TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FAA-AM-71-6		

4. Title and Subtitle	5. Report Date
ALCOHOL AND DISORIENTATION-RELATED RESPONSES. I. NYSTAGMUS AND "VERTIGO" DURING CALORIC AND OPTO-KINETIC STIMULATION	February 1971
	6. Performing Organization Code
7. Author(s) David J. Schroeder, 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

The study was conducted under Tasks AM-B-69-Psy-10, AM-A-70-PSY-10, and AM-A-71-PSY-27.

16. Abstract

Although the sensory systems (vestibular and visual) most involved in disorientation and "pilot's vertigo" would appear to be affected by the ingestion of alcohol, the locus and nature of the effect are not established. For example, there are apparently conflicting data concerning the effects of alcohol on vestibular responses to caloric irrigations. While some authors report that alcohol enhances vestibular responses, others indicate response suppression.

This study was designed to investigate the effects of two levels of alcohol on the "vertigo" and nystagmic responses resulting from caloric irrigations with visual conditions and the alertness of the subjects carefully controlled. Additional information concerning the effects of alcohol on optokinetic nystagmus was also obtained.

The data clearly indicate that alcohol suppresses the nystagmic response to calorizations in total darkness. However, under conditions where visual fixation is permitted and where visual fixation would normally inhibit caloric vestibular responses, the ingestion of alcohol results in a high-frequency, low-amplitude nystagmus. This response, however, is not due to increased vestibular sensitivity, but rather to the suppression, by alcohol (directly or indirectly), of the visual fixation system. This visual inhibition was also evident in the suppression of the optokinetic response by alcohol. "Vertigo" responses to caloric irrigations showed only slight suppression or some enhancement in darkness following alcohol ingestion; however, blurring of vision was prominent when visual fixation was permitted.

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

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	29	$3.00

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ALCOHOL AND DISORIENTATION-RELATED RESPONSES. I. NYSTAGMUS AND "VERTIGO" DURING CALORIC AND OPTOKINETIC STIMULATION

I. Introduction.

Although the sensory systems (vestibular and visual) most involved in disorientation and "pilot's vertigo" would appear to be affected by the ingestion of alcohol, the locus and nature of the effect are not established. For example, there are apparently conflicting data concerning the effects of alcohol on vestibular responses to caloric irrigations. Manz[16] found that the duration of caloric nystagmus (a patterned eye-movement response) frequently was prolonged under alcohol; in one case, it increased as much as 59 seconds. Schwab and Ey[22 23] reported variability (shortening in most cases) in the duration of the nystagmic responses to calorizations following alcohol ingestion; however, they also noted a reduction in the latency of the first nystagmic beat. The latter finding was supported by the work of Rauschke[20] who indicated an earlier onset of caloric nystagmus following alcohol consumption.

Data from a study by Bochenek and Ormerod[4] contradicted the conclusions reached in earlier studies; the response following alcohol ingestion was reported to be clearly suppressed although the authors failed to present any quantitative data concerning the extent of the suppression. The difference in results between early studies and those of Bochenek and Ormerod[4] may be due to the fact that visual fixation was allowed in the earlier studies whereas Bochenek and Ormerod[4] recorded the response under conditions of total darkness.

An additional factor which was not controlled in previous alcohol studies concerns the effect of variations in alertness on the response to caloric irrigations. Collins[2 8 10] has shown that instructions designed to maintain alertness result in a nystagmus of higher amplitude and longer duration than that obtained when the subject is instructed to relax and daydream. Control over alertness would seem to be especially important in studies involving pre and post testing, or in studies where depressants are used.

This study was designed to investigate the effects of two levels of alcohol on the nystagmic response to calorization with visual stimulation and alertness of the subjects systematically varied. Additional information was obtained concerning the effects of alcohol on optokinetic nystagmus.

II. Method.

Subjects. Subjects were 30 male college students with no previous laboratory experience involving vestibular stimulation. They ranged from 21 to 30 years of age and were randomly placed in three groups of 10 each. One group was designated as "high alcohol," one as "moderate alcohol," and the other served as a control group without alcohol.

Caloric Apparatus. Two water baths equipped with Bronwill constant temperature circulators maintained water temperature at 30° C. and 44° C. Rubber tubing from the base of the water baths passed through solenoids and ended in plastic nozzles through which the caloric stimuli were administered. The solenoids were opened and closed by a foot switch, through a Hunter electric timer, to provide a 30-second period of irrigation; the rate of water flow was 15 cc per second.

Data presented here were submitted to the Psychology Department, University of Oklahoma, in partial fulfillment of the requirements for the degree of Doctor of Philosophy under the guidance of Dr. William E. Collins. The assistance of Gail Kranz, Ruth Ann Mertens, Cynthia Cochran, Carlyn Manley, and Nancy Rice in the conduct of this study, of Dr. Earl Folk and Mrs. Rosalie Melton for some of the statistical analyses, and of Dr. Delbert Lacefield and Mrs. Pat Roberts in the collection and analysis of the blood samples, is gratefully acknowledged.

Optokinetic Drum. Horizontal optokinetic nystagmus was elicited by rotation of a drum positioned upright and painted alternately with black (2-inch) and white (2¼-inch) stripes along the longitudinal axis. The drum, 20 inches in diameter and 16 inches high, was located three feet in front of the subject. The drum speed was set at eight rpm.

Recording. Silver disc electrodes were taped by the outer canthi of the eyes to record horizontal components of eye movements. An electrode on the forehead served as a ground. The electrodes picked up the changes in corneoretinal potential that were relayed through a terminal board to Offner recorders. These signals were then amplified and recorded using a three-second time constant.

III. Procedure.

Calorizations in Darkness. The caloric irrigations were administered while the subject reclined in a supine position on an examining table in total darkness (see Figure 1). The subject's head was anteverted 30° by means of a head rest which also served as a water receptacle.[9]

There were four caloric trials consisting of two irrigations of the right ear with water at 30° C. (Rc) and two irrigations of the left ear with water at 44° C. (Lw). Both stimuli drive nystagmus in the same direction, with the fast phases of the eye movement to the left.

Prior to each trial, the subject was given instructions designed either to enhance or reduce alertness. Under the Alert condition, the subject was instructed to signal, by depression of a microswitch, the start, peak, and end of his "vertigo" sensation; he was also instructed to pay careful attention to his sensation so that he could describe it and rate its intensity at the end of the trial. A few seconds after signaling the end of his sensation, the subject was given a reaction-time task, i.e., he was told to react as quickly as possible, by depression of the microswitch, to a series of 500 cps tones, each 1/10 of a second in duration. The reaction time task was used purely as an alerting technique.[8 10] For the Reduced Alertness Condition (Reverie), the subject was instructed to relax, ignore the environment, and daydream. Each subject received one Rc and Lw trial in the Alert condition and one Rc and Lw trial in the Reverie condition. The order in which the subjects received these tasks was counterbalanced. Trials were separated by 15-minute periods to insure a return to normal of the temperature within the ear.

At the end of the second calorization, the subject was asked to rate the two trials in terms of the intensity of the sensations. The trial with the stronger sensation was rated as 100% and all others were rated in reference to it. The subject was instructed to remember the 100% trial because his ratings during subsequent testing would be made in reference to that rating. This technique has been used successfully in previous studies.[9 11]

The foregoing procedure for Pre-ingestion testing was repeated the following day after drinking. Post-ingestion sessions, I and II respectively, started 45 minutes and four hours after drinking.

Calorization in Room Illumination. Six additional subjects were administered Lc caloric irrigations with the room lights on. Under this condition, the subject was instructed to fixate on a black dot located on the ceiling directly above him. These Lc irrigations were administered one hour before and 45 minutes after the ingestion of alcohol.

Optokinetic Stimulation. Immediately following each caloric testing session, the subject was taken to an adjoining room and seated in front of the optokinetic drum. He was told to fixate on the surface of the drum during its rotation and to maintain fixation after the rotation had ended until he was told that the test was over. While watching the drum, the subject was instructed not to track the stripes actively, but to let his eyes follow naturally.

