feeling Sleepy

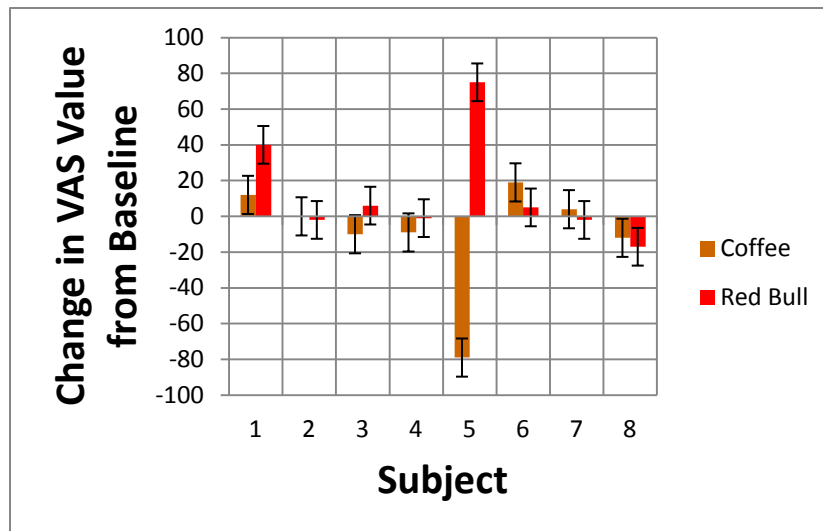


Figure 9. Change in VAS Value from Baseline for Feeling Talkative

4.2 Objective Testing

The PVT was used to test for objective levels of alertness. Figure 10 shows the change in reaction speed from baseline for each subject during each session. The average decrease in reaction time for coffee was 26.2 ms, while the average decrease in reaction time for Red Bull was 5.2 ms. However, this was not a statistical difference, as the paired t-test resulted in a p-value of 0.1407.

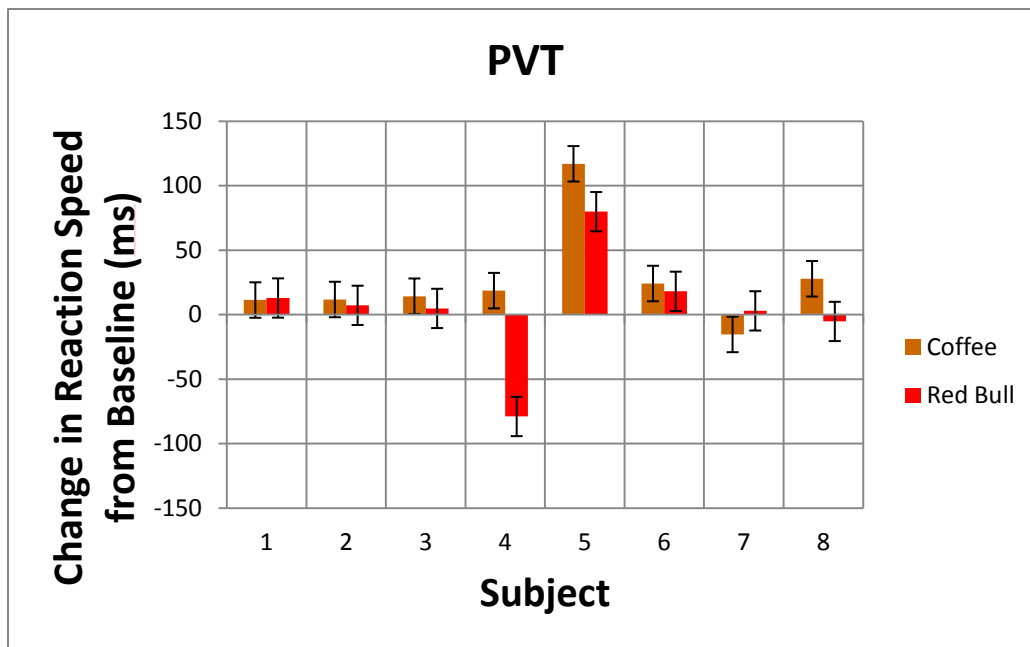


Figure 10. Change in Reaction Speed from Baseline for Each Subject

5.0 DISCUSSION

The battery of tests given to the research participants demonstrated that both coffee and Red Bull have the ability to improve alertness in fatigued individuals. However, the energy drink (Red Bull) had no statistically greater effects on objective cognitive performance in acutely fatigued individuals when compared to a control with the same amount of caffeine and sugar.

