TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FAA-AM-71-34		

4. Title and Subtitle	5. Report Date
ALCOHOL AND DISORIENTATION-RELATED RESPONSES. IV. EFFECTS OF DIFFERENT ALCOHOL DOSAGES AND DISPLAY ILLUMINATION ON TRACKING PERFORMANCE DURING VESTIBULAR STIMULATION.	July 1971
	6. Performing Organization Code
7. Author(s) Richard D. Gilson, Ph.D., David J. Schroeder, Ph.D., William E. Collins, Ph.D., and Frederick E. Guedry, Jr., Ph.D.	8. Performing Organization Report No.
9. Performing Organization Name and Address FAA Civil Aeromedical Institute P. O. Box 25082 Oklahoma City, Oklahoma 73125	10. Work Unit No. 11. Contract or Grant No.
12. Sponsoring Agency Name and Address Office of Aviation Medicine Federal Aviation Administration 800 Independence Avenue, S.W. Washington, D. C. 20590	13. Type of Report and Period Covered OAM Report 14. Sponsoring Agency Code

15. Supplementary Notes

This research was performed under Task No. AM-A-71-PSY-27.

16. Abstract

A previous CAMI laboratory investigation showed that alcohol impairs the ability of men to suppress vestibular nystagmus while visually fixating on a cockpit instrument, thus degrading visual tracking performance (eye-hand coordination) during angular acceleration. Reduced display illumination, independently, has also been shown to degrade tracking performance during vestibular stimulation. The present study investigated the way in which low and moderate dosages of alcohol and two levels of instrument-display illumination combined to affect tracking performance (a) in a static (no motion) environment, and (b) in a dynamic (whole-body motion) environment. Mean blood alcohol as low as .027 per cent significantly decreased ($p < .05$) tracking performance during whole-body motion, yet caused little change in performance in a stationary environment. Impairment was much more pronounced with dim display lighting (0.1 ft-L) than with bright lighting (1.0 ft-L). These results suggest that serious problems may be encountered by the pilot who drinks even lightly and who considers flying, especially at night.

17. Key Words		18. Distribution Statement
Alcohol	Angular Acceleration	Availability is unlimited. Document may be released to the National Technical Information Service, Springfield, Virginia 22151, for sale to the public.
Performance	Vestibular	
Nystagmus	Illumination Level	

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	12	$3.00

Form DOT F 1700.7 (8-69)

ALCOHOL AND DISORIENTATION-RELATED RESPONSES. IV. EFFECTS OF DIFFERENT ALCOHOL DOSAGES AND DISPLAY ILLUMINATION ON TRACKING PERFORMANCE DURING VESTIBULAR STIMULATION.

I. Introduction

Recently, effects of laboratory vestibular stimulation on the visibility of a cockpit instrument have been examined.[1 2 3] These effects have been of interest because eye movements induced by whole-body angular acceleration normally help to stabilize the position of the eye in relation to stationary objects, but they are inappropriate for viewing objects which are moving with the observer. In flight situations, the result can be blurring of vision in the cockpit and impairment of performance.

A pilot can usually suppress these eye movements by fixation on an instrument. Evidence has been presented, however, that this suppressive ability is impaired after alcohol consumption and that compensatory tracking performance is affected.[2] Thus, although visibility of cockpit instruments and tracking performance may not be measurably degraded by some amounts of alcohol in static environments (absence of vestibular stimulation), they may be seriously impaired during dynamic flight environments.

This problem may be even more severe at night since reduced display illumination recommended for night flying has been shown to increase the blurring and performance decrements that result from vestibular nystagmus.[3] Moreover, there is the possibility that even relatively low dosages of alcohol are effective in producing these undesired consequences in dynamic environments.

The present investigation was designed to study the way in which these two conditions, alcohol and low instrument illumination, combine to affect performance during vestibular stimulation.

II. Method

A. *Subjects.* Twenty-four male college students ranging in age from 21 to 30 years served as subjects. Each was a paid volunteer and none had had previous laboratory experience involving vestibular stimulation.

B. *Apparatus.* The rotational device, recording techniques, eye-movement calibration procedures, and the tracking task have been described in detail previously.[2] The subject was seated upright in a small cockpit-enclosure mounted on a Stille-Werner RS–3 rotator with his horizontal semicircular canals approximately in the plane of rotation. The angular velocity of the device followed a triangular waveform and alternately reached a peak velocity of 120 deg/sec in the clockwise and counterclockwise directions. A complete cycle required 48 seconds.

Lateral eye movements were recorded during vestibular stimulation by a conventional electro-oculographic technique. Mean values of the nystagmic beats and the amount of slow phase eye velocity were measured at two sample 5-second intervals for each trial and were chosen to include maximum nystagmus output in a single direction.

A compensatory visual-tracking task provided the measure of visual performance. A sinusoidal "forcing function" deflected the vertical needle of an aircraft localizer/glide-slope indicator

This study was conducted at the FAA's Civil Aeromedical Institute and was co-sponsored by the FAA, the Army (U.S. Army Medical Research and Development Command) and the Navy (USN Aerospace Medical Research Laboratory, Pensacola). Lt. Gilson is a Research Psychologist and Dr. Guedry is Head, Psychophysiology Division at USNAMRL; Dr. Schroeder is a Research Psychologist and Dr. Collins is Chief of the Psychology Laboratory at CAMI. The expert assistance of Carl Moore in obtaining the blood samples, and of Elizabeth Gilson, Carlyn Manley, Cynthia Cochran, and Blair Fennell in the collection and scoring of the data are gratefully acknowledged. Gas chromatographic analyses of the blood samples were performed under contract by Dr. Kurt Dubowski, University of Oklahoma Medical Center.