A 10-second practice trial was conducted to insure that the subject was watching correctly and to check the nystagmus recording. The testing session comprised four trials; two involved 60 seconds and two involved 15 seconds of optokinetic stimulation. For one 15-second and one 60-second trial, the light was turned off at the end of the stimulus period. The subject's eye movements were recorded throughout the stimulus period and for a subsequent period of 30 seconds in darkness. On the other 15- and 60-second trials the drum was stopped at the end of the stimulus period and the lights remained on. The subject's response was recorded during and for

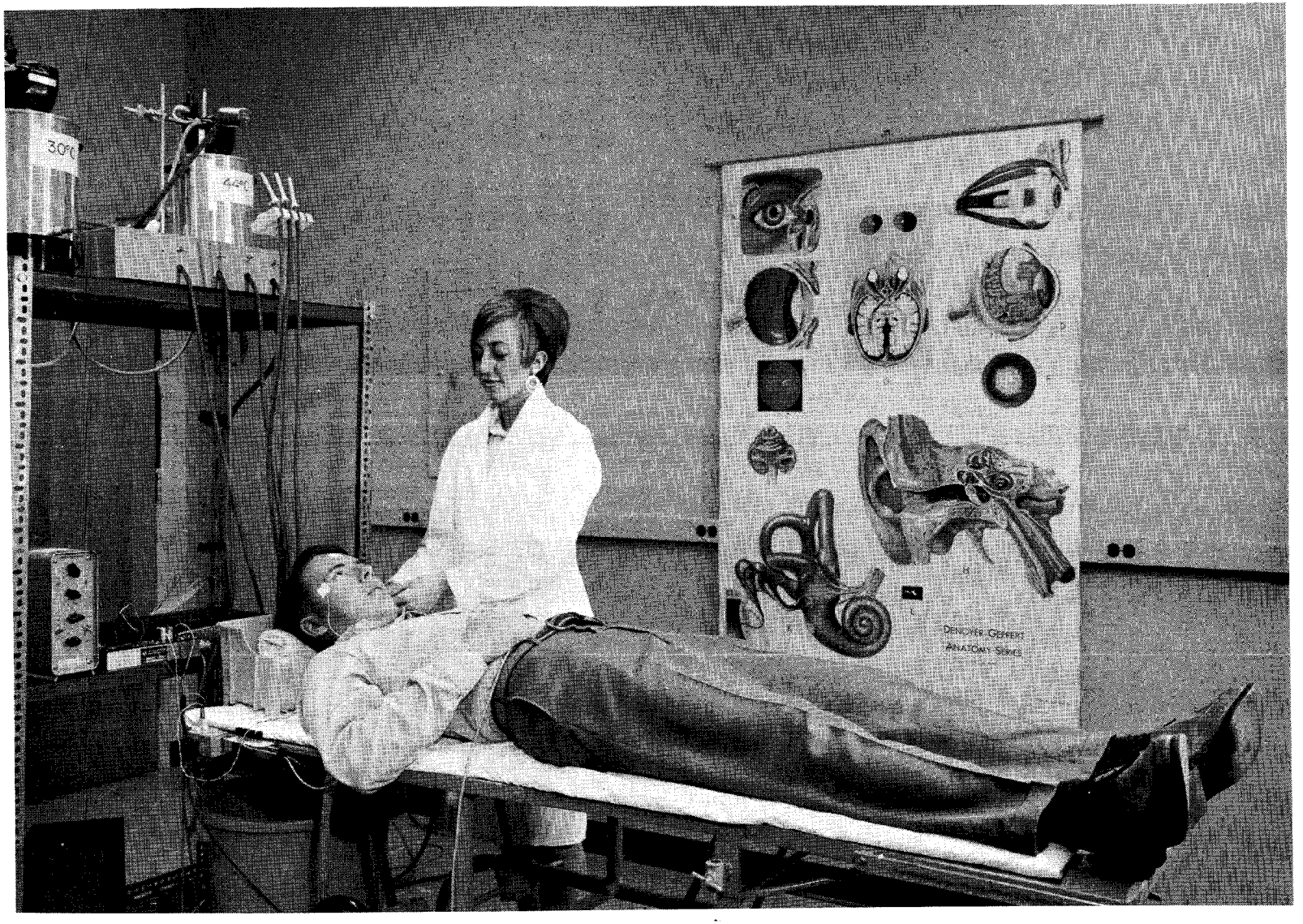

FIGURE 1. The experimental apparatus used to administer the caloric irrigations. The water passed from the water baths (30° or 44° C.) through the solenoids, down the tubing, and through a plastic nozzle into the subject's external auditory canal. A foot switch activated the Hunter timer, which in turn opened and closed the solenoids in order to provide 30-sec irrigations. The device used to antevert the subject's head also served as a collection basin for the return flow of water from the subject's ear.

a few seconds following stimulation. To prevent fatigue, there was a two-minute rest period between trials. The order of presentation of the various trials was counterbalanced.

Alcohol Ingestion and Blood Tests. Subjects given alcohol drank a mixture of 100-proof Smirnoff vodka and orange juice. The mixture contained 2.5 cc of vodka per kilogram of body weight for the high alcohol group, and 1.25 cc of vodka per kilogram of body weight for the moderate alcohol group. Subjects who were given the calorizations in the light received a dosage of 2 cc per kilogram. The control group drank orange juice with a few drops of rum extract added to alter the taste somewhat (they were not aware that they would not receive alcohol). All subjects consumed their drinks in a 15-minute period.

Venous blood samples of from three to five cc were drawn a few minutes prior to drinking, then one-half hour, one hour, and four hours after ingestion of alcohol. The blood alcohol levels were determined by means of gas chromatography. Whereas all blood samples were analyzed for the alcohol groups, only the first sample was analyzed for the control group.

Scoring. The caloric nystagmus was scored with respect to duration, frequency, slow phase output (degrees of eye movement), and slow phase velocity (degrees/sec) at peak slow phase output. Only the slow phase output and frequency measures were used in scoring the optokinetic nystagmus. Duration refers to the time interval between the start of the stimulus and the last nystagmic beat. Frequency was obtained by counting the number of nystagmic beats within specified time intervals. Amount of slow phase eye movement was determined by measuring (in millimeters) the amplitude of each nystagmic beat from slow-phase peak to baseline; these values were summed for all beats in three-second intervals (optokinetic trials) or five-second intervals (caloric trials). These sums were converted into degrees of slow phase eye movement by means of calibration factors calculated from measurements of recorded eye sweeps through known distances demarcated on special panels; these eye sweeps were obtained from each subject prior to each trial. Using Bodin's[5] formula, the velocity of the eye movement was calculated from the average angle of the slow phase of the nystagmus during the five-second interval where the slow phase output was maximum.

IV. Results and Discussion.

Blood Alcohol Levels (BAL). Means and standard deviations for the blood alcohol levels are presented in Table 1. The mean value for the high alcohol group was more than double (87 vs 38 mg.%) that of the moderate alcohol group at the one-hour testing session. At the Post II testing session four hours after drinking, the mean BAL for the high alcohol group (65 mg.%) was still above the maximum level reached by the moderate alcohol group.

TABLE 1.—Means and Standard Deviations for the Blood Alcohol Levels (in mg. per 100 ml.). Each Value is Based on a Mean for 10 Subjects.

Group		Time Since the Ingestion of Alcohol		
		Thirty Minutes	One Hour	Four Hours
Moderate	M	41.6	38.4	8.7
Alcohol	SD	16.7	11.2	5.0
High	M	70.9	86.9	64.8
Alcohol	SD	23.6	15.3	10.1

Alertness. Almost all of the mean nystagmus scores for the Task trials were above the mean values for the Rev trials (Tables 2 to 5). Although these differences were less apparent in the peak velocity and frequency measures, the "instruction" variable was significant, according to the analyses of variance (Table 6), for all measures of the nystagmic response.

Differences in the response under the Task and Rev conditions are evident in the nystagmic tracings for one of the subjects in the high alcohol group (Figure 2). The effects of alertness are apparent throughout the slow phase displacement and frequency response curves presented in Figures 3 to 10. These data support earlier work,[7 8 10] in that alerting instructions produced a higher amplitude, longer duration response. According to the present data, instructions may also affect the frequency and peak velocity of the slow phase nystagmus; the latter measures were not obtained in previous studies.

Subjective Responses. Means and standard deviations for ratings of the intensity of "vertigo" resulting from the caloric irrigations are pre-

TABLE 2.—Means and Standard Deviations for the Slow Phase Nystagmus Displacement (in Degrees) Resulting from the Caloric Irrigations. Each Group Was Comprised of Ten Subjects.

