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Sleep deprivation does not cause eye movements that mimic alcohol intoxication

Abstract

INTRODUCTION. Previous research shows that sleep deprivation (SD) produces cognitive and some motor impairment similar to that caused by alcohol intoxication. Consequently, SD often has been used as an excuse in place of driving while intoxicated. We wanted to determine if SD would cause changes in performance on field sobriety tests (FSTs) - walk-and-turn (WAT), one leg stand (OLS), Romberg balance, horizontal gaze nystagmus (HGN), vertical gaze nystagmus (VGN), and lack of convergence (LOC) - in a manner that could be confused with intoxication.

METHODS. Twenty-nine healthy adult Caucasian subjects participated in 2 alcohol workshops each, one after wakefulness of at least 24 hrs, the other after a full night's rest. Subjects consumed prescribed amounts of alcohol over a 2-hr period during each workshop; some subjects were maintained as placebo drinkers. Subjects received a \$20 gift card after their participation. At each workshop, trained police officers assessed FSTs similar to the manner in which an impaired driver would be assessed at roadside. We also measured attentional field of view (AFOV), convergence nearpoint (NPC), and presence of endpoint nystagmus (EN). We monitored blood pressure (BP), pulse rate, and pupil size throughout the study. Measures were assessed at Baseline, after 1 hour of drinking, after 2 hours of drinking, and at least 1 hour after the end of drinking (Final). To avoid practice effects, WAT, OLS, and Romberg balance were assessed only at Baseline and Final. A calibrated breath analysis instrument was used to measure blood alcohol concentration (BAC). Subjects and evaluators were masked to the BAC readings during the workshops. Evaluators did not confer regarding their findings during the workshops.

RESULTS. Subjects' BACs ranged up to 0.115 g/dl. Regardless of subject restedness, the presence and number of impairment clues increased with increasing BAC for HGN, VGN, LOC, AFOV, NPC, EN, and the other FSTs, most at statistically significant levels ($p < 0.05$). However, there were no significant differences for any of these tests when comparing baseline measures for the SD and well-rested conditions, prior to the consumption of any alcohol. Blood pressure and pulse rates did not vary significantly, regardless of condition. Pupil sizes in room light were about 1 mm larger following SD, but there was no variation with intoxication.

DISCUSSION. While SD may affect cognitive ability and certain motor skills, we found no evidence that it affects eye movements, FOV, or motor skills assessed with FSTs or standard clinical tests, unless the subject is also intoxicated.

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**SLEEP DEPRIVATION DOES NOT CAUSE EYE MOVEMENTS
THAT MIMIC ALCOHOL INTOXICATION**

By

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CHAD J. KREZELOK

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A thesis submitted to the faculty of the
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BIOGRAPHIES

Ashlee Arlien obtained her Bachelor of Arts degree in both Chemistry and Biology at Valley City State University in North Dakota. She then went on to Pacific University College of Optometry and became an active member in many of the college's clubs and associations as well as volunteering her time wherever needed. When the possibility of a thesis study came to study alcohol's effects on driving and sleep deprivation, Ashlee jumped at the chance to participate. Throughout her life she has recognized and had experience with the devastating effects of people driving while impaired. Because of this, after graduation Ashlee hopes to continue working with traumatic brain injured patients and gain more experience in the neuro-rehabilitation area of optometry.

Christopher Jons was born in 1978 to LeRoy and Vicky Jons, and graduated high school from Lyman, Wyoming. He attended college at the University of Wyoming where he graduated in 2002 with a B.S. in Zoology and Physiology with a minor in Chemistry while participating in Collegiate Athletics on the Track and Field and Cross Country Teams. After graduation, he went straight to Pacific University College of Optometry and plans on graduating in 2006 with hopes to practice Optometry in Rural Wyoming. Christopher recently got engaged to Tracy Grefsrud.

Chad Krezelok was born and raised in Sheridan, Wyoming. He received a bachelors in Marketing from Montana State University-Billings. Chad enjoys skiing, golfing, fishing, and spending time in the mountains of Wyoming and Montana.

Joseph D. Neron will receive a Doctorate in Optometry to be conferred May 2006 from Pacific University College of Optometry. He has been active in AMIGOS, a student-organized service organization, organizing and implementing free vision screenings to local communities within Oregon from 2002 to 2004. Joseph received a Bachelor of Science in Biology from the University of Oregon in 2001. He was a University of Oregon Dean's list recipient in the fall of 2000. Joseph is originally from Beaverton, Oregon, and plans to work in a private practice in the Portland metro area after graduation.

ABSTRACT

INTRODUCTION. Previous research shows that sleep deprivation (SD) produces cognitive and some motor impairment similar to that caused by alcohol intoxication. Consequently, SD often has been used as an excuse in place of driving while intoxicated. We wanted to determine if SD would cause changes in performance on field sobriety tests (FSTs) – walk-and-turn (WAT), one leg stand (OLS), Romberg balance, horizontal gaze nystagmus (HGN), vertical gaze nystagmus (VGN), and lack of convergence (LOC) – in a manner that could be confused with intoxication.

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RESULTS. Subjects' BACs ranged up to 0.115 g/dl. Regardless of subject restedness, the presence and number of impairment clues increased with increasing BAC for HGN, VGN, LOC, AFOV, NPC, EN, and the other FSTs, most at statistically significant levels ($p < 0.05$). However, there were no significant differences for any of these tests when comparing baseline measures for the SD and well-rested conditions, prior to the consumption of any alcohol. Blood pressure and pulse rates did not vary significantly, regardless of condition. Pupil sizes in room light were about 1 mm larger following SD, but there was no variation with intoxication.

DISCUSSION. While SD may affect cognitive ability and certain motor skills, we found no evidence that it affects eye movements, FOV, or motor skills assessed with FSTs or standard clinical tests, unless the subject is also intoxicated.

INTRODUCTION

Previous studies assessing cognitive function, simulator driving,⁴⁻⁸ and actual driving performance⁹⁻¹⁹ demonstrated that sleep deprivation (SD) produces impairment similar to that caused by alcohol intoxication. Certainly, driving while fatigued causes significant ethical and legal considerations in today's society.²⁰ Recent studies suggest that SD causes changes in visual and visuomotor functions, some of which could be mistaken for intoxication.²¹⁻²³ Consequently, SD often has been offered as an excuse in place of driving under the influence (DUI). Since most jurisdictions do not yet make it a crime to drive while fatigued, an intoxicated driver could escape severe legal and civil penalties if he can convince the judge and jury that he was only fatigued.

Many law enforcement officers have casually reported to the authors that they can distinguish between fatigued and intoxicated drivers. However, we have found no prior research that fully assesses the psychophysical procedures used by officers to establish driver impairment, known as field sobriety tests (FSTs), with regard to SD.