TABLE 1.—Means and standard deviations by session for slow phase nystagmus (deg/sec), frequency of nystagmus (beats/sec), and tracking error (arbitrary units).

Measure	Group	Cond.		0.1 ft. L Sessions				1.0 ft. L Sessions			
				Pre	1-Hour	2-Hour	4-Hour	Pre	1-Hour	2-Hour	4-Hour
Slow Phase Nystagmus	Cont.	Dyn.	Mean	6.32	4.84	3.59	3.21	7.06	5.19	3.39	3.59
			SD	2.87	2.06	1.68	1.11	3.24	2.31	1.38	2.07
Nystagmus Frequency	Cont.	Dyn.	Mean	2.38	2.14	1.71	1.52	2.52	2.15	1.59	1.70
			SD	0.56	0.80	0.63	0.25	0.56	0.54	0.62	0.57
Slow Phase Nystagmus	Low Alco.	Dyn.	Mean	7.00	8.12	6.81	3.65	5.36	7.54	4.66	3.18
			SD	4.92	4.87	4.55	2.04	3.06	3.73	3.07	1.66
Nystagmus Frequency	Low Alco.	Dyn.	Mean	2.01	2.60	2.09	1.35	1.9	2.56	1.64	1.28
			SD	1.07	1.20	0.96	0.73	0.99	0.99	0.99	0.71
Slow Phase Nystagmus	Mod. Alco.	Dyn	Mean	5.52	15.35	11.09	6.46	5.85	12.46	10.25	6.39
			SD	1.69	8.30	7.68	3.41	2.52	6.20	6.12	2.75
Nystagmus Frequency	Mod. Alco.	Dyn.	Mean	2.27	3.10	3.00	2.30	2.25	3.16	3.00	2.44
			SD	0.55	0.87	0.84	0.74	0.68	0.93	0.78	0.73
Tracking Error	Cont.	Stat.	Mean	4.57	4.38	4.22	3.77	4.23	4.01	3.59	3.76
			SD	1.24	1.07	0.51	0.81	1.05	1.17	0.58	0.84
	Cont.	Dyn.	Mean	6.90	5.66	4.91	5.18	5.93	4.86	4.62	4.63
			SD	1.68	1.57	1.52	1.41	1.83	1.31	1.03	1.19
Tracking Error	Low Alco.	Stat.	Mean	5.18	4.27	3.84	3.17	4.75	4.30	3.56	3.01
			SD	1.98	1.83	1.28	1.74	1.94	1.77	1.45	0.97
	Low Alco.	Dyn.	Mean	7.16	7.22	6.19	5.00	5.36	5.52	4.72	3.88
			SD	2.13	2.99	3.58	2.91	1.53	1.41	1.79	1.51
Tracking Error	Mod. Alco.	Stat.	Mean	5.39	5.02	4.60	3.81	5.06	4.93	4.48	3.67
			SD	1.60	1.04	0.70	0.65	1.73	1.55	1.02	0.58
	Mod. Alco.	Dyn.	Mean	6.66	10.99	8.27	6.23	6.12	7.89	6.01	4.85
			SD	1.27	2.66	2.24	1.27	1.32	2.17	1.53	0.99

while the subject attempted to maintain the needle in the null position by manipulation of a control stick. Deviations of the needle were considered as errors and these were integrated over consecutive 1-second intervals. The values were then summed and an average value was obtained for each trial.

Light was projected through a tube to localize on the display and to minimize reflection in the otherwise darkened room. Voltage across the 3vDC light source was adjusted for a luminance of 1.0 ft-L (in a calibration procedure using a MacBeth illuminometer). A second illumination level of 0.1 ft-L was also used; this was produced by placing a 1.0 neutral density filter in front of the projected light source. Both levels of illumination are within a range recommended for aircraft instruments.[4]

C. *Procedure.* Prior to being tested, each subject was given five minutes of tracking practice with the rotational device stationary. He then underwent an experimental sequence consisting of four tracking sessions: a pre-drinking session and post-drinking sessions at 1, 2, and 4 hours after a 30-minute drinking period had been completed.

Each session consisted of 2.5 minutes of "static" tracking with the rotational device stationary, and 2.5 minutes of "dynamic" tracking with the device rotating. This was carried out with the two display illumination levels, one trial at 1.0 ft-L and one trial at the 0.1 ft-L level. The order of presentation of these conditions (static or dynamic tracking and a bright or dim display illumination) was counterbalanced across subjects, and at least a 1-minute interval was allowed between tracking periods. Before each testing session, a venous blood sample was drawn from those subjects receiving alcohol for analysis of blood alcohol by gas chromatography; only one blood sample was taken from each control subject. Eye-movement calibrations were obtained for each session.

Three groups were used, each composed of eight subjects. Those in two groups received a mixture of 100-proof Smirnoff vodka and orange juice. Subjects in the "low alcohol" group received one ml of vodka per kilogram of body weight and those in the "moderate alcohol" group received two ml of vodka per kilogram of body weight. Subjects in the control group were given orange juice without vodka but with a few drops of rum extract added to impart an alcoholic taste. Subjects were separated by groups and were not informed concerning the amounts of alcohol they had received.

III. Results

The mean blood alcohol level for the moderate alcohol group was .077 per cent, slightly more than double the .027 per cent level for the low alcohol group at the one-hour testing session. After two hours, these blood alcohol levels were reduced to .076 per cent and .018 per cent, respectively; after four hours they were further reduced to .041 per cent and .000 per cent, respectively (see Appendix A).