Group	Condition		44°C to the left ear (Lw)			30°C to the right ear (Rc)		
			Pre	Post I	Post II	Pre	Post I	Post II
Control	Task	M	1338.1	1048.3	1087.0	1387.5	1180.7	1129.8
		SD	581.2	368.9	577.4	602.6	409.4	497.1
	Rev	M	1285.9	1018.4	909.2	1295.0	948.2	1023.5
		SD	601.1	473.6	331.7	796.3	382.5	453.2
Moderate Alcohol	Task	M	1419.4	1175.2	1136.6	1467.3	1157.9	1166.3
		SD	623.5	710.2	596.1	668.1	416.0	624.3
	Rev	M	1192.4	1071.8	1050.2	1319.3	828.2	1078.2
		SD	666.0	650.5	588.6	415.8	360.6	650.5
High Alcohol	Task	M	1481.7	795.0	1352.0	1485.4	967.5	1496.8
		SD	785.6	473.5	783.6	668.6	493.0	546.5
	Rev	M	1041.8	650.8	976.8	1144.2	614.0	1039.2
		SD	828.3	505.4	608.3	564.2	426.7	616.6

TABLE 3.—Means and Standard Deviations for the Number of Nystagmic Beats Resulting from the Caloric Irrigations. Each Group Was Comprised of Ten Subjects.

Group	Condition		44°C to the left ear (Lw)			30°C to the right ear (Rc)		
			Pre	Post I	Post II	Pre	Post I	Post II
Control	Task	M	228.5	228.2	216.2	234.4	237.9	228.2
		SD	55.2	70.4	37.2	38.0	41.3	37.7
	Rev	M	223.4	212.6	223.5	241.0	224.9	241.1
		SD	38.3	57.5	50.4	38.9	40.4	44.6
Moderate Alcohol	Task	M	242.1	202.4	215.1	250.7	202.6	215.4
		SD	102.9	77.6	98.1	80.1	60.2	87.4
	Rev	M	220.9	193.5	196.1	255.2	170.9	201.3
		SD	110.9	83.6	83.9	87.4	69.6	91.2
High Alcohol	Task	M	197.3	145.4	174.5	214.9	130.5	189.5
		SD	86.4	111.0	70.0	63.8	60.5	52.0
	Rev	M	177.5	126.3	185.1	189.3	115.2	172.9
		SD	87.6	107.4	96.5	50.1	77.0	83.4

TABLE 4.—Means and Standard Deviations for the Peak Velocity (Deg/Sec) of the Slow Phase Nystagmus Resulting From the Caloric Irrigations. Each Group Was Comprised of Ten Subjects.

Group	Condition		44°C to the left ear (Lw)			30°C to the right ear (Rc)		
			Pre	Post I	Post II	Pre	Post I	Post II
Control	Task	M	19.2	17.8	16.8	18.3	16.9	15.8
		SD	7.8	5.6	6.1	6.5	5.5	6.7
	Rev	M	20.1	18.4	17.3	16.6	14.8	16.3
		SD	8.5	6.9	6.5	8.4	5.9	5.1
Moderate Alcohol	Task	M	23.4	22.1	20.5	21.7	20.4	21.2
		SD	13.3	12.6	10.0	10.6	9.0	14.7
	Rev	M	19.6	23.2	21.8	20.4	17.2	19.0
		SD	13.4	14.3	9.6	8.2	6.8	9.5
High Alcohol	Task	M	24.8	17.4	24.4	20.6	17.2	22.1
		SD	9.5	8.5	10.2	6.8	7.1	8.5
	Rev	M	21.8	16.5	21.4	19.2	15.4	18.4
		SD	19.5	8.3	10.0	7.0	7.7	10.0

TABLE 5.—Means and Standard Deviations for the Duration (in Seconds) of the Nystagmus Resulting From the Caloric Irrigations. Each Group Was Comprised of Ten Subjects.

Group	Condition		44°C to the left ear (Lw)			30°C to the right ear (Rc)		
			Pre	Post I	Post II	Pre	Post I	Post II
Control	Task	M	163.3	157.2	150.8	182.3	166.8	161.4
		SD	36.0	20.9	25.9	48.3	23.5	38.4
	Rev	M	153.4	131.8	138.0	169.8	148.4	157.2
		SD	29.9	21.3	19.2	30.9	24.2	27.0
Moderate Alcohol	Task	M	187.1	149.5	161.2	185.3	156.4	166.4
		SD	54.1	29.1	38.6	29.2	12.1	24.1
	Rev	M	185.8	137.4	145.6	186.8	130.6	156.1
		SD	52.0	41.4	44.6	35.4	35.6	30.5
High Alcohol	Task	M	162.5	108.1	135.6	171.0	128.7	149.2
		SD	25.6	48.4	21.7	51.1	30.6	34.4
	Rev	M	145.0	100.5	127.1	161.0	116.6	118.6
		SD	25.9	38.3	17.3	30.0	38.7	50.9

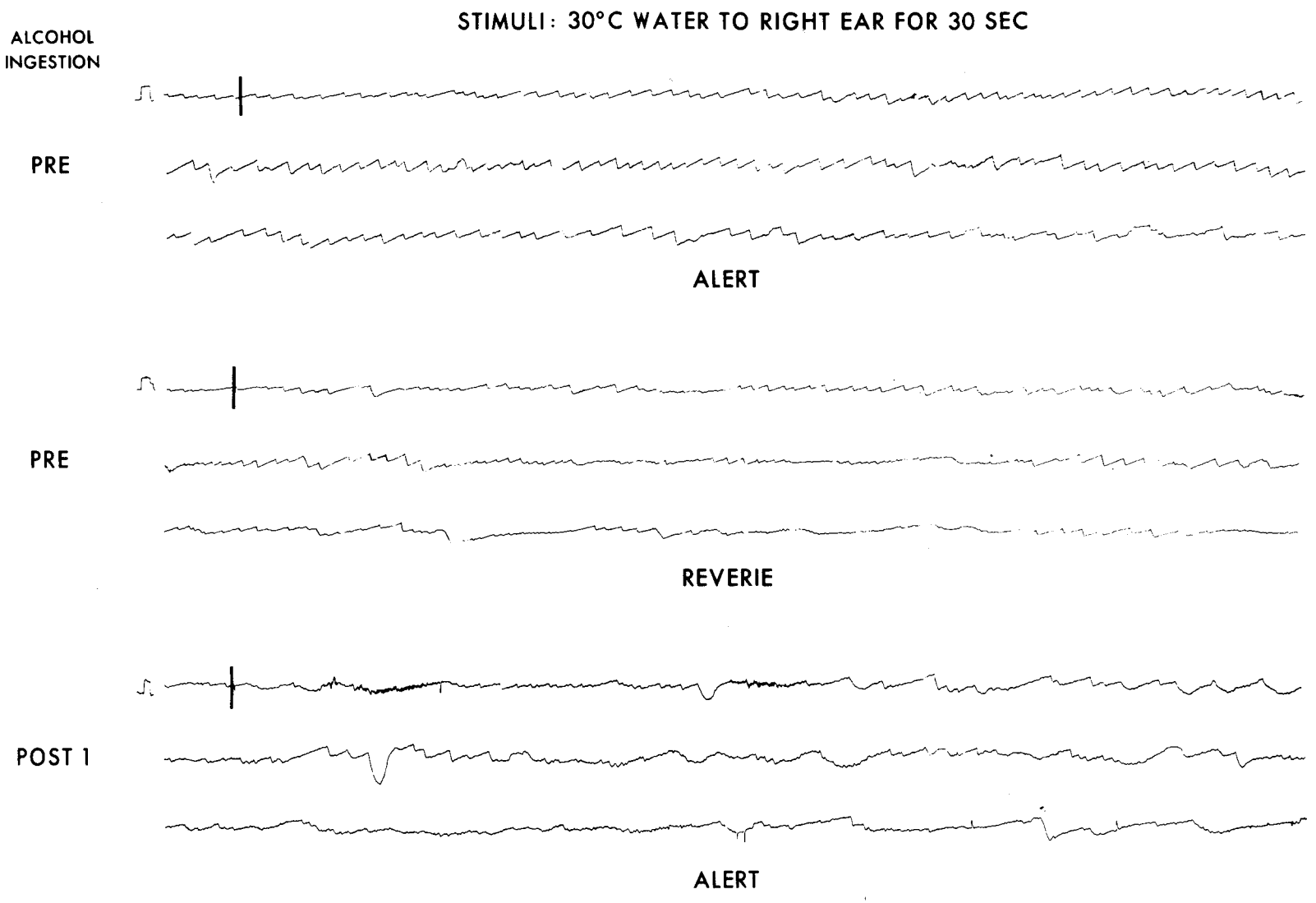

FIGURE 2. A portion of the nystagmic tracings of responses by subject TW to a 30° C. unilateral irrigation to the right ear. The calibrations, appearing before each of the trials, represent 20° of eye movement. The vertical bars indicate the end of the stimulus. Comparison of nystagmus under the Alert and Reverie conditions prior to alcohol ingestion indicates an enhanced response under the Alert condition. A comparison of the Alert responses for the Pre and the Post I (45 min after alcohol ingestion) conditions reveals the suppressive influence of alcohol; nystagmus is much weaker following alcohol ingestion and resembles more closely the response during Reverie prior to alcohol ingestion than it does the pre-drinking Alert response.