The goal of this research is to determine if SD would cause changes in performance on FSTs in a manner that could be confused with intoxication. In addition, we conducted optometric clinical tests and monitored vital signs to determine if these would change with SD so as to be confused with intoxication,

METHODS

SUBJECTS

Thirty-one Caucasian subjects (15 female, 16 male) volunteered for the study, chosen from a sample of convenience. Subjects were either students of Pacific University, or friends or spouses of students.

All subjects were over the age of 21, as confirmed by a valid driver's license. Subjects reviewed and signed informed consent and model release forms, approved by the Pacific University Institutional Review Board, before beginning the study. Subjects completed a detailed questionnaire regarding personal and health histories and experience with consuming alcohol. (See Appendix A) Potential subjects who admitted to a history of alcohol or substance abuse, use of certain medications, pregnancy, or presence of any medical condition with which alcohol consumption is contraindicated would have been excluded from the study.

Subjects were asked to participate in two alcohol workshops each, one after a full night's rest, and a second after wakefulness of at least 24 hrs (see below). Subjects were assigned to each workshop based on availability. Subjects were required to have designated drivers available to take them home after each workshop.

One female subject participated in only one session and did not return for the second session, for reasons unrelated to the study; her data are not included in the analyses below. One male subject started his participation with the overnight observation period. After a few hours, and before completion of the overnight period and consumption of any alcohol, he decided not to continue; no data were collected on this subject. Consequently, the analyses reported below are based on data from the remaining 29 subjects, whose demographic information is provided in Table I. Two subjects (one male, one female) are authors of this study; the remaining 27 subjects each received a \$20 gift card as a token of appreciation for their participation.

Table 1. Demographic data for subjects who completed the study. s.d.=standard deviation.

		Female	Male
Age, yrs	Number	14	15
	Mean (s.d.)	27.3 (7.92)	25.45 (2.24)
	Minimum	21.4	22.6
	Maximum	52.3	30.7
Weight, lbs	Mean (s.d.)	131.6 (14.55)	182.5 (38.87)
	Minimum	110	135
	Maximum	165	300
Prescription for Driving	Spectacles	4	5
	Contact Lenses	6	5
Hours Awake at Start of Workshop:			
Normal Sleep	Mean (s.d.)	4.0 (1.59)	4.1 (1.73)
	Minimum	2.0	2.5
	Maximum	7.2	7.9
Sleep Deprived	Mean (s.d.)	30.3 (0.80)	29.4 (1.80)
	Minimum	28.8	24.4
	Maximum	32.1	31.9

OVERNIGHT OBSERVATION PERIOD

Subjects assigned to be awake for at least 24 hrs prior to an alcohol workshop typically arrived at Pacific University College of Optometry in Forest Grove, Oregon, at about 10 PM on the evening before the workshop after a full day of classes or work. Subjects stayed in the student lounge area and were allowed to study, play games, and watch movies throughout the night, as monitored by shifts of researchers. (See Figure 1) Subjects and monitors were provided with snack and breakfast foods, soft drinks, and water. Each subject's vital signs – blood pressure (BP), pulse, and pupil sizes – were checked at regular intervals throughout the overnight period.

Three subjects worked in an overnight clerical office away from campus. These subjects monitored themselves for wakefulness, as well as the regular checks of BP, pulse, and pupil size.

Figure 1. Subjects staying awake by playing a game during the overnight observation period.



MEASURES

A calibrated breath analysis instrument, Intoxilyzer 5000, similar to one used during actual DUI investigations in Oregon, was used to measure each subject's blood alcohol concentration (BAC) multiple times throughout each workshop. (See Figure 2)

Trained law enforcement officers assessed FSTs similar to the manner in which an impaired driver would be assessed at roadside or during a drug evaluation at a police station. The FSTs include walk-and-turn (WAT), one-leg stand (OLS), Romberg balance, horizontal gaze nystagmus (HGN), vertical gaze nystagmus (VGN), and lack of convergence (LOC), and have been described in detail elsewhere.²⁴⁻²⁶ Figures 3-8 demonstrate subjects performing each of these tests. To avoid practice effects, WAT, OLS, and Romberg balance were assessed only at the beginning and end of the workshop.

Researchers monitored vital signs and performed additional tests – nearpoint of convergence (NPC), presence of endpoint nystagmus (EN), and attentional field of view (AFOV)

– similar to the manner in which these are conducted clinically and have been described elsewhere.²⁷(See Figure 9)

Figure 2. Subject providing a breath sample on the Intoxilyzer 5000.



Figure 3. Subject performing walk-and-turn (WAT) test.

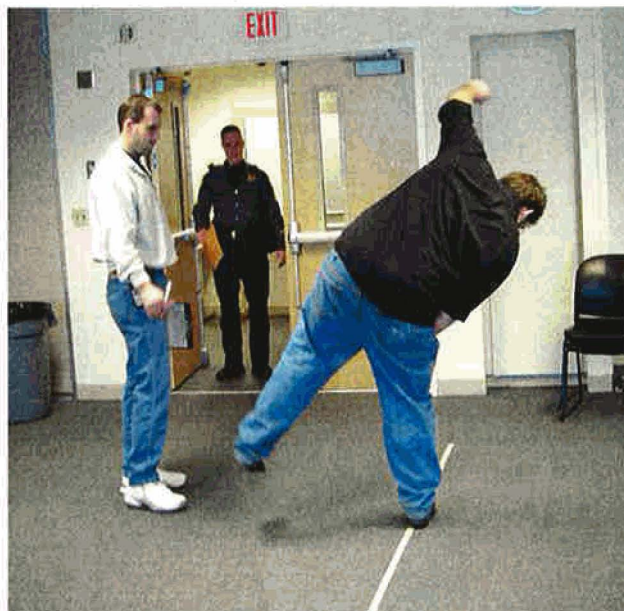


Figure 4. Subject performing one-leg stand (OLS) test.

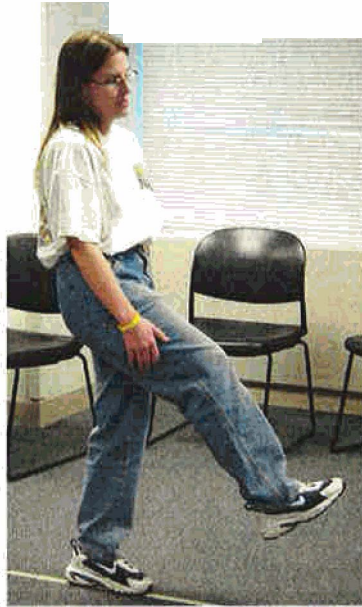


Figure 5. Subject performing Romberg balance test.