Means and standard deviations for the slow phase and frequency measures of nystagmus during dynamic trials and for tracking error during both static and dynamic trials are presented in Table 1 for both conditions of display illumination. Figure 1 represents the measured samples of nystagmus as mean values of slow phase velocity in deg/sec and frequency in beats/sec plotted for the two levels of illumination and separated by group. Both measures show essentially the same results: that nystagmus in light is disinhibited after consumption of alcohol. Subjects in both alcohol groups show a sizeable first-hour increase in the nystagmus measures from the pre-drinking level, whereas those in the control group show a decrease in nystagmus with repeated trials. The reduction of one log unit in display illumination was relatively ineffective in changing nystagmus, although the 0.1 ft-L level is associated with somewhat greater nystagmus. Samples of tracings appear in Figure 2. (Nystagmus and performance scores for individual subjects appear in Appendix B-G.)

The tracking results are shown in Figure 3 as the percentage increase or decrease in tracking error for the three post-drinking tests with respect to the pre-drinking error level. These are plotted for the three groups and the four testing conditions: tracking with or without vestibular stimulation (dynamic or static) and with a display illumination of either 0.1 or 1.0 ft-L (dim or bright). Results of statistical comparisons are in Tables 2 and 3.

Tracking errors increased over the pre-drinking level only for the alcohol groups during dynamic tracking. Although this effect is more striking for those in the moderate alcohol group, it is apparent that those in the low alcohol group also exhibited the effect. (The difference between the low alcohol and the control group is significant at the .05 level for the first post-drinking test. See Table 3.)

Also apparent is that the dim display illumination greatly increased the error rate during dynamic tracking. For the decrease of one log unit in luminance, the error rate increase was approximately doubled (see Figure 3).

During static tracking, however, the alcohol groups did no worse than the controls; during most of the static testing they decreased their errors somewhat more quickly. This again was more apparent under dim illumination than bright.

IV. Discussion

The results show clearly, despite what appears to be for the control group a persistent practice effect, that alcohol ingestion significantly decreased performance during vestibular stimulation yet caused little change in static tracking performance.

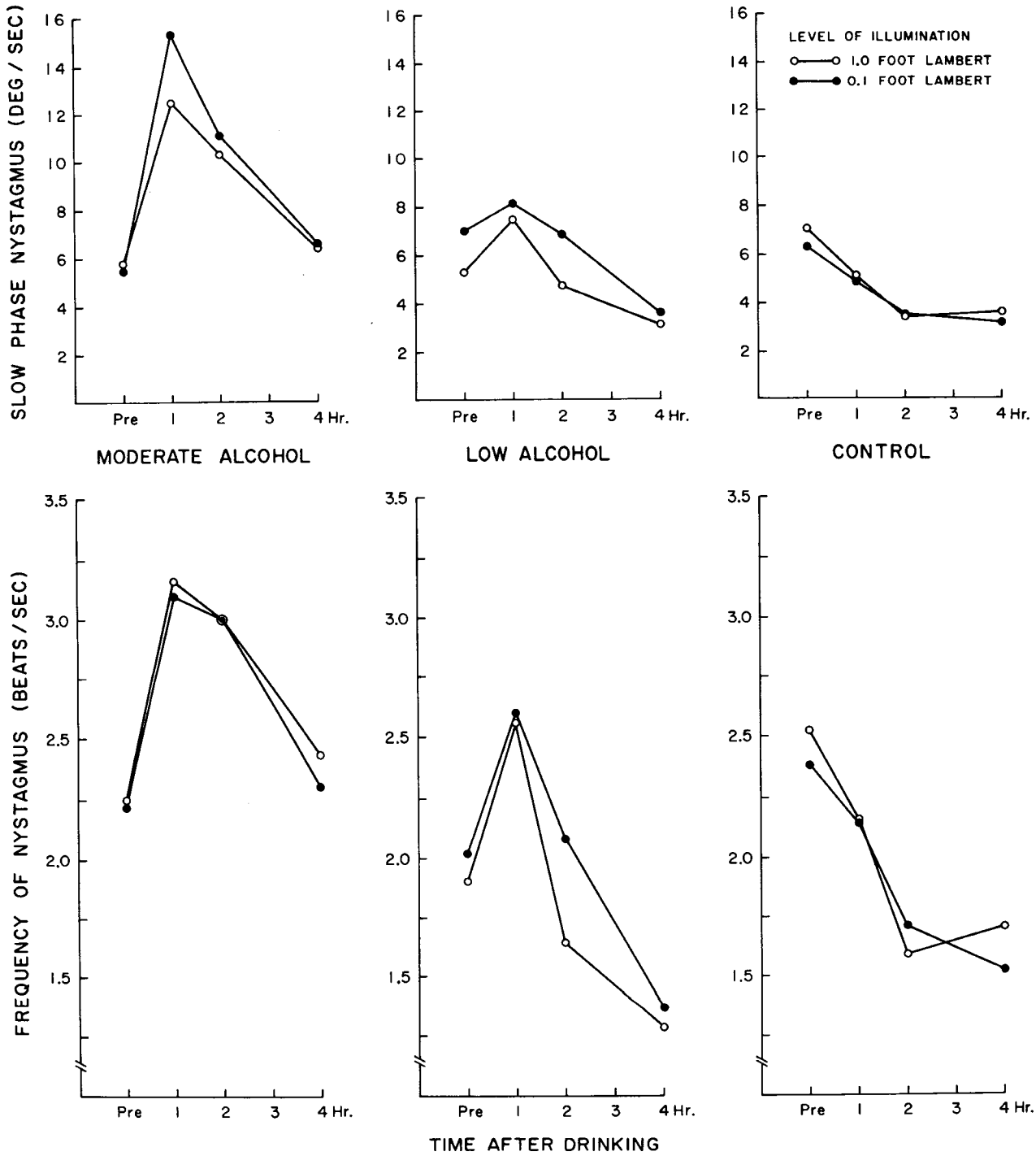

FIGURE 1. Frequency and slow phase velocity of nystagmus during angular acceleration for the control and alcohol groups.