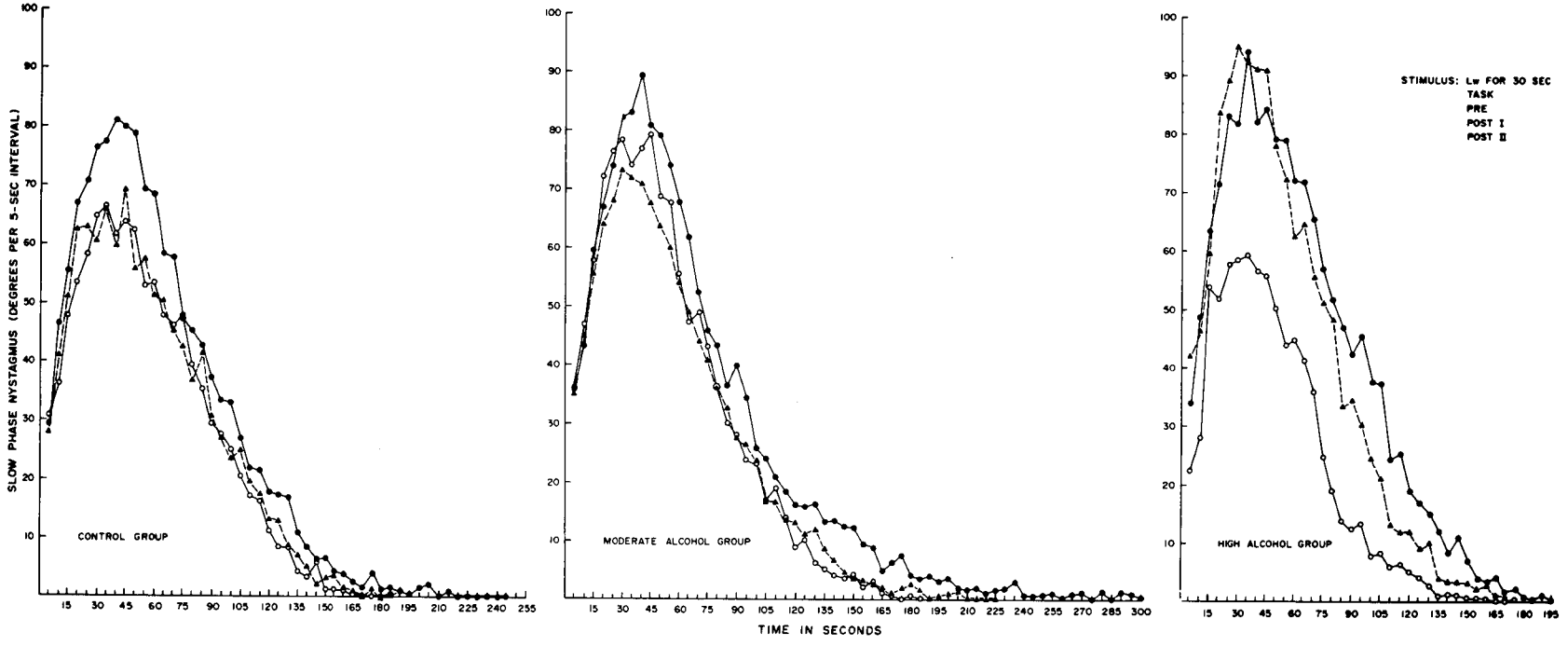

FIGURE 3. Response data for the average number of degrees of slow phase eye movement resulting from the Lw caloric irrigations under the Task condition. Pre refers to the response recorded prior to the ingestion of alcohol, while the Post I and Post II data were obtained, respectively, 45 minutes and four hours after ingestion. The stimulation, in each case, was a 30-second unilateral irrigation. The values are plotted in 5-second intervals beginning immediately after the end of the irrigation; each point is a mean for 10 subjects.

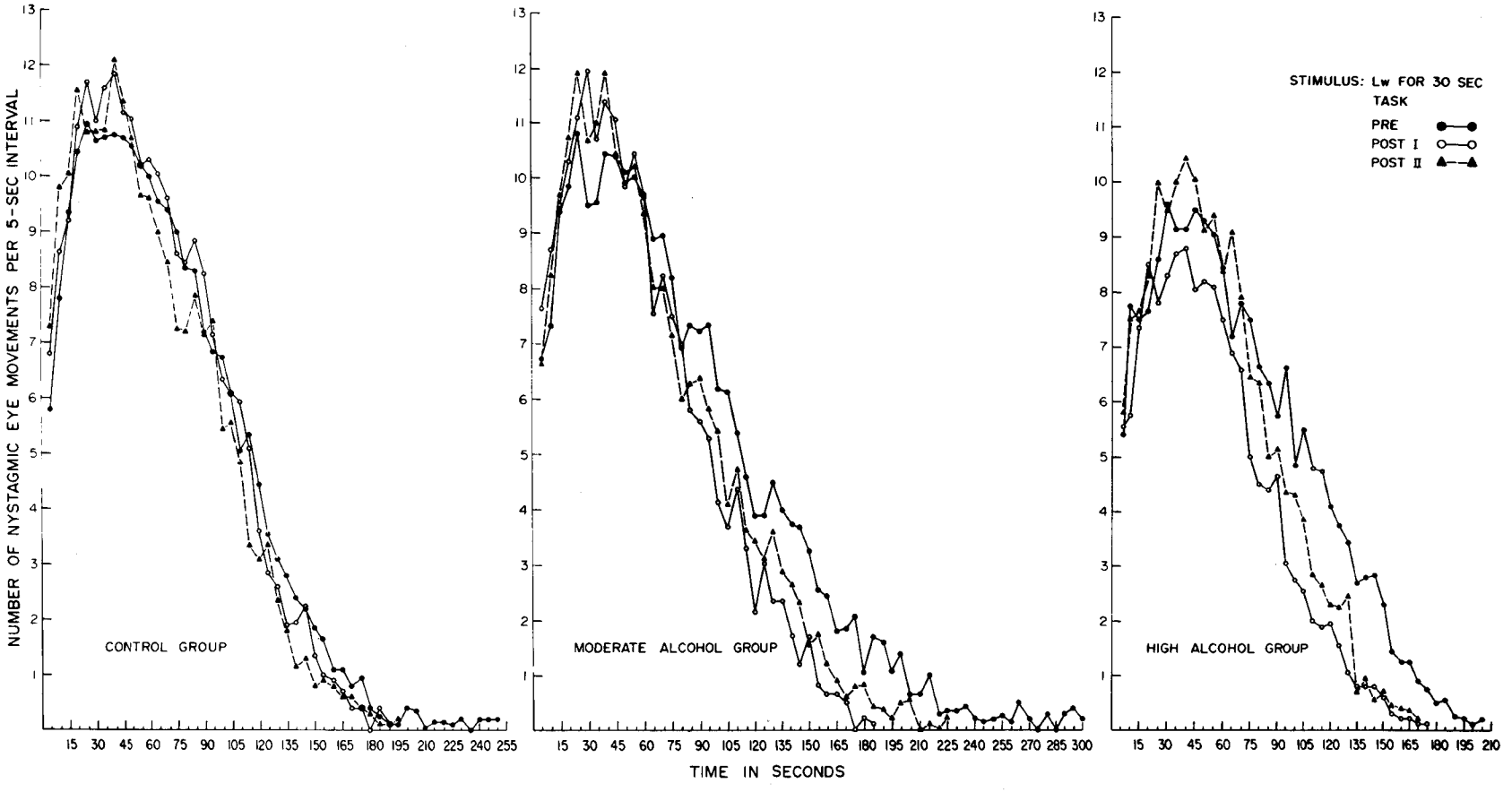

FIGURE 4. Response data for the average number of nystagmic eye movements resulting from the Lw caloric irrigations under the Task condition. Symbols and markings are identical to those used in Figure 3.