Figure 6. Subject performing horizontal gaze nystagmus (HGN) test.



Figure 7. Subject performing vertical gaze nystagmus (VGN) test.



Figure 8. Subject performing lack of convergence (LOC) test.

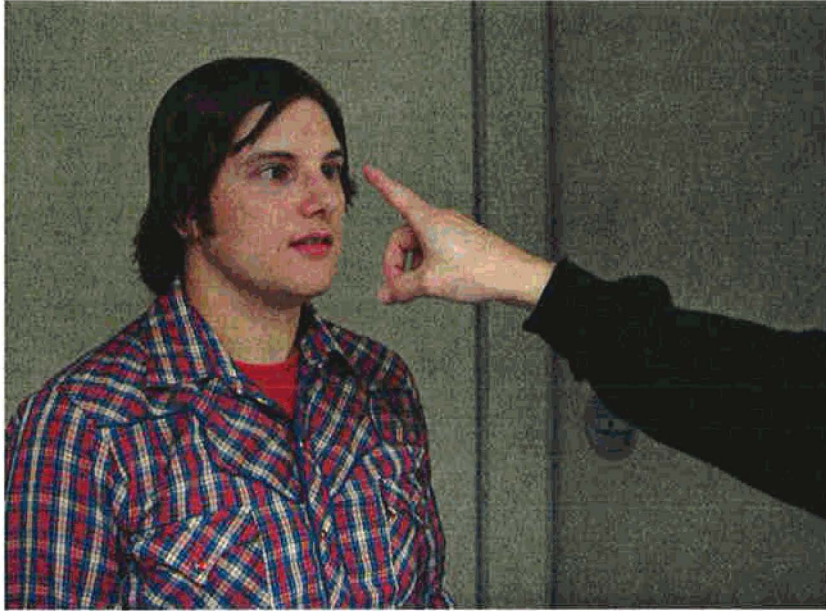


Figure 9. Arc perimeter used to assess the presence of endpoint nystagmus and attentional field of view.



ALCOHOL WORKSHOPS

Alcohol workshops were conducted in a training room at Washington County Sheriffs Office in Hillsboro, Oregon. A total of nine workshops were held either on a Friday or Saturday during the spring of 2005, based on availability of subjects and the facility. Workshops started between noon and 1 PM, and subjects were driven **from** Forest Grove to Hillsboro by the researchers.

Prior to the start of the workshop, subjects affirmed that they did not consume any alcohol for at least 12 hours and that they did not have a large meal or significant snacks for at least 4 hours. All vital signs and measures were assessed at the start of each workshop (Baseline), before the consumption of any alcohol. Each subject began each workshop with a BAC of 0.00 g/dl, confirmed with the Intoxilyzer 5000. Subjects and evaluators were masked to the BAC readings during the workshops. Evaluators did not confer regarding their findings during the workshops.

Each subject received a prescribed dose of 80-proof liquor of his or her choice (vodka, gin, rum, or whiskey). Each subject's dose was based on the subject's gender, weight, and intended maximum BAC.

Since all subjects served under both states of restedness, each subject was his or her own control with regard to any potential effects of SD and alcohol intoxication. Nonetheless, three subjects within each state of restedness were maintained as placebo drinkers. For non-placebo subjects, the intended maximum BAC was no greater than 0.11 g/dl; for placebo drinkers, it was less than 0.04 g/dl.

The total dose for each subject was divided into two equal portions, usually with water added to mask the actual amount of alcohol served. Subjects could add ice and as much of any mixer they wanted (e.g., orange juice, tonic water, cola, etc.).

Subjects were requested to consume the first portion of the alcohol dose within the first 45 minutes after the start of drinking. To maximize alcohol absorption, subjects were not allowed to eat any food during this time. All vital signs and measures, other than WAT, OLS, and Romberg balance, were assessed after the first portion of alcohol was consumed (First Period). The time to complete the measures was often sufficient to meet the legally-mandated minimum 15-minute "deprivation period," when DUI suspects are not allowed to eat, drink, or regurgitate

anything before providing a breath sample for the Intoxilyzer 5000. Thus, subjects' BACs were measured about 1 hr after the first drink.

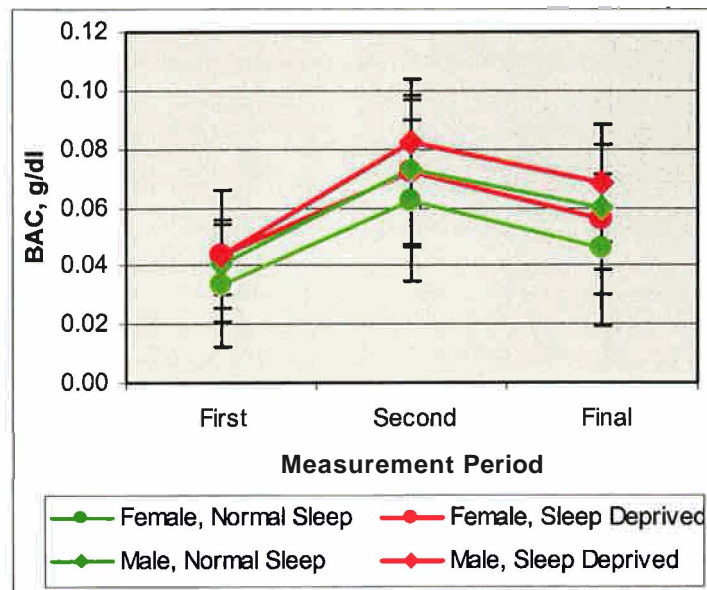
Subjects were requested to consume the second portion of the alcohol dose within the first 45 minutes of the second full hour of drinking. Since some alcohol already had entered the bloodstream, subjects were allowed to eat snack foods at this time. As before, all vital signs and measures, except for WAT, OLS, and Romberg balance, were assessed after the second portion of alcohol was consumed (Second Period). Consequently, subjects' BACs were measured about 2 hrs after the first drink.

After the Second Period, subjects enjoyed snack foods and soft drinks for an additional 45 minutes. At this time, all vital signs and measures, including WAT, OLS, and Romberg balance, were assessed once more (Final Period). Therefore, subjects' BACs were measured at least 1 hr after the last drink was consumed.

RESULTS

Figure 10 shows the average BACs at each of the test periods. The highest BAC reached by a single subject at one measure was 0.11 g/dl. Placebo drinkers typically had BACs of 0.00-0.03 g/dl throughout the workshop, and none reached a BAC of 0.05 g/dl or higher at any single measure.

Figure 10. Average BAC at each test period. Standard deviations indicated.



