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TRACKING PERFORMANCE DURING VESTIBULAR STIMULATION**

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NAVAL AEROSPACE MEDICAL RESEARCH LABORATORY

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SUMMARY PAGE

THE PROBLEM

A previous investigation showed that alcohol impairs the ability to suppress vestibular nystagmus, thus degrading visual compensatory tracking performance 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.

FINDINGS

Mean blood-alcohol levels as low as 0.027 per cent significantly ($p < .05$) decreased 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 even by the pilot who drinks lightly and who considers flying, especially at night.

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Findings in this report are not to be construed as official Departments of the Army and Navy positions, unless so designated by other authorized documents.

INTRODUCTION

Recently, effects of laboratory vestibular stimulation on the visibility of a cockpit instrument have been examined (1-3). 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 that 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 fixating 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). Thus, 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.

PROCEDURE

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.

Three groups were used, each composed of eight subjects. Those in two groups received a mixture of 100-proof vodka and orange juice. Subjects in the "low alcohol" group received 1 ml of vodka per kilogram of body weight and those in the "moderate alcohol" group received 2 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.

APPARATUS

The rotational device, recording techniques, eye-movement calibration procedures, and the compensatory tracking task have been described in detail previously (2).

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

The instrument was illuminated by projecting light through a tube to localize on the display. This served to minimize reflection in the otherwise darkened room. Voltage across the 3-V dc light source was adjusted for a luminance of 1.0 ft-L as measured with 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).

METHOD

Prior to being tested, each subject was given 5 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 0.1 ft-L. 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. Eye-movement calibrations were obtained for each session.

RESULTS

The mean blood-alcohol level for the moderate alcohol group was 0.077 per cent,

somewhat more than double the 0.027 per cent level for the low alcohol group at the 1-hour testing session. After 2 hours, these blood-alcohol levels were reduced to 0.076 per cent and 0.018 per cent, respectively; after 4 hours they were further reduced to 0.041 per cent and 0.000 per cent, respectively.

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 I for both conditions of display illumination. Figure 1 represents the measured samples of nystagmus as mean values of slow phase velocity, in degrees per second, and frequency in beats per second plotted for the two levels of illumination and separated by group. Both measures showed essentially the same results: that nystagmus in light was greater after consumption of alcohol. Subjects in both alcohol groups showed a sizeable first-hour increase in the nystagmus measures from the pre-drinking level, whereas those in the control group showed a decrease in nystagmus with repeated trials. The 1-log unit reduction in display illumination was relatively ineffective in changing nystagmus, although the 0.1 ft-L level was associated with somewhat greater nystagmus. Statistical evaluations are in Table II.

The tracking results are shown in Figure 2 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 ft-L or 1.0 ft-L (dim or bright).

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

Also apparent was the fact that the dim display illumination greatly increased the error rate during dynamic tracking. For the 1-log unit decrease in luminance, the error rate increase was approximately doubled (see Figure 2).

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

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.

STATIC TRACKING

During static tracking vestibular nystagmus is not present, and therefore, no blurring or performance impairment can occur from this source. There was a slightly faster improvement in static tracking performance across sessions by those given the low alcohol dose over the control group. 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.

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 dosages of alcohol. 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 0.027 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.

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.

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, the pilot encounters vestibular stimulation as a result of maneuvers, turbulence, or some inner-ear dysfunction, he may experience some blurring of vision. The visual control of his eye movements has 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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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	1.90	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	5.00	4.44	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

Table II

Results of t Tests Between Pre-Drinking and Each Post-Drinking Measure of the Slow Phase Displacement
and the Frequency of Nystagmus

Level of Illumination	Group	Nystagmus Comparisons: Pre vs.					
		(Slow Phase)			(Frequency)		
		1-Hour	2-Hour	4-Hour	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**

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

Table III

Results of t Tests for Within-Group and Between-Group Comparisons of Tracking Error[#]

Level of Illumination	Group	Within-Group Comparisons: Pre vs. (Dynamic)					
		(Static)					
		1-Hour	2-Hour	4-Hour	1-Hour	2-Hour	4-Hour
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
Comparison	Between-Group Comparisons						
	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

[#] Within-group analysis was based on the difference in error scores between pre-drinking and each post-drinking session. Between-group analysis was made by comparing control, low alcohol, and moderate alcohol subjects with pre/post difference scores.