Additionally, the energy drink had no statistically significant effects on subjective cognitive performance in acutely fatigued individuals when compared to a control with the same amount of caffeine and sugar. The only area that did demonstrate any statistical significance was the subjective feeling of the ability to concentrate. In that case, the coffee seemed to give a more profound effect.

As previously mentioned, there is no current U.S. Air Force or Department of Defense policy regulating the use of energy drinks. Regular caffeinated beverages, such as coffee, tea, and soda, are allowed as possible fatigue countermeasures. Given that the energy drink tested performed similarly to coffee, there is no evidence to support recommending the use of Red Bull in flying operations over the use of coffee, tea, or soda. However, for definitive guidance, further research should be performed looking at other energy drinks. Additionally, side effect profiles need to be studied and possible adverse interactions with current fatigue countermeasures (dextroamphetamine and modafinil) need to be investigated.

6.0 REFERENCES

1. Caldwell JA, Caldwell JL. Fatigue in military aviation: an overview of U.S. military-approved pharmacological countermeasures. *Aviat Space Environ Med* 2005; 76(7 Suppl):C39-51.
2. Kenagy DN, Bird CT, Webber CM, Fischer JR. Dextroamphetamine use during B-2 combat missions. *Aviat Space Environ Med* 2004; 75(5):381-6.
3. Zwylghuizen-Doorenbos A, Roehrs TA, Lipschutz L, Timms V, Roth T. Effects of caffeine on alertness. *Psychopharmacology (Berl)* 1990; 100(1):36-9.
4. Wesentren NJ, Belenky G, Thorne DR, Kautz MA, Balkin TJ. Modafinil vs. caffeine: effects on fatigue during sleep deprivation. *Aviat Space Environ Med* 2004; 75(6):520-5.
5. McLellan TM, Kamimori GH, Bell DG, Smith IF, Johnson D, Belenky G. Caffeine maintains vigilance and marksmanship in simulated urban operations with sleep deprivation. *Aviat Space Environ Med* 2005; 76(1):39-45.
6. Ahmad Z, Minch D. Energy drinks: the truth behind the boost fact sheet [Internet]. New Brunswick, NJ: Rutgers, The State University of New Jersey; 2009 Jul. Fact Sheet FS1108. Retrieved 10 February 2013 from <http://someset.njaes.rutgers.edu/pdfs/fs1108.pdf>.
7. Malinauskas BM, Aeby VG, Overton RF, Carpenter-Aeby T, Barber-Heidal K. A survey of energy drink consumption patterns among college students. *Nutr J* 2007; 6:35.
8. Roberson L. Guzzling energy drinks but more tired than ever? *NBCNews.com*; 2012 19 Mar. Retrieved 10 February 2013 from http://www.nbcnews.com/id/46764607/ns/health-mens_health/t/guzzling-energy-drinks-more-tired-ever/.
9. Kaida K, Takahashi M, Akerstedt T, Nakata A, Otsuka Y, Haratani T, et al. Validation of the Karolinska sleepiness scale against performance and EEG variables. *Clin Neurophysiol* 2006; 117(7):1574-81.
10. Dittner AJ, Wessely SC, Brown RG. The assessment of fatigue: a practical guide for clinicians and researchers. *J Psychosom Res* 2004; 56(2):157-70.

11. Dorrian J, Rogers NL, Dinges DF. Psychomotor vigilance performance: neurocognitive assay sensitive to sleep loss. In: Kushida CA, ed. Sleep deprivation: clinical issues, pharmacology, and sleep loss effects. New York: Marcel Dekker; 2005:39-70.
12. Loh S, Lamond N, Dorrian J, Roach G, Dawson D. The validity of psychomotor vigilance tasks of less than 10-minute duration. Behav Res Methods Instrum Comput 2004; 36(2):339-46.

LIST OF ABBREVIATIONS AND ACRONYMS

KSS	Karolinska sleepiness scale
PDA	personal digital assistant
PVT	psychomotor vigilance task
VAS	visual analog scale