For Figures 11-22, data from the three test periods were combined and organized in increments of 0.02 g/dl. All figures include the Baseline measures. Values on the bars of each figure represent the number of measures that contributed to that value.

Figure 11. Average number of HGN clues with respect to BAC. Standard error bars indicated.

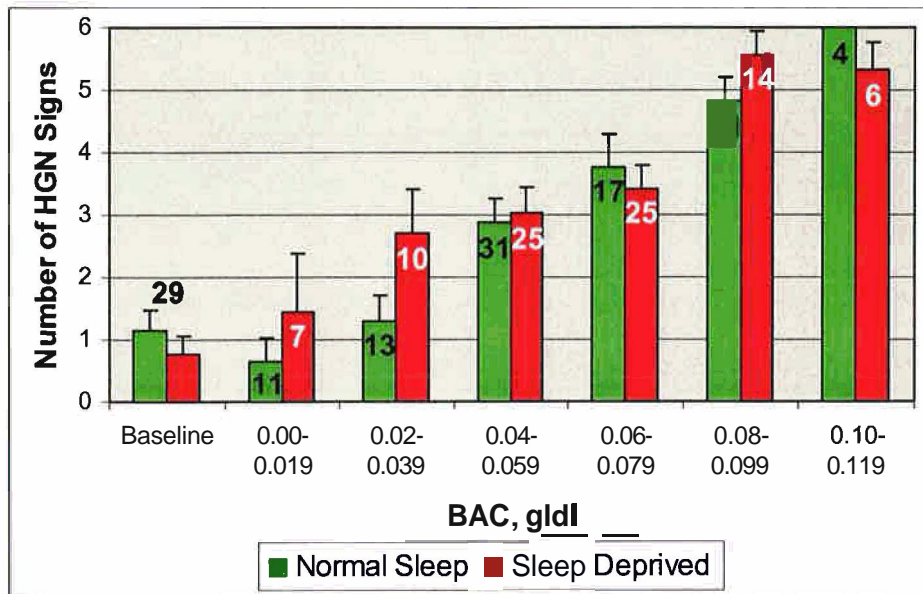


Figure 12. Percentage of subjects who exhibited VGN with respect to BAC.

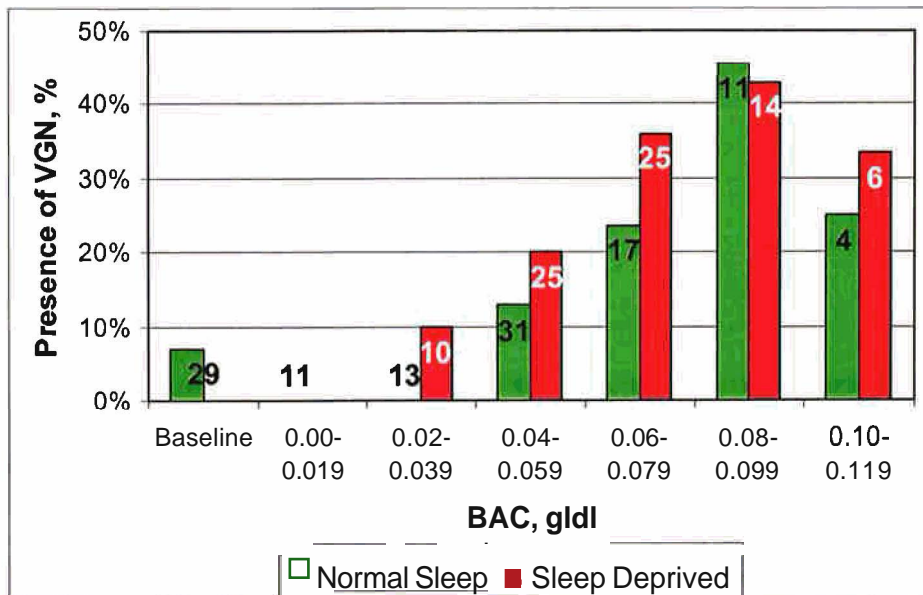


Figure 13. Percentage of subjects who exhibited LOC with respect to BAC.

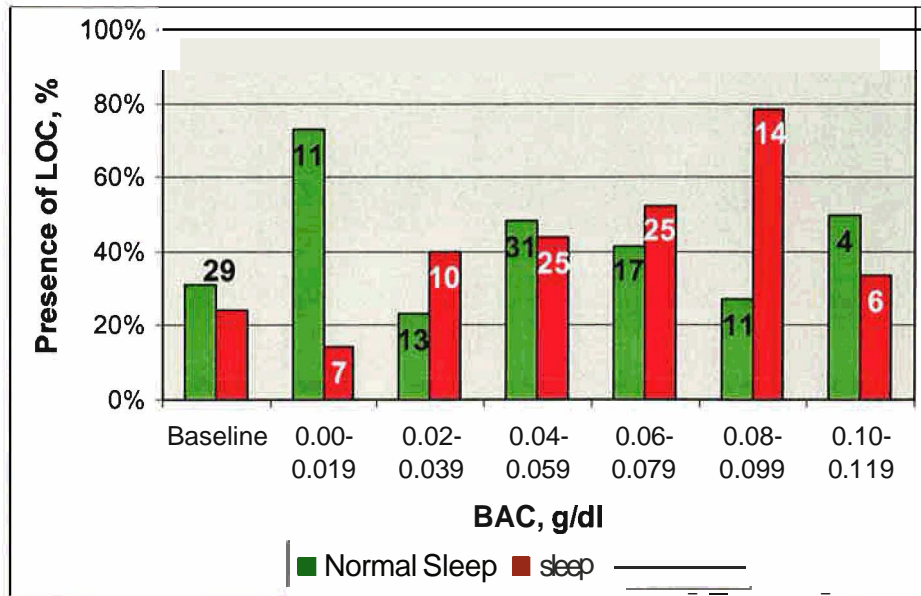


Figure 14. Percentage of subjects who exhibited EN (Eye Nystagmus) with respect to BAC.