* $p < .05$

** $p < .01$

*** $p < .001$

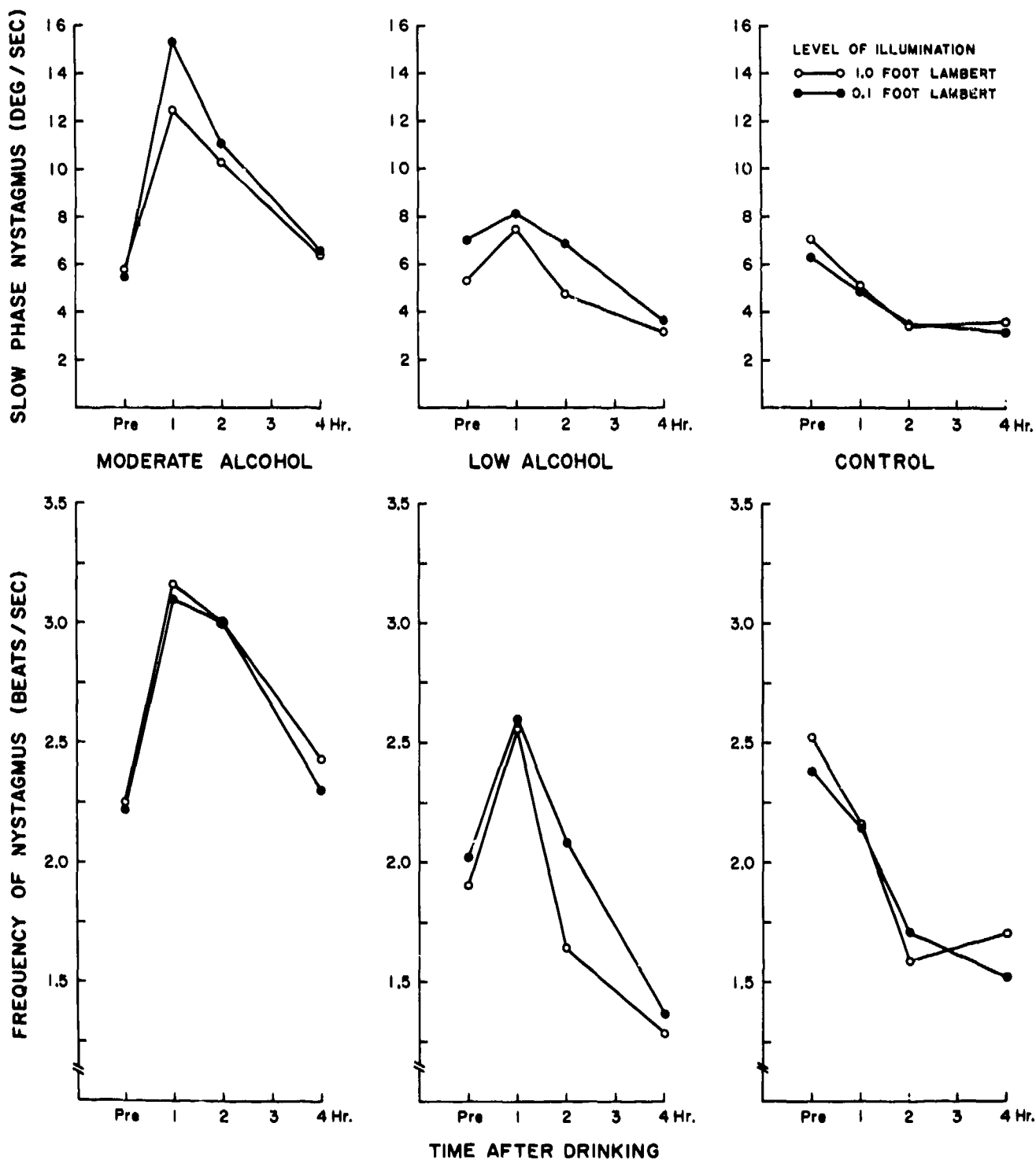


Figure 1

Nystagmus frequency and slow phase velocity during dynamic tracking. Data points are shown as mean values for eight subjects based on two sample 5-second intervals for each trial.