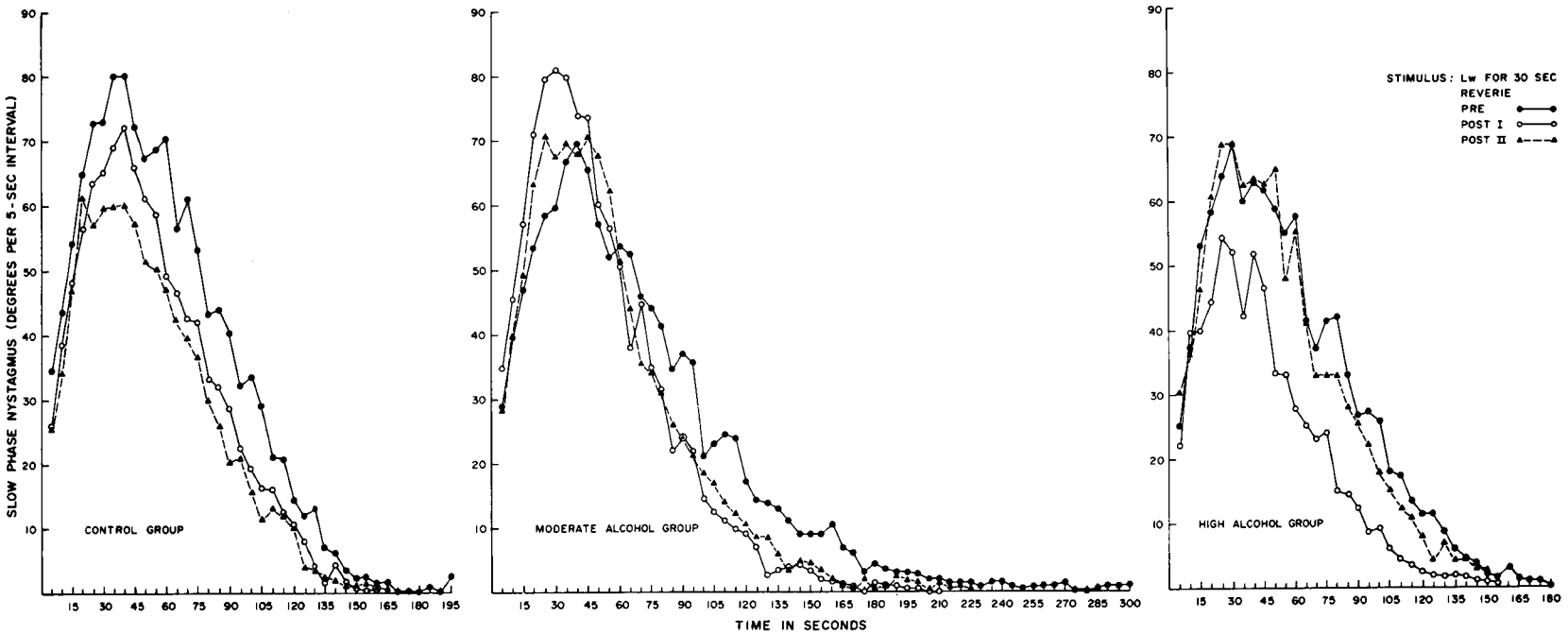

FIGURE 5. Response data for the average number of degrees of slow phase eye movement resulting from the Lw caloric irrigations under the Reverie condition. Symbols and markings are identical to those used in Figure 3.

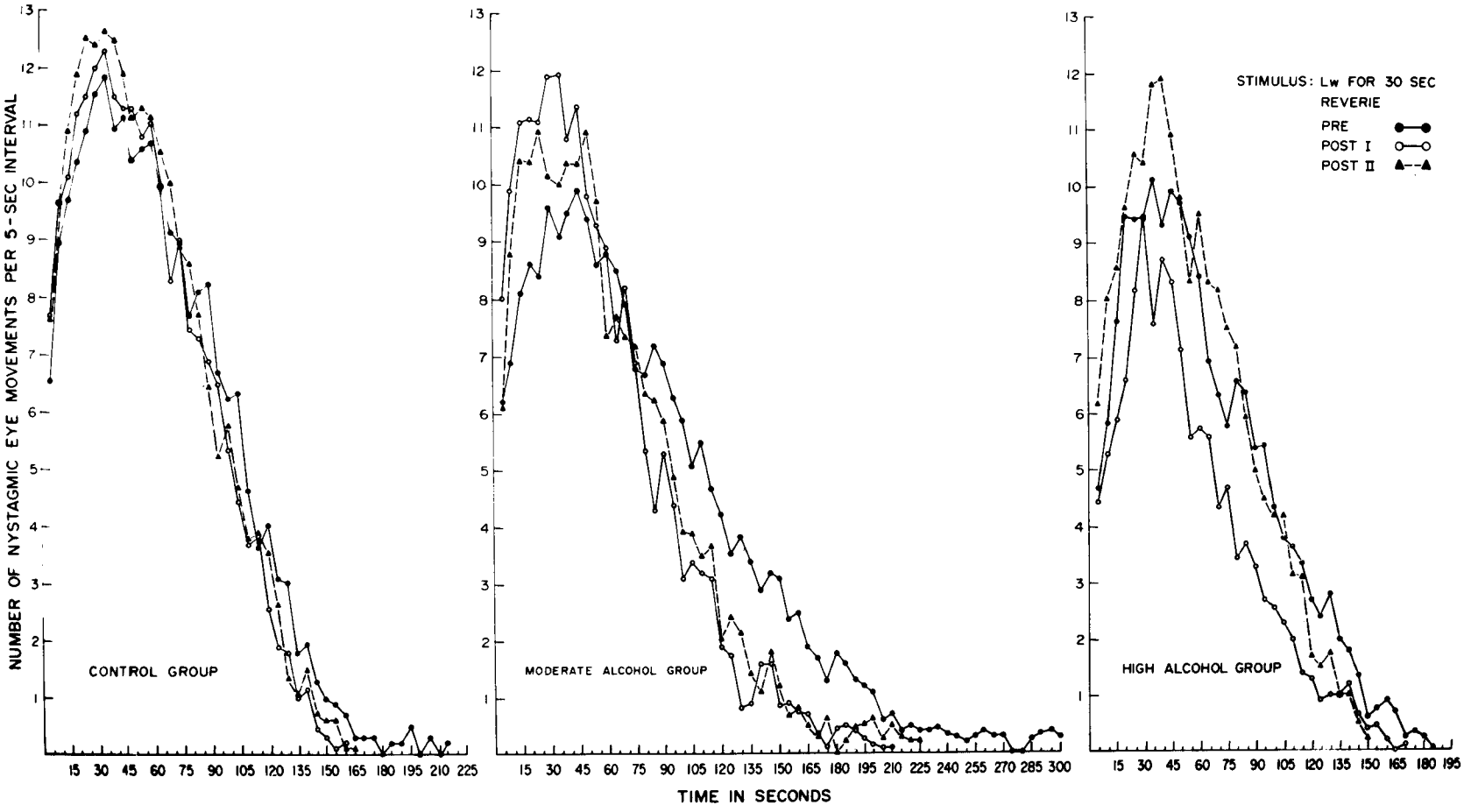

FIGURE 6. Response data for the average number of nystagmic eye movements resulting from the Lw caloric irrigations under the Reverie condition. Symbols and markings are identical to those used in Figure 3.