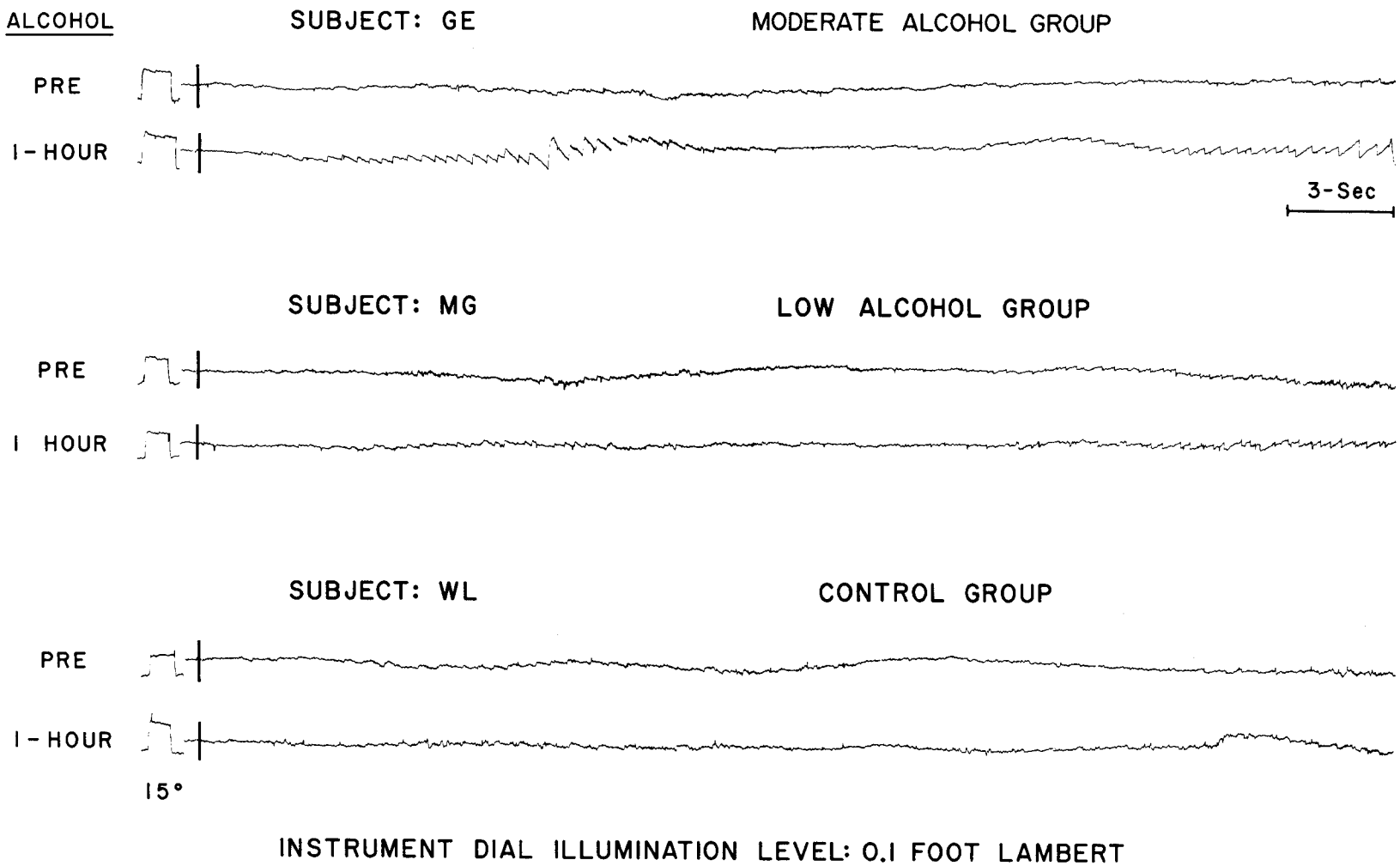

FIGURE 2. Tracings of nystagmus from a subject in each of the three groups. Vertical bars through the tracings indicate the start of an acceleration cycle; a 15° eye-movement calibration precedes each strip of tracing. Note the lack of change from the Pre to the 1-hour session for the Control subject, and the successively greater Pre-to-1-hour session increases in nystagmus for the Low Alcohol and the Moderate Alcohol subjects.

TABLE 2.—Results of t tests between pre-alcohol and each post-alcohol measure of the slow phase displacement and the frequency of nystagmus resulting from angular accelerations and of tracking error under static and dynamic conditions

Level of Illumination	Group	Nystagmus Comparisons: Pre vs. (Slow Phase) 1-Hour	2-Hour	4-Hour	(Frequency) 1-Hour	2-Hour	4-Hour
0.1 ft. L	Moderate	−3.86**	−2.56*	−1.36	−3.73**	−3.81**	−0.55
	Low	−1.27	0.11	2.33	−2.56*	−0.35	3.01*
	Control	2.33	4.33**	4.34**	1.06	3.90**	5.03**
1.0 ft. L	Moderate	4.06**	−3.08*	−1.12	−4.70**	−4.09**	−1.34
	Low	−3.43*	1.32	3.32*	−3.33*	1.25	2.36*
	Control	3.10*	4.51**	3.55**	4.07**	5.32**	4.51**
		Tracking Error Comparisons: Pre vs. (Static)			(Dynamic)		
0.1 ft. L	Moderate	1.06	1.76	3.56**	−5.23**	−2.10	1.11
	Low	2.37*	3.16*	3.64**	−0.12	0.99	2.91*
	Control	0.70	1.01	3.28*	3.94**	7.31***	4.07**
1.0 ft. L	Moderate	0.38	0.93	2.63*	−2.94*	0.18	3.43*
	Low	1.48	3.99**	3.67**	−0.44	1.62	4.17**
	Control	0.95	2.25	1.57	3.68**	2.38	1.92

* $p < .05$ ** $p < .01$ *** $p < .001$

TABLE 3.—Results of t tests comparing Control, Moderate Alcohol, and Low Alcohol subjects on measures of nystagmus and tracking error. Comparisons were made between difference scores for each session (i.e., the difference in scores of each post-ingestion session from those of the pre-ingestion session).