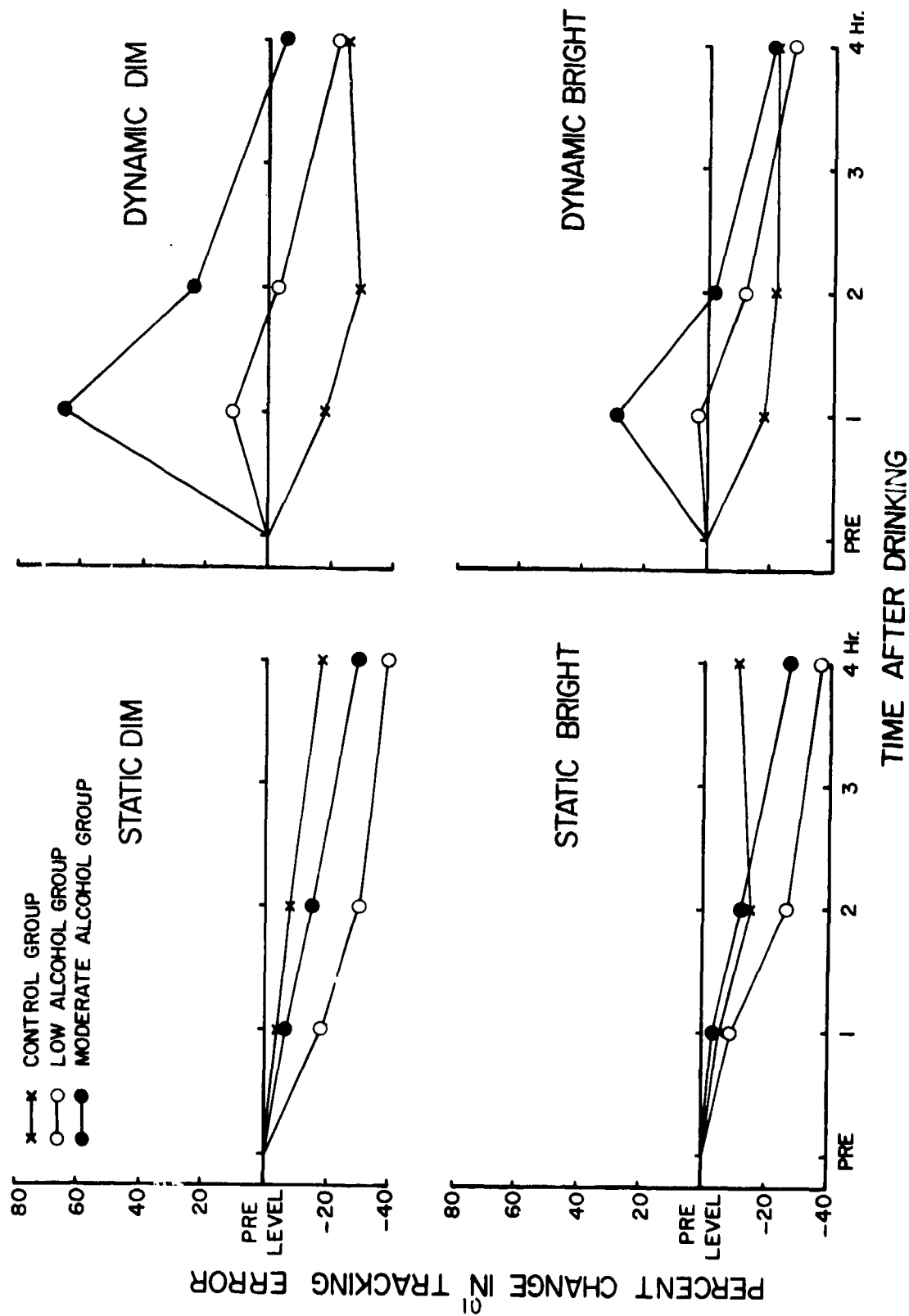


Figure 2

Per cent change in compensatory tracking error from the pre-drinking level. Display illumination levels were 0.1 ft-L and 1.0 ft-L.

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