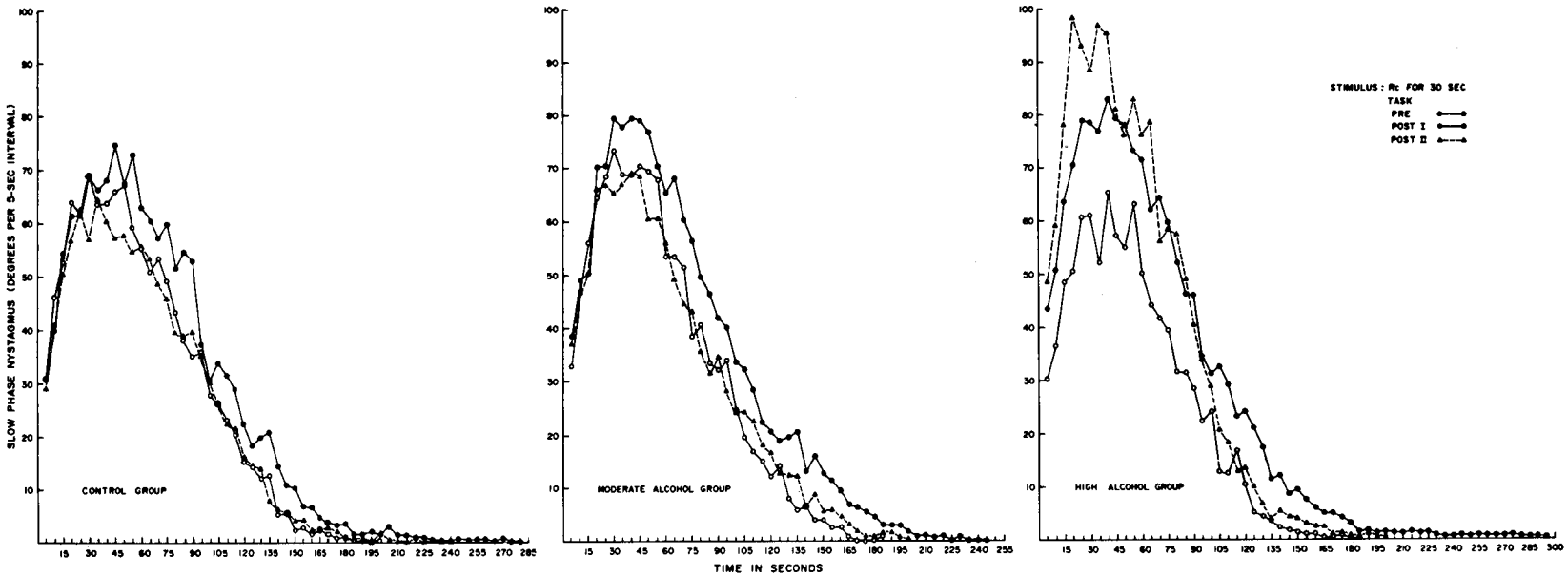

FIGURE 7. Response data for the average number of degrees of slow phase eye movement, resulting from the Rc caloric irrigations under the Task condition. Symbols and markings are identical to those used in Figure 3.

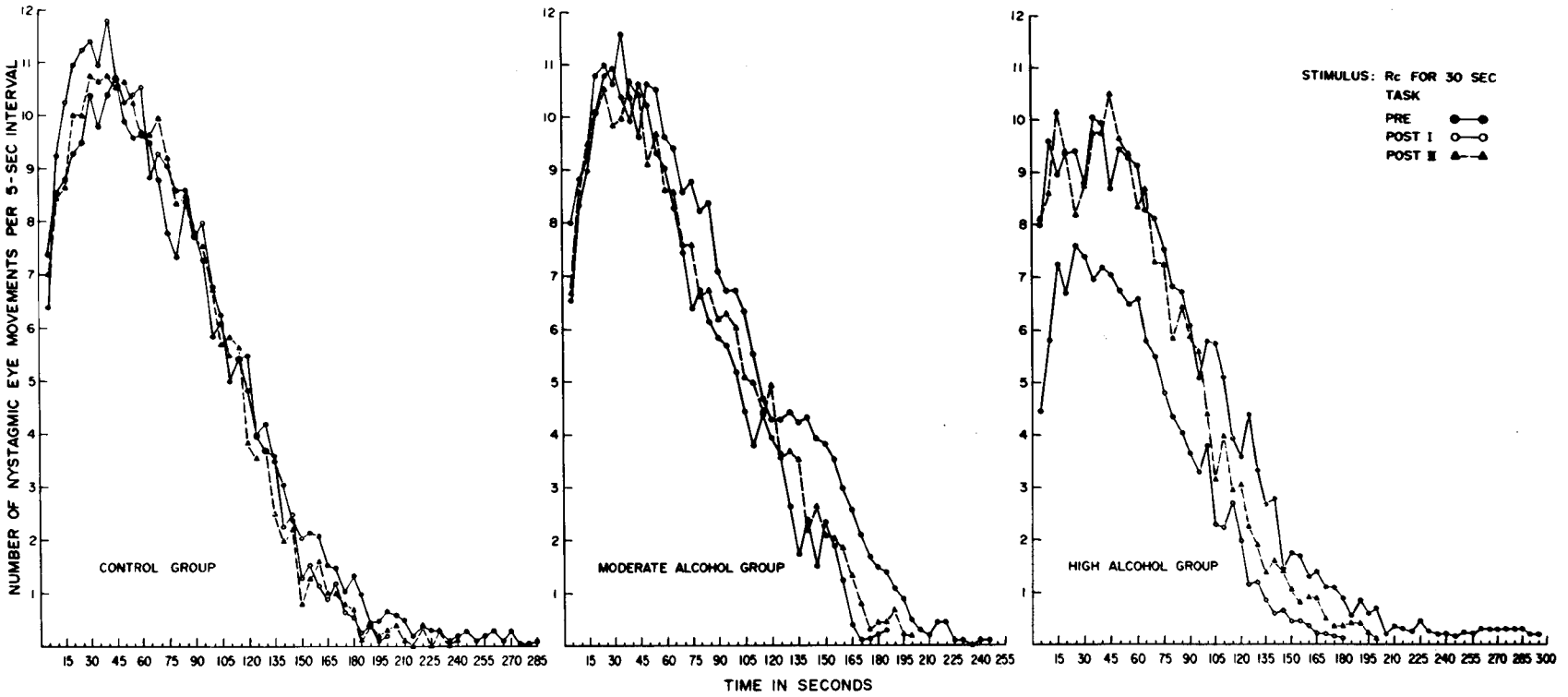

FIGURE 8. Response data for the average number of nystagmic eye movements, resulting from the Rc caloric irrigations under the Task condition. Symbols and markings are identical to those used in Figure 3.

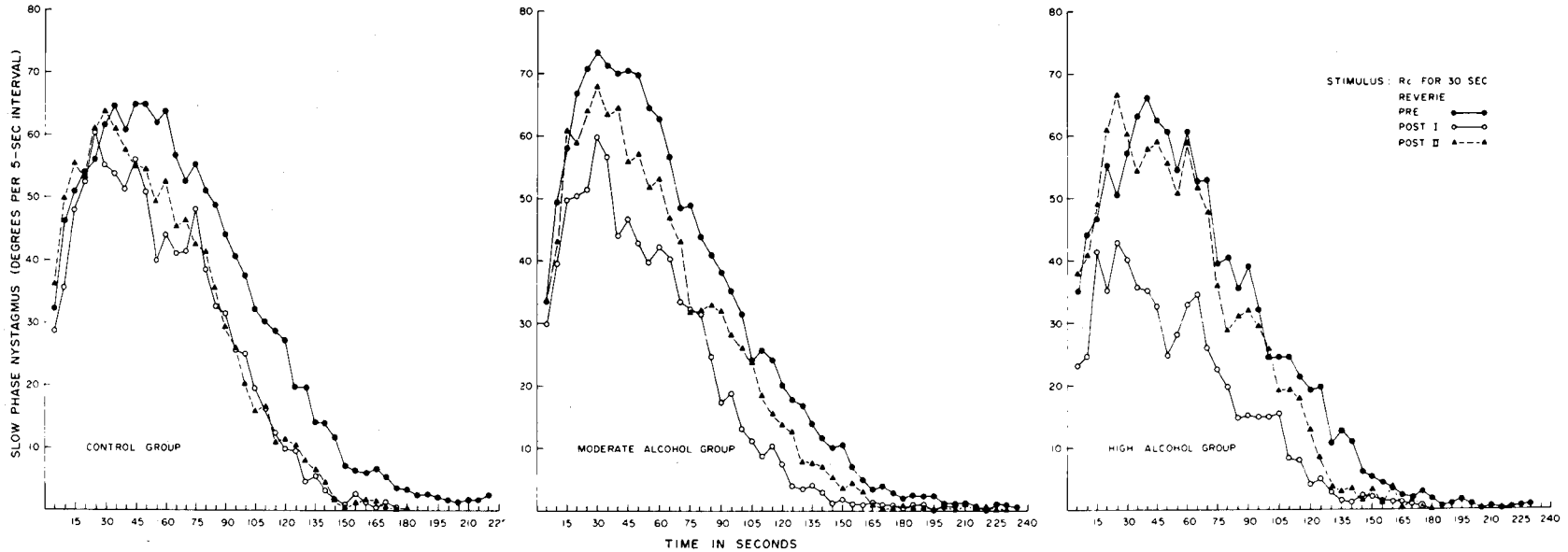

FIGURE 9. Response data for the average number of degrees of slow phase eye movement, resulting from the Rc caloric irrigations under the Reverie condition. Symbols and markings are identical to those used in Figure 3.