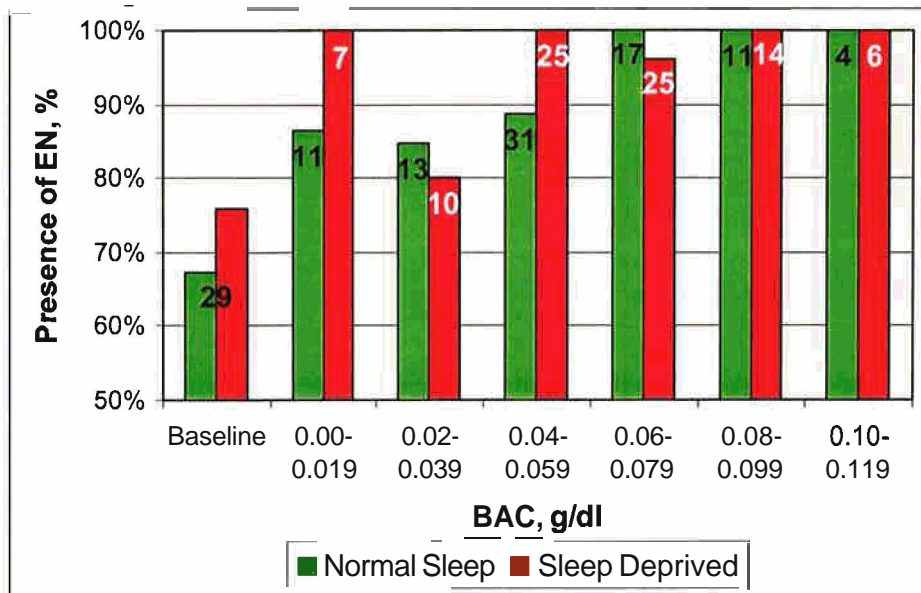


Figure 15. Average NPC, in cm, with respect to BAC. Standard error bars indicated.

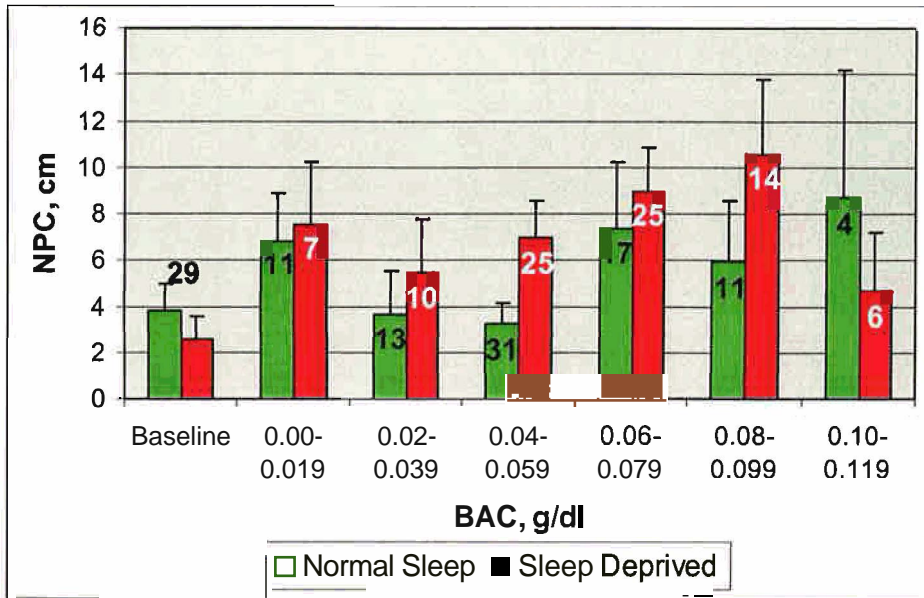


Figure 16. Average AFOV, in deg, with respect to BAC. Standard error bars indicated.

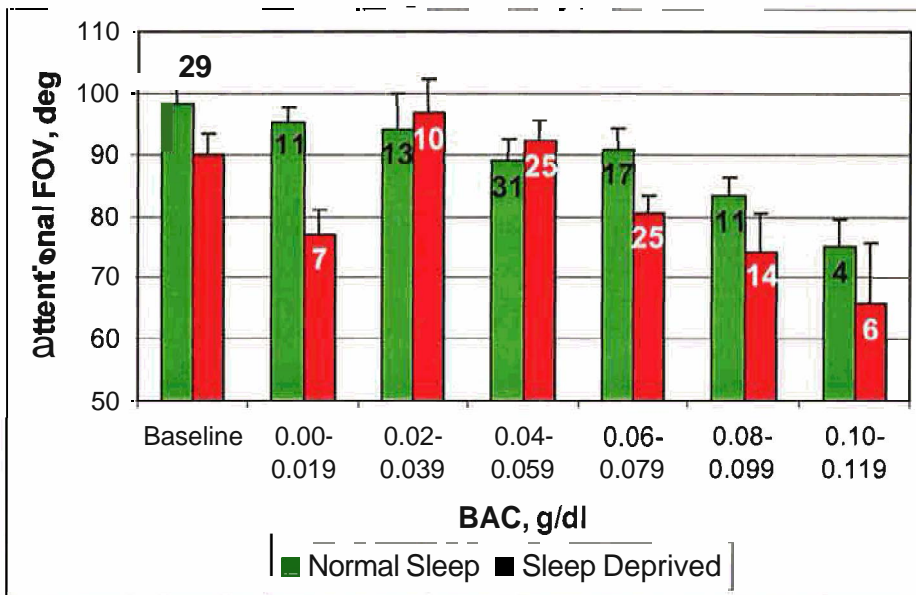


Figure 17. Average WAT clues with respect to BAC.