Level of Illumination	Comparison	Slow Phase 1-Hour	2-Hour	4-Hour	Frequency 1-Hour	2-Hour	4-Hour
0.1 ft. L	C vs L	−2.39*	−1.40	0.15	−2.57*	−2.68*	−0.37
	C vs M	−4.31***	−3.67**	−4.07***	−3.43**	−5.42***	−4.25***
	M vs L	3.23**	2.08	2.68*	0.88	2.35*	2.84*
1.0 ft. L	C vs L	−4.62***	−3.06**	−1.09	−4.73***	2.46*	−0.62
	C vs M	−4.88***	−4.91***	−3.68**	−5.99***	−6.64***	−4.40***
	M vs L	2.54*	3.35**	3.34**	0.90	3.62**	2.71*
		Static Tracking Error			Dynamic Tracking Error		
0.1 ft. L	C vs L	1.54	1.83	2.02	−2.31*	−1.02	0.50
	C vs M	0.42	0.78	1.55	−6.29***	−4.42***	−2.25*
	M vs L	1.03	0.90	0.61	4.51***	2.08	2.06
1.0 ft. L	C vs L	0.57	1.32	2.26*	−2.67*	−0.99	0.23
	C vs M	−0.19	−0.08	1.51	−4.27***	−1.40	−0.03
	M vs L	0.66	2.26*	0.48	2.31*	0.69	0.38

* $p < .05$ ** $p < .01$ *** $p < .001$

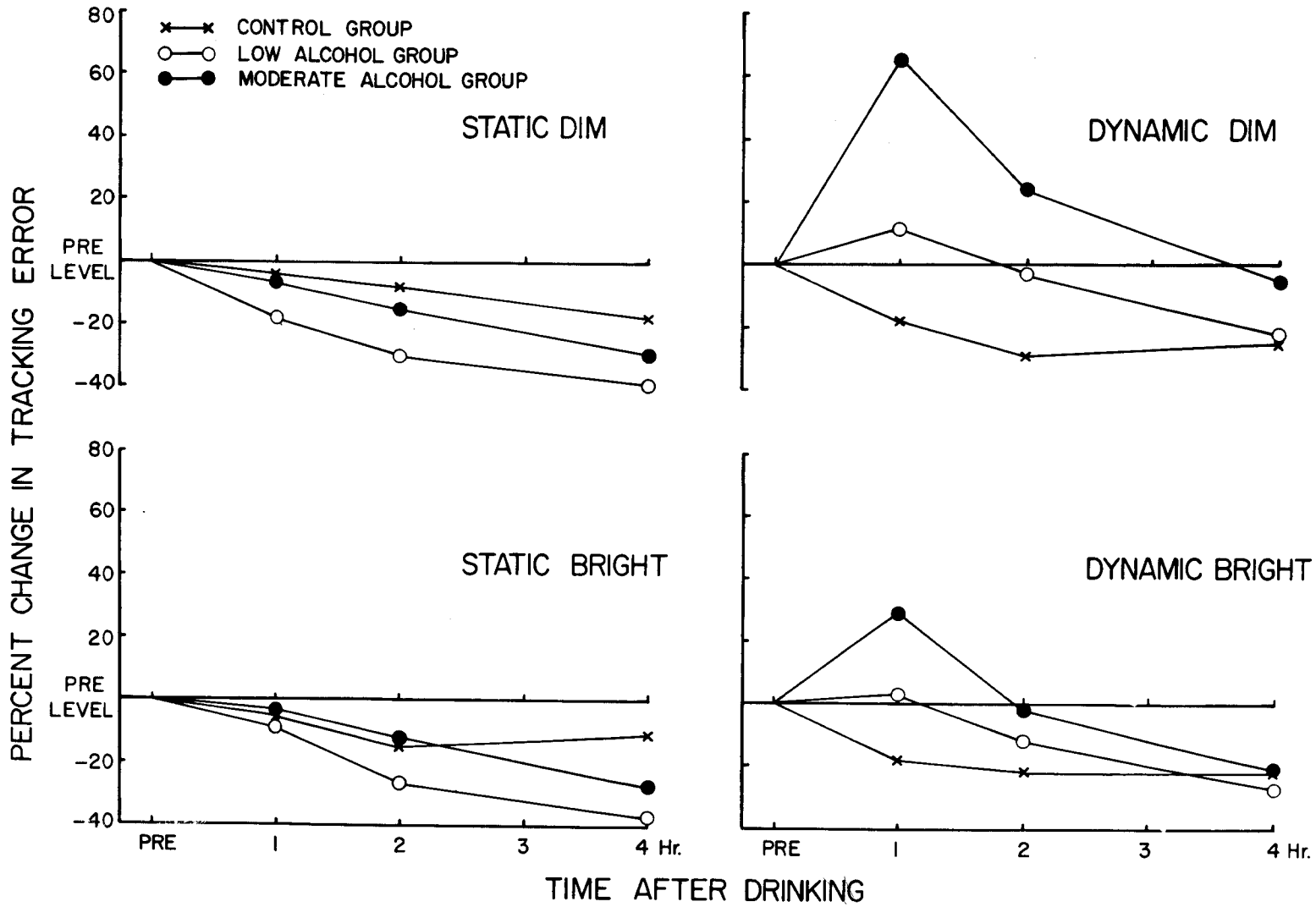

FIGURE 3. Changes in tracking performance for the control and alcohol groups under dim and bright illumination of the task instrument in static and dynamic (angular acceleration) conditions. The "Pre Level" (0) line represents the base level of tracking error during the pre-drinking trials. Tracking error scores for the four post-drinking sessions were converted to percentages of increase or decrease from the base level.