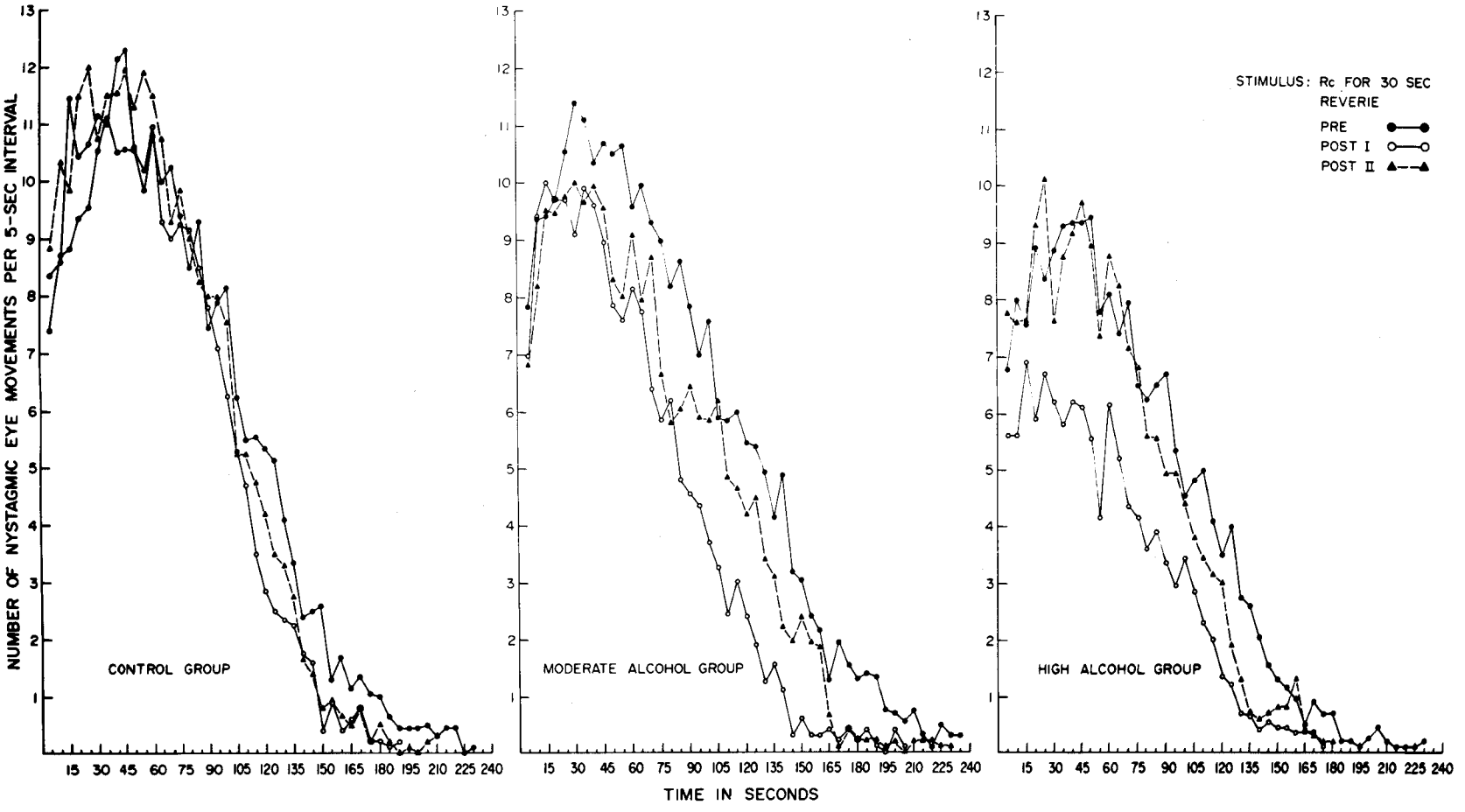

FIGURE 10. Response data for the average number of nystagmic eye movements resulting from the Rc caloric irrigations under the Reverie condition. Symbols and markings are identical to those used in Figure 3.

TABLE 6.—Results of the Analyses of Variance for the Various Measures of the Nystagmic Responses Resulting from the Caloric Irrigations.

	F				
	Slow Phase Displacement	Frequency	Duration	Peak Velocity	Subjective Intensity
Group (G)	0.11	2.49	3.43*	0.60	0.59
Temp (Te)	0.30	0.97	2.45	2.96	8.83**
Te x G	0.10	0.32	0.32	0.02	1.05
Instructions (I)	41.52***	6.98*	6.23*	6.67*	0.05
I x G	4.19*	1.38	0.39	1.45	1.20
Trials (Tr)	16.33***	17.10***	30.96***	4.02*	21.67***
Tr x G	2.25	4.32*	0.79	2.45	1.19
Te x I	0.68	0.00	0.77	1.12	0.03
Te x I x G	0.07	1.04	0.15	0.28	1.11
Te x Tr	0.44	1.52	0.46	0.11	6.81**
Te x Tr x G	0.56	0.37	0.60	0.74	0.81
I x Tr	0.08	1.99	2.34	0.24	0.82
I x Tr x G	0.87	0.95	0.96	0.55	0.90
I x Tr x Te	2.82	0.86	0.26	0.63	2.69
I x Tr x Te x G	0.13	1.02	1.65	0.45	0.66

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

TABLE 7.—Means and Standard Deviations for the Intensity Ratings of the Vertigo Resulting From the Caloric Irrigations. Each Group Was Comprised of Ten Subjects.

Group	Condition		44°C to the left ear (Lw)			30°C to the right ear (Rc)		
			Pre	Post I	Post II	Pre	Post I	Post II
Control	Task	M	73.8	55.0	40.5	68.5	38.5	32.5
		SD	29.4	26.1	25.1	26.5	34.8	27.2
	Rev	M	76.0	54.5	44.5	75.0	33.5	24.1
		SD	33.7	26.6	27.6	26.2	20.2	22.0
Moderate Alcohol	Task	M	85.5	79.5	35.5	66.7	32.0	16.0
		SD	53.5	82.8	36.5	33.0	17.2	17.1
	Rev	M	73.8	106.3	46.5	71.5	33.8	20.0
		SD	44.5	80.9	35.4	38.7	30.0	24.9
High Alcohol	Task	M	81.5	90.5	40.0	73.8	53.5	37.4
		SD	35.0	54.1	29.5	32.0	31.4	27.0
	Rev	M	63.3	87.8	36.0	69.1	52.8	41.5
		SD	36.3	58.0	35.0	31.2	45.0	34.2

TABLE 8.—Means and Standard Deviations for the Duration (in Seconds) of the Subject's "Vertigo" Sensations Resulting from the Caloric Irrigations under the Task Condition.

Group		44°C to the left ear (Lw)			30°C to the right ear (Rc)		
		Pre	Post I	Post II	Pre	Post I	Post II
Control	M	74.0	70.1	55.2	84.7	66.1	49.4
	SD	22.4	19.3	16.7	23.3	21.4	22.9
Moderate Alcohol	M	85.0	73.7	46.5	62.1	62.3	38.1
	SD	29.5	20.8	30.1	38.3	28.3	27.1
High Alcohol	M	76.4	67.8	53.1	84.7	58.7	55.3
	SD	31.2	20.1	24.8	35.8	29.6	26.2

sented in Table 7; the durations of those sensations are noted in Table 8. Results of the analyses of variance for these two measures (Tables 6 and 9) indicate a significant effect for the "trial" factor, i.e., for Pre to Post I to Post II changes in the intensity and duration of the "vertigo" sensations. The "temperature" and "temperature by trial" factors were also significant for the intensity ratings.