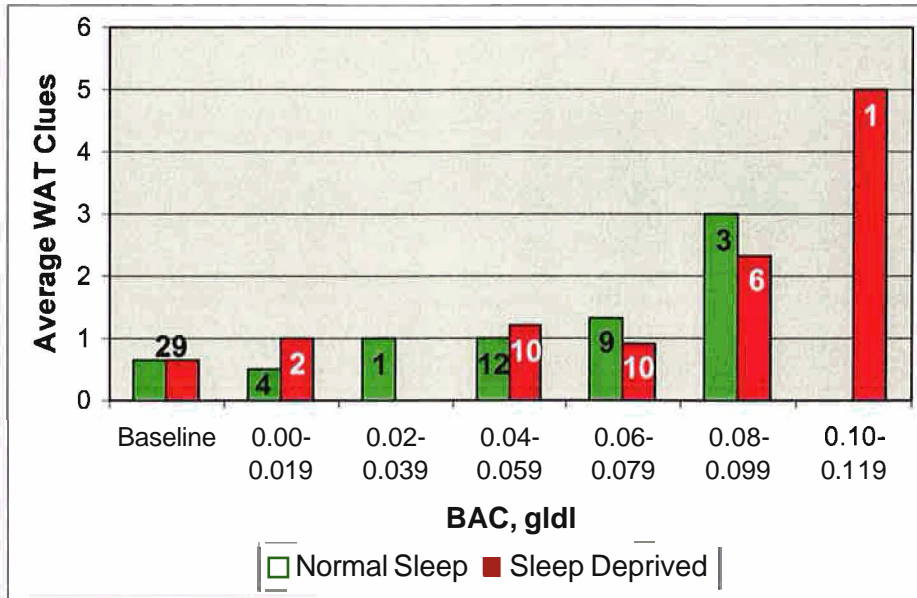
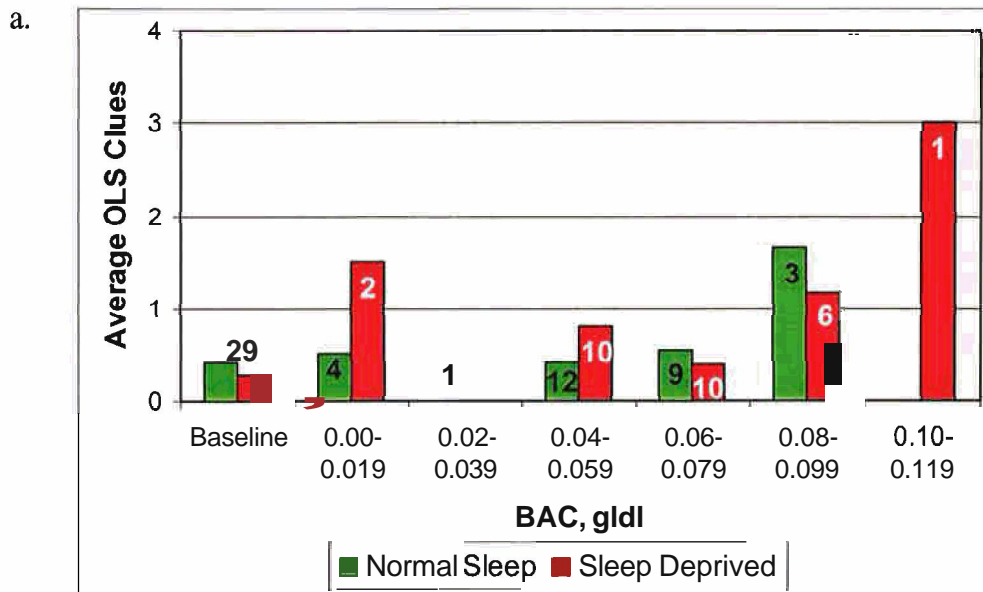


Figure 18. Average OLS (a) clues and (b) count with respect to BAC. Standard error bars indicated.



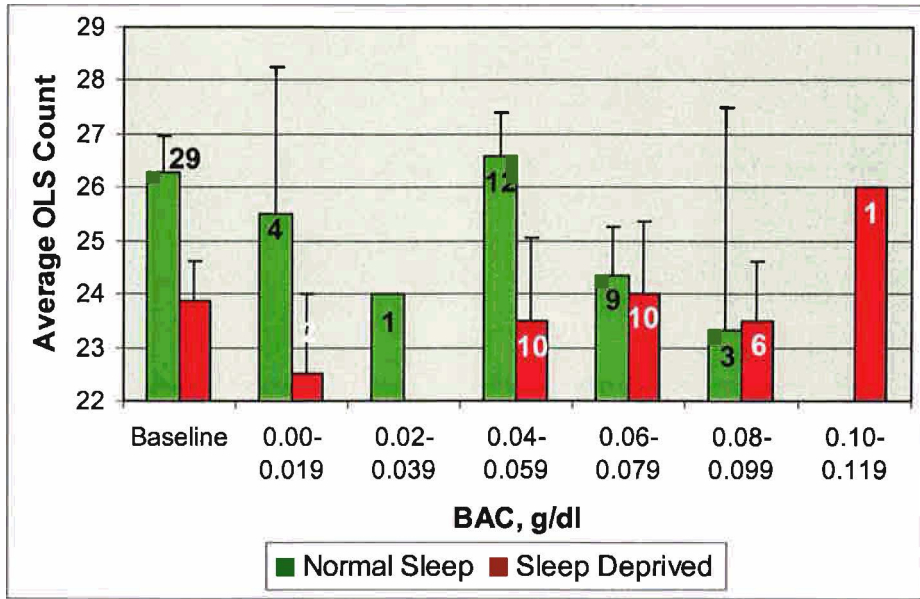
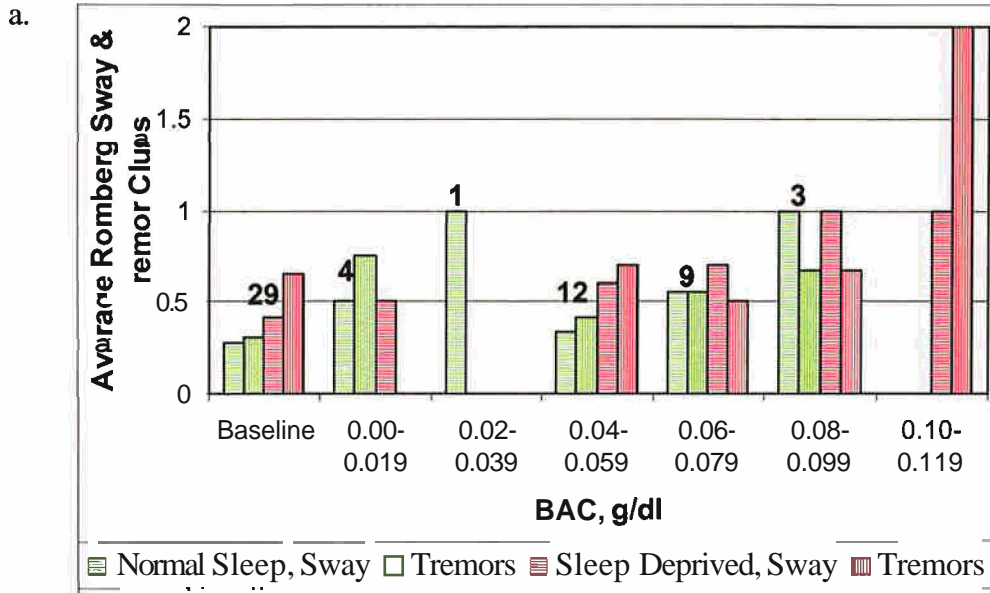


Figure 19. Average Romberg balance (a) sway and tremor clues and (b) estimation of the passage of 30 sec (time) with respect to BAC. Standard error bars indicated.



b.