A. *Static Tracking.* During static tracking, vestibular nystagmus was not present, and therefore there was no visual blurring or performance impairment from this source. The slightly faster improvement in static tracking performance across sessions by those given the low alcohol dose over the control group may have occurred because of awareness on the part of these subjects that they had actually received alcohol and a concomitant increase in their motivation to "prove they could do it." However, the only point at which there was any significant difference between the control and low alcohol groups in static tracking was during the 4-hour post-drinking session when there were no longer measurable quantities of alcohol present in the blood samples of the low alcohol subjects; as such, the static tracking differences may more closely reflect differences in eye-hand coordination abilities among the groups.

B. *Dynamic Tracking.* These results confirm those reported in a previous study,[2] which showed that the vestibular nystagmus evoked during dynamic tracking was not suppressed as well by subjects under the influence of moderate alcohol dosages. Thus, blurring of vision and the impairment of performance ensued. The present study indicates that these same effects are significant for average blood alcohol levels as low as .027 per cent. It should be noted that these latter alcohol levels were achieved with alcohol dosages equivalent to less than two social drinks for the average-sized man.

C. *Display Illumination.* The effects of vestibular stimulation on tracking were much more pronounced during the dim display illumination. Increased blurring and performance degradation with reduced illumination during dynamic tracking has previously been reported[3] and the absence of a commensurate change in nystagmus was cited as evidence of a visual phenomenon. This phenomenon was magnified in the present study by the unsuppressed nystagmus due to alcohol. The combination of the dim illumination, vestibular stimulation, and the influence of alcohol produced the poorest tracking performance, whereas the control group, with greatly suppressed nystagmus, was not affected significantly by the illumination change at these relatively low angular velocities.

D. *Implications.* The dramatic impairment in tracking performance only in the dynamic environment shows the insidious nature of this effect. A pilot who drinks lightly may be able to convince himself on the ground that his abilities are unimpaired and thus may feel safe to enter the cockpit. Results of this study suggest, however, that he is entering a potentially dangerous situation. If, while flying, particularly at night with dim display illumination, that pilot encounters vestibular stimulation as a result of maneuvers, turbulence, or some inner ear dysfunction, he may experience blurring of vision. The visual control of his eye movements will have been reduced by the alcohol and vestibular control is free to take over driving the eyes relative to the instruments. This increases the likelihood that he will misread the instruments and react incorrectly, causing more severe maneuvering and what may be the beginning of an irreversible, vicious circle.

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APPENDIX A—Blood alcohol levels in percent determined by gas chromatography for Alcohol and Control subjects.

Control Group		Low Alcohol					Moderate Alcohol				
			Session					Session			
Subj.	Pre	Subj.	Pre	1-Hr.	2-Hr.	4-Hr.	Subj.	Pre	1-Hr.	2-Hr.	4-Hr.
JJ	0	MG	0	.032	.024	0	BT	0	.068	.068	.037
TL	0	BB	0	.028	.014	0	GE	0	.078	.086	.068
JB1	0	RK	0	.012	.007	0	FS	0	.081	.082	.046
CH	0	LS	0	.031	.023	0	VH	0	.084	.067	.036
PS	0	FE	0	.011	.012	0	LJ	0	.109	.102	.041
DM	0	RF	0	.031	.016	0	BS	0	.071	.074	.032
WL	0	CD	0	.043	.028	0	FG	0	.053	.056	.029
JBt	0	PD	0	.028	.017	0	JM	0	.071	.071	.035
Mean	0	Mean	0	.027	.018	0	Mean	0	.077	.076	.041
SD	0	SD	0	.011	.007	0	SD	0	.016	.014	.012

APPENDIX B.—Control Group: Nystagmus measures from the angular accelerations based on two 5-sec samples from each session for each subject.

Level of Illumination	Subject	Slow Phase Nystagmus (deg/sec)				Frequency (beats/sec)			
		Pre	1-Hour	2-Hour	4-Hour	Pre	1-Hour	2-Hour	4-Hour
	JJ	2.9	3.0	2.5	2.0	1.9	1.8	1.4	1.3
	TL	6.6	4.7	3.5	3.6	2.3	2.3	1.8	1.8
	JB1	6.7	8.1	4.6	3.4	2.6	3.1	2.7	1.6
	CH	7.7	4.5	4.2	4.4	2.9	1.3	1.5	1.7
0.1 ft. L	PS	10.7	7.0	4.2	3.5	3.2	3.4	2.0	1.4
	DM	4.7	3.1	2.5	2.6	2.3	1.7	1.8	1.5
	WL	8.9	6.0	6.4	4.7	2.4	2.3	2.0	1.8
	JBt	2.4	2.3	0.8	1.5	1.4	1.2	0.5	1.1
	Mean	6.32	4.84	3.59	3.21	2.38	2.14	1.71	1.52
	SD	2.87	2.06	1.68	1.11	0.56	0.80	0.63	0.25
	JJ	4.7	2.8	2.9	1.7	2.0	1.5	1.4	1.0
	TL	5.3	5.1	3.2	2.6	2.6	1.9	2.1	1.9
	JB1	8.5	6.0	4.1	3.6	3.0	2.8	1.9	2.1
	CH	8.6	8.5	3.1	3.8	2.0	2.1	1.0	1.3
1.0 ft. L	PS	13.0	7.9	5.1	4.0	3.6	3.0	2.1	1.8
	DM	3.8	3.3	3.1	3.5	2.4	2.2	2.3	2.2
	WL	8.9	5.7	4.9	8.1	2.6	2.2	1.4	2.4
	JBt	3.7	2.2	0.7	1.4	2.0	1.5	0.5	0.9
	Mean	7.06	5.19	3.39	3.59	2.52	2.15	1.59	1.70
	SD	3.24	2.31	1.38	2.07	0.56	0.54	0.62	0.57

APPENDIX C.—Low Alcohol Group: Nystagmus measures from the angular accelerations based on two 5-sec samples from each session for each subject.