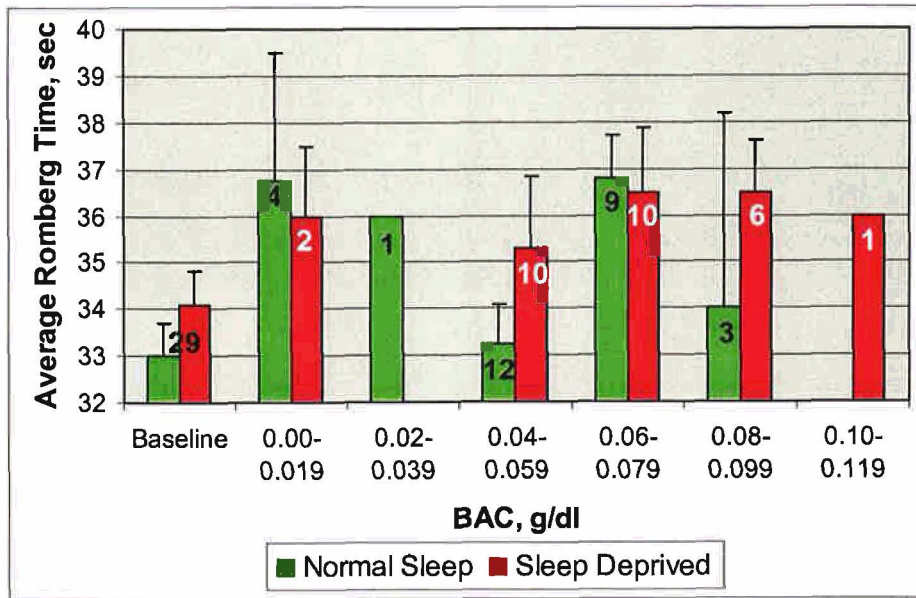


Figure 20. Average BP, systolic (upper curves) and diastolic (lower curves), in mmHg, with respect to BAC. Standard error bars indicated.

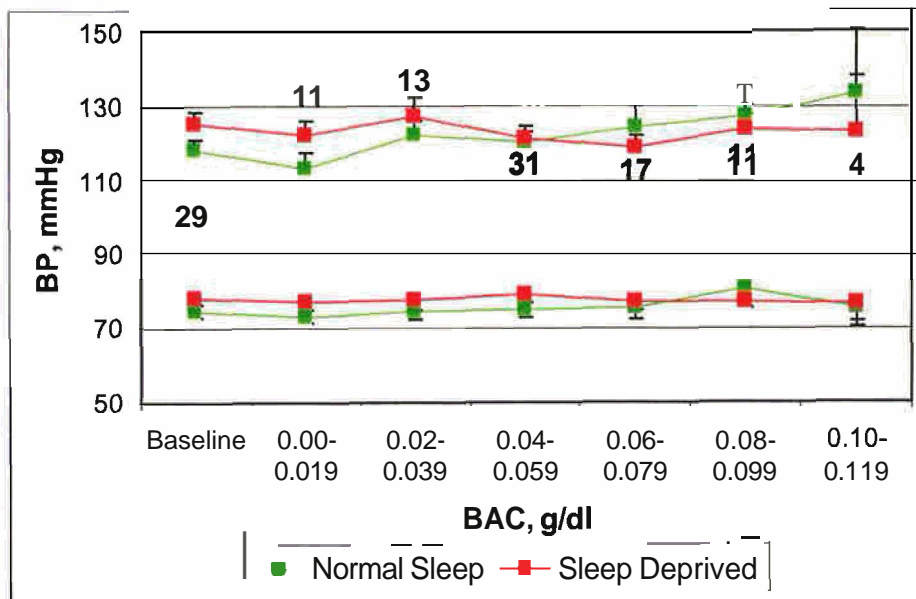


Figure 21. Average pulse, in bpm, with respect to BAC. Standard error bars indicated.

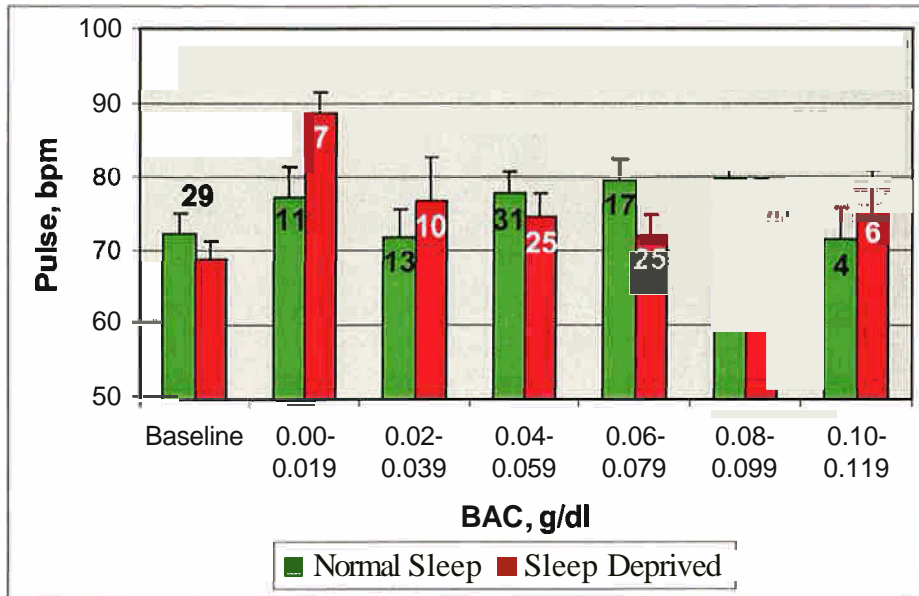
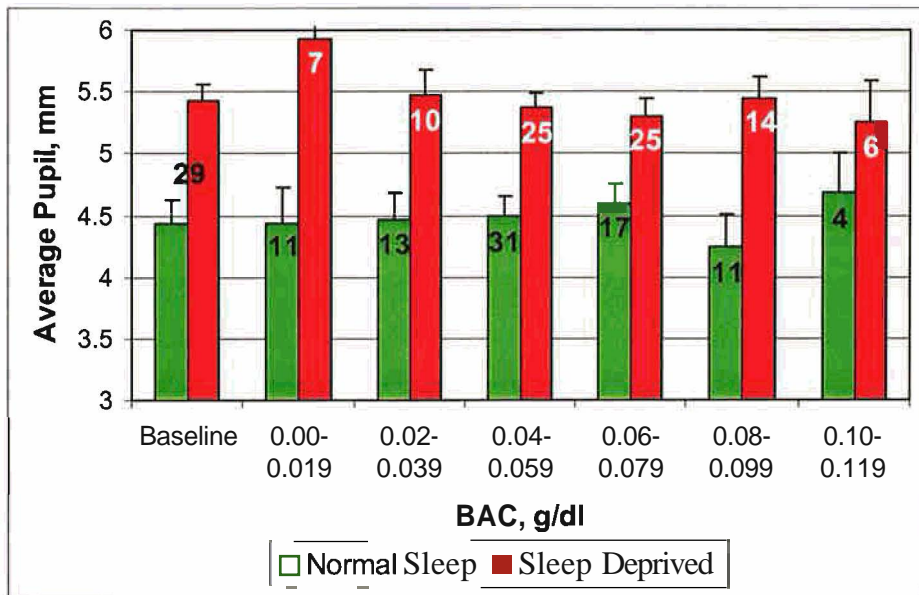


Figure 22. Average pupil size, in mm, with respect to BAC. Standard error bars indicated.