Level of Illumination	Subject	Slow Phase Nystagmus (deg/sec)				Frequency (beats/sec)			
		Pre	1-Hour	2-Hour	4-Hour	Pre	1-Hour	2-Hour	4-Hour
0.1 ft. L	MG	15.3	18.7	14.6	7.7	3.9	4.7	3.8	2.4
	BB	13.8	11.1	5.6	2.6	2.8	3.2	1.8	1.1
	RK	3.8	4.1	13.1	3.2	0.9	1.1	1.9	0.7
	LS	6.6	5.8	3.9	2.4	1.7	1.8	1.7	0.9
	FE	3.0	4.0	2.9	3.4	1.2	1.3	0.8	1.2
	RF	5.6	8.5	6.4	4.7	2.5	3.4	3.0	2.1
	CD	2.0	7.0	2.7	0.8	0.8	2.8	1.3	0.4
	PD	5.9	5.8	5.3	4.4	2.3	2.5	2.4	2.0
	Mean	7.00	8.12	6.81	3.65	2.01	2.60	2.09	1.35
	SD	4.92	4.87	4.55	2.04	1.07	1.20	0.96	0.73
1.0 ft. L	MG	11.1	16.3	11.7	6.6	3.3	4.5	3.5	2.2
	BB	6.7	6.8	5.8	2.8	1.9	1.9	1.7	0.8
	RK	4.2	7.0	2.7	3.0	1.3	2.3	0.6	0.9
	LS	6.3	5.9	3.0	2.8	2.8	2.4	1.3	1.0
	FE	2.2	5.3	3.0	0.6	1.0	1.8	0.9	0.3
	RF	5.5	7.0	4.4	3.6	2.2	3.0	2.0	1.7
	CD	1.1	4.1	2.3	2.5	0.3	1.4	0.7	1.0
	PD	5.8	7.9	4.4	3.5	2.4	3.2	2.4	2.3
	Mean	5.36	7.54	4.66	31.8	1.9	2.56	1.64	1.28
	SD	3.06	3.73	3.07	1.66	0.99	0.99	0.99	0.71

APPENDIX D.—Moderate Alcohol Group: Nystagmus measures from the angular accelerations based on two 5-sec samples from each session for each subject.

Level of Illumination	Subject	Slow Phase Nystagmus (deg/sec)				Frequency (beats/sec)			
		Pre	1-Hour	2-Hour	4-Hour	Pre	1-Hour	2-Hour	4-Hour
0.1 ft. L	BT	3.8	7.9	6.3	2.5	1.7	2.9	2.6	2.0
	GE	4.3	19.8	8.7	6.3	2.0	2.4	2.6	2.5
	FS	7.1	18.8	19.0	8.4	2.2	3.7	4.0	2.5
	VH	5.0	19.3	8.3	6.4	2.7	3.7	3.4	3.0
	LJ	4.4	11.2	7.4	4.8	1.7	3.4	2.6	1.5
	BS	5.5	7.0	7.4	5.5	1.9	2.0	2.3	1.6
	FG	5.2	8.0	4.8	4.1	2.3	2.2	2.1	1.7
	JM	8.9	30.8	26.8	13.7	3.3	4.5	4.4	3.6
	Mean	5.52	15.35	11.09	6.46	2.27	3.10	3.00	2.30
	SD	1.69	8.30	7.68	3.41	0.55	0.87	0.84	0.74
1.0 ft. L	BT	3.7	7.0	7.9	3.4	1.5	2.4	2.7	1.8
	GE	4.4				2.6	3.1	3.0	3.1
	FS	7.0	14.3	13.4	7.6	2.3	4.3	3.8	2.8
	VH	4.6	11.4	7.4	3.6	1.8	2.8	3.0	2.4
	LJ	5.5	7.8	5.7	6.2	2.3	3.4	3.1	2.4
	BS	4.9	11.1	8.0	6.3	1.9	2.6	2.2	2.1
	FG	5.1	5.9	4.7	4.5	1.9	2.0	1.9	1.3
	JM	11.6	24.2	23.7	11.8	3.7	4.7	4.3	3.6
	Mean	5.85	12.46	10.25	6.39	2.25	3.16	3.000	2.44
	SD	2.52	6.20	6.12	2.75	0.68	0.93	0.78	0.73

APPENDIX E.—Control group: Dynamic and Static tracking error in arbitrary units under bright and dim illumination conditions.