Analyses were conducted on the Baseline measures, to see if a difference exists between the well-rested and SD measures at the beginning of the workshops: t-tests for parametric data of BP, pulse, pupil size, AFOV, NPC, HGN, WAT, OLS, and Romberg balance; simple χ^2 tests for non-parametric data of VGN, LOC, and EN. Analyses also were conducted on the measures across BAC increments, as shown in the figures above, assessing the main effects of changes due to restedness and to intoxication level. Repeated measures analysis of variance were conducted on the parametric data, and complex χ^2 tests were conducted on the non-parametric data. Table 2 shows the analyses that result in significant differences at a level of less than 0.05.

Table 2. Significance levels for statistical tests of comparisons at Baseline and for main effects of restedness and BAC. N.S.=not significant.

		Difference at Baseline?	Change with Restedness?	Change with BAC?
Vital Signs:	BP, Systolic	N.S	N.S.	N.S.
	BP, Diastolic	N.S	p=0.019	N.S.
	Pulse	N.S	N.S.	p=0.026
	Pupil Size	p=0	p=0	N.S.
Clinical Tests:	AFOV	N.S.	p=0.004	p=0
	EN	N.S.	N.S.	N.S.
	NPC	N.S.	N.S.	p=0.016
FSTs:	HGN	N.S.	N.S.	p=0
	VGN	N.S.	N.S.	N.S.
	LOC	N.S.	N.S.	N.S.
	WAT	N.S.	N.S.	p=0
	OLS Clues	N.S.	N.S.	p=0.004
	OLS Count	p=0.022	p=0.004	N.S.
	Romberg Sway	N.S.	N.S.	p=0.005
	Romberg Tremor	p=0.044	N.S.	N.S.
	Romberg Time	N.S.	N.S.	N.S.

DISCUSSION

Regardless of subject restedness, the presence and number of impairment clues increased with increasing BAC for HGN, VGN, LOC, AFOV, NPC, EN, and the other FSTs, most at statistically significant levels ($p < 0.05$). However, there were no significant differences for any of these tests when comparing Baseline measures for the SD and well-rested conditions, prior to the consumption of any alcohol. BP and pulse rates did not vary significantly, regardless of condition. Pupil sizes in room light were about 1 mm larger following SD, but there was no variation with intoxication. This, as well as muscle tremor during Romberg balance, was likely due to the changes in stress hormones that occur with SD. The significant difference in OLS count can be attributed to the fact that counting is a cognitive function, which previous research has shown will be affected by SD; nonetheless, the OLS count is not a clue of impairment that is normally assessed during that test.

While SD may affect cognitive ability and certain motor skills, we found no evidence that it affects eye movements, AFOV, or motor skills assessed with FSTs or standard clinical tests, unless the subject is also intoxicated.

ACKNOWLEDGMENTS

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APPENDIX A

VOLUNTEER DRINKER QUESTIONNAIRE

INSTRUCTIONS: This form is to be completed before the beginning of the alcohol workshop. Each Yes/No blank will be initialed, and other blanks filled in appropriately, by the volunteer drinker.

Printed name _____ Today's Date ____ / ____ / ____

1. ____ Yes ____ No I volunteer to serve as a drinking subject.
2. ____ Yes ____ No I can consume at least one (1) alcoholic drink of 80 proof liquor in 1 hour.
3. ____ Yes ____ No I can consume at least three (3) alcoholic drinks of 80 proof liquor in 1 hour.
4. ____ Yes ____ No I understand that I will be required to consume alcoholic beverages. If I initialed "No" on Question 3, I may attain a blood alcohol concentration of about 0.05%; otherwise, I may attain a blood alcohol concentration possibly as high as 0.16%.
5. ____ Yes ____ No I understand that my ability to operate a motor vehicle or any kind of power equipment would be impaired to an unsafe degree because of alcohol consumption and/or fatigue.
6. ____ Yes ____ No I understand that I would be in violation of state and local laws if I were to drive impaired because of alcohol consumption.
7. ____ Yes ____ No I agree to refrain from operating a motor vehicle or any kind of power equipment for at least twelve (12) hours after having stopped drinking alcoholic beverages in connection with this alcohol workshop.
8. ____ Yes ____ No I understand that if I drove to the alcohol workshop I will not be able to drive after the workshop is completed and I will make the necessary arrangements to have myself removed from the workshop site.
9. ____ Yes ____ No I understand that I will be required to submit to a series of physical and breath tests designed to monitor and evaluate my degree of alcohol impairment and to assess the concentration of alcohol in my blood.
10. ____ Yes ____ No I am in good physical health, and am not currently under a doctor's care.
11. ____ Yes ____ No I have never been diagnosed with *alcoholism, diabetes, hypertension, epilepsy, a heart condition, history of substance abuse*, or *any* other chronic medical condition with which I should not drink alcohol. I also represent that I have no reason to believe that I suffer from any of these conditions. I understand that the consumption of alcohol while suffering from any of these ailments may be harmful to me.

11a. ___ Yes ___ No Female subjects only: I am NOT pregnant, and I have no reason to believe that I may be pregnant.

12. ___ Yes ___ No I understand that consumption of alcohol while taking certain medications may result in sickness or injury.

13. ___ Yes ___ No I am NOT taking any prescription medications that may adversely react with alcohol, such as pain killers, muscle relaxants, antidepressants, or anti-anxiety drugs.

14. ___ Yes ___ No I am NOT taking any non-prescription or over-the-counter medications that may adversely react with alcohol, such as antihistamines, cough syrup, ibuprofen (Advil), or certain herbal supplements.

15. ___ Yes ___ No I am NOT taking any recreational, illegal, or illicit drug of any type.

16. ___ Yes ___ No I have consumed no alcohol for at least the previous twelve (12) hours.

17. ___ Yes ___ No I understand that my participation is strictly voluntary and that I am free to refuse any and all alcoholic beverages, and that I am free to withdraw from the alcohol workshop at any time.

18. I do ___ / do not ___ have any weapons in my possession, including pocket knives.

19. ___ Yes ___ No I understand and agree that when I reach my final destination (e.g., residence) by a designated driver that the workshop is concluded and that Washington County Sheriff's Office and any other agency or individual associated with this project assumes no responsibility from that moment on.

VOLUNTEER CERTIFICATION

I certify that I have read this questionnaire in its entirety and that I have truthfully answered all questions contained in the document.

Date

Signature

Witness