Level of Illumination	Subject	Static				Dynamic			
		Pre	1-Hour	2-Hour	4-Hour	Pre	1-Hour	2-Hour	4-Hour
0.1 ft. L	JJ	4.98	4.05	3.80	3.22	6.96	4.67	3.86	4.25
	TL	5.35	4.64	4.09	4.65	7.16	5.68	5.76	5.13
	JB1	6.65	5.43	4.97	4.88	8.73	6.85	6.27	7.32
	CH	3.92	4.82	3.99	3.59	6.90	5.92	4.46	7.01
	PS	5.42	6.12	5.05	4.39	9.28	8.87	7.70	5.62
	DM	2.84	3.11	4.04	2.64	4.70	4.51	3.37	3.44
	WL	3.75	3.57	4.17	3.83	7.01	4.64	4.31	4.71
	JBt	3.64	3.29	3.66	2.98	4.50	4.18	3.54	3.92
	Mean	4.57	4.38	4.22	3.77	6.90	5.66	4.91	5.18
	SD	1.24	1.07	0.51	0.81	1.68	1.57	1.52	1.41
1.0 ft. L	JJ	3.98	3.01	3.17	3.12	5.01	4.00	3.68	3.78
	TL	5.40	5.55	3.79	5.01	8.90	6.36	5.53	4.56
	JB1	4.70	4.65	3.91	3.72	7.78	6.75	4.97	5.65
	CH	4.34	4.76	4.62	4.28	4.60	4.64	6.24	6.50
	PS	5.72	4.54	3.83	3.59	7.39	5.97	5.33	4.56
	DM	2.94	2.12	2.76	2.77	4.61	3.38	3.60	3.20
	WL	4.01	4.50	3.55	4.71	5.29	3.94	4.10	5.53
	JBt	2.76	2.94	3.08	2.86	3.84	3.82	3.53	3.27
	Mean	4.23	4.01	3.59	3.76	5.93	4.86	4.62	4.63
	SD	1.05	1.17	0.58	0.84	1.83	1.31	1.03	1.19

APPENDIX F.—Low Alcohol group: Dynamic and Static tracking error in arbitrary units under bright and dim illumination conditions.

Level of Illumination	Subject	Static				Dynamic			
		Pre	1-Hour	2-Hour	4-Hour	Pre	1-Hour	2-Hour	4-Hour
0.1 ft. L	MG	8.68	6.60	5.54	4.43	11.28	12.06	9.34	7.90
	BB	5.45	3.23	2.50	2.21	7.46*	6.57	3.23	3.21
	RK	6.95	7.58	5.31	6.98	8.40	11.42	13.65	10.97
	LS	5.70	4.31	5.15	2.67	8.07	7.67	5.93	4.84
	FE	4.80	3.68	3.64	2.41	5.63	5.11	4.60	3.15
	RF	4.05	2.60	2.76	1.65	5.99	5.04	3.97	3.22
	CD	2.69	2.93	2.93	2.55	4.44	4.22	3.49	3.25
	PD	3.15	3.23	2.86	2.44	6.00	5.63	5.33	3.43
	Mean	5.18	4.27	3.84	3.17	7.16	7.22	6.19	5.00
	SD	1.98	1.83	1.28	1.74	2.13	2.99	3.58	2.91
1.0 ft. L	MG	7.72	7.03	5.58	3.21	7.01	8.20	7.84	5.61
	BB	2.95	2.72	1.82	2.27	4.48	4.48	3.31	2.46
	RK	7.10	6.67	5.80	5.09	7.50	6.27	7.10	6.49
	LS	4.74	5.20	3.94*	3.34	5.71	6.66	4.75*	4.47
	FE	3.71	3.38	3.14	2.25	4.67	5.04	4.44	2.31
	RF	3.30	3.41	2.54	2.23	3.86	4.50	3.11	3.17
	CD	2.64	2.53	2.51	2.43	3.25	4.07	3.66	3.30
	PD	5.87	3.45	3.19	3.27	6.39	4.90	3.58	3.27
	Mean	4.75	4.30	3.56	3.01	5.36	5.52	4.72	3.88
	SD	1.94	1.77	1.45	0.97	1.53	1.41	1.79	1.51

*Approximate score due to recording problem.

APPENDIX G.—Moderate Alcohol group: Dynamic and static tracking error in arbitrary units under bright and dim illumination conditions.

Level of Illumination	Subject	Static				Dynamic			
		Pre	1-Hour	2-Hour	4-Hour	Pre	1-Hour	2-Hour	4-Hour
0.1 ft. L	BT	4.35	4.35	4.17	3.12	4.99	8.92	6.45	4.71
	GE	5.52	3.97	4.78	3.82	7.44	14.17	10.29	7.12
	FS	3.65	3.85	3.80	3.14	4.46	8.91	8.45	4.49
	VH	6.63	6.53	5.24	4.73	7.23	12.48	8.95	6.59
	LJ	8.11	6.51	4.99	3.79	7.83	11.18	8.25	5.90
	BS	6.26	5.01	4.37	4.43	7.52	7.13	6.36	5.56
	FG	3.40	4.66	3.76	3.10	6.39	10.51	5.31	7.71
	JM	5.21	5.24	5.72	4.33	7.43	14.64	12.12	7.76
	Mean	5.39	5.02	4.60	3.81	6.66	10.99	8.27	6.23
	SD	1.60	1.04	0.70	0.65	1.27	2.66	2.24	1.27
1.0 ft. L	BT	3.51	3.19	4.15	3.14	4.29	5.72	6.57	3.61
	GE	2.58	3.90	3.88	3.15	4.42	7.97	6.87	5.43
	FS	4.18	3.90	3.38	3.00	6.15	7.01	4.86	3.63
	VH	5.40	6.62	6.39	3.83	8.33	11.73	8.84	6.57
	LJ	8.01	7.43	3.99	3.53	6.80	9.23	5.37	5.05
	BS	4.53	4.20	4.50	3.90	5.89	6.26	4.85	4.28
	FG	6.01	4.10	3.90	4.70	6.77	5.58	4.05	5.25
	JM	6.30	6.07	5.64	4.09	6.34	9.63	6.67	4.96
	Mean	5.06	4.93	4.48	3.67	6.12	7.89	6.01	4.85
	SD	1.73	1.55	1.02	0.58	1.32	2.17	1.53	0.99