TABLE 9.—Results of the Analysis of Variance for the Durations of the Subjects' "Vertigo" Sensations Resulting from the Caloric Irrigations

Source	df	Mean Squares	F
Groups (G)	2	510.27	0.24
Sub/Group (S/G)	27	2,121.81	
Temperature (Te)	1	900.48	1.13
Te x G	2	1,068.07	1.34
Te x S/G	27	800.00	
Trial (Tr)	2	12,069.52	31.71***
Tr x G	4	371.74	0.98
Tr x S/G	54	380.64	
Tr x Te	2	178.38	0.64
Tr x Te x G	4	454.89	1.64
Tr x Te x S/G	54	277.92	

***$p < .001$

A comparison of the mean intensity ratings for the Lw and the Rc trials revealed a possible differential effect of alcohol. The Pre to Post I declines in the intensity of the Rc calorics appeared to occur equally for all three groups (alcohol apparently produced little change). However, the Post I intensity ratings by both alcohol groups for the Lw trials were nearly the same as or above, their Pre levels. In contrast, the control group evidenced a decline in intensity ratings. These rating differences between the two stimulus temperatures, produced the significant "trials by temperature" interaction and also contributed to the significant effect noted for "temperature."

With the exception of the Lw trials for the moderate alcohol group, the Post II mean intensity ratings were all significantly below their Pre levels (Table 10).

The durations of the "vertigo" sensations failed to evidence any significant alcohol effect. For all groups, the durations for the Post I trials were somewhat lower than their Pre levels although most of these declines were not significant according to t tests. However, the Pre to Post II declines were significant for all trials, except the Lw trial for the control group (Table 11).

There was little evidence of any suppressive effect of alcohol on the "vertigo" sensations resulting from the caloric irrigations. The differential effect of alcohol on the intensity ratings depending upon stimulus temperature was not evident in the "vertigo" duration data or in any of the objective (nystagmic) measures of the response. Further research is required to determine if the difference between Lw and Rc intensity ratings is artifactual or a result of the ingestion of alcohol.

The most noticeable change in the subjective measures was a steady decline from the Pre to Post II trials. Since the nystagmic response was always in the same direction, the decline would appear to be due to repeated stimulation (i.e., habituation). These effects were more evident in the "vertigo" responses than in any of the objective (nystagmic) measures.

TABLE 10.—Results of the Paired t Tests for the Intensity Ratings Resulting From the Caloric Irrigations.

Group	Comparison	44°C to the left ear (Lw)		30°C to the right ear (Rc)	
		Task	Reverie	Task	Reverie
Control	Pre vs. Post I	1.79	2.20	2.27*	3.96***
	Pre vs. Post II	2.78*	2.79*	6.30***	4.69**
Moderate Alcohol	Pre vs. Post I	.23	1.14	3.89**	3.54**
	Pre vs. Post II	3.06*	1.37	5.11***	5.03***
High Alcohol	Pre vs. Post I	.63	1.42	3.60**	1.27
	Pre vs. Post II	3.11*	2.73*	4.21**	3.29**

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

TABLE 11.—Results of the Paired t Tests for the Durations of the Subjects' "Vertigo" Sensations Resulting From the Caloric Irrigations Under the Task Condition.

Group	44°C to the left ear (Lw)		30°C to the right ear (Rc)	
	Pre vs. Post I	Pre vs. Post II	Pre vs. Post I	Pre vs. Post II
Control	0.54	2.16	4.15**	4.44**
Moderate Alcohol	2.04	3.60**	0.02	2.61*
High Alcohol	1.06	2.73*	3.24*	3.21*

*p <.05
**p <.01

Caloric Nystagmus in Darkness. Means and standard deviations for the total number of degrees of slow phase eye displacement, frequency, duration, and mean peak velocity of nystagmus obtained during the caloric trials in darkness are presented in Tables 2 to 5. Results of the analyses of variance for these measures appear in Table 6; results of t tests are in Tables 12 to 14.

The Pre to Post I declines in control group responses were much smaller than those noted for either the moderate alcohol or high alcohol groups; only the duration measures for the Lw and Rc irrigations under the Rev condition were significantly below their Pre levels (Table 12). Most of the scores for the Post II trials of the control group were not significantly different from Pre values.

With the exception of a 19% increase in peak eye velocity for the Lw trial, all of the nystagmus measures for the moderate alcohol group at the Post I testing session were below their Pre levels. All of the Post I reductions in nystagmus duration were statistically significant, and several other measures also evidenced significant Pre to Post I declines (Table 13). Although the majority of the Post II mean responses showed recovery from their Post I levels, several remained significantly below Pre values; the majority of the significant t tests occurred for the duration measure.

Declines from the Pre to Post I trials were much larger for the high alcohol group (16–46%). According to t tests, all of the mean Post I measures were significantly below their Pre values (Table 14). At the Post II testing session, all mean responses were above Post I levels, and only (a) Post II durations for both Lw trials, and (b) frequency for the Rc Task trial were still significantly below their initial levels. In terms of per cent of change, the high alcohol group evidenced greater response recovery on the Post II trials than did the moderate alcohol group.

These data indicate that alcohol had a depressive effect on the nystagmic response to calorizations in darkness. The changes in the response following alcohol ingestion are evident in the slow phase and frequency response curves presented in Figures 3 to 10. A representative

TABLE 12.—Results of the Paired t Tests for the Pre vs. Post I and Pre vs. Post II Comparisons of the Nystagmic Responses of the Control Group to the Caloric Irrigations.

Measure	Comparison	44°C to the left ear (Lw)		30°C to the right ear (Rc)	
		Task	Reverie	Task	Reverie
Displacement	Pre vs. Post I	1.86	1.88	1.24	1.49
	Pre vs. Post II	1.49	2.63*	2.19	1.21
Frequency	Pre vs. Post I	0.04	0.90	0.33	1.11
	Pre vs. Post II	1.21	0.01	0.59	0.01
Duration	Pre vs. Post I	0.72	2.84*	1.56	2.42*
	Pre vs. Post II	1.28	2.11	3.72**	1.51
Velocity	Pre vs. Post I	0.68	0.88	0.67	0.72
	Pre vs. Post II	0.96	1.58	1.66	0.10

*p <.05 **p <.01

TABLE 13.—Results of the Paired t Tests for the Pre vs. Post I and Pre vs. Post II Comparisons of the Nystagmic Responses of the Moderate Alcohol Group to the Caloric Irrigations.

Measure	Comparison	44°C to the left ear (Lw)		30°C to the right ear (Rc)	
		Task	Reverie	Task	Reverie
Displacement	Pre vs. Post I	1.42	0.76	2.39*	7.99***
	Pre vs. Post II	2.31*	0.89	2.33*	1.91
Frequency	Pre vs. Post I	2.97*	1.02	6.13***	4.12**
	Pre vs. Post II	2.95*	0.93	1.89	2.84*
Duration	Pre vs. Post I	3.04*	4.14**	4.61**	4.28**
	Pre vs. Post II	1.85	3.21**	5.60***	2.83*
Velocity	Pre vs. Post I	0.54	1.37	0.40	3.07*
	Pre vs. Post II	1.61	0.59	0.13	0.71

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

TABLE 14.—Results of the Paired t Tests for the Pre vs. Post I and Pre vs. Post II Comparisons of the Nystagmic Responses of the High Alcohol Group to the Caloric Irrigations.

Measure	Comparison	44°C to the left ear (Lw)		30°C to the right ear (Rc)	
		Task	Reverie	Task	Reverie
Displacement	Pre vs. Post I	3.56**	1.99	4.69**	3.93**
	Pre vs. Post II	1.04	0.51	0.08	0.62
Frequency	Pre vs. Post I	1.90	1.66	7.16***	4.37**
	Pre vs. Post II	1.69	0.72	2.29*	0.76
Duration	Pre vs. Post I	4.07**	5.77***	4.38**	6.64***
	Pre vs. Post II	3.28**	2.41*	1.59	2.14
Velocity	Pre vs. Post I	2.38*	1.01	2.09	2.03
	Pre vs. Post II	0.18	0.09	0.78	0.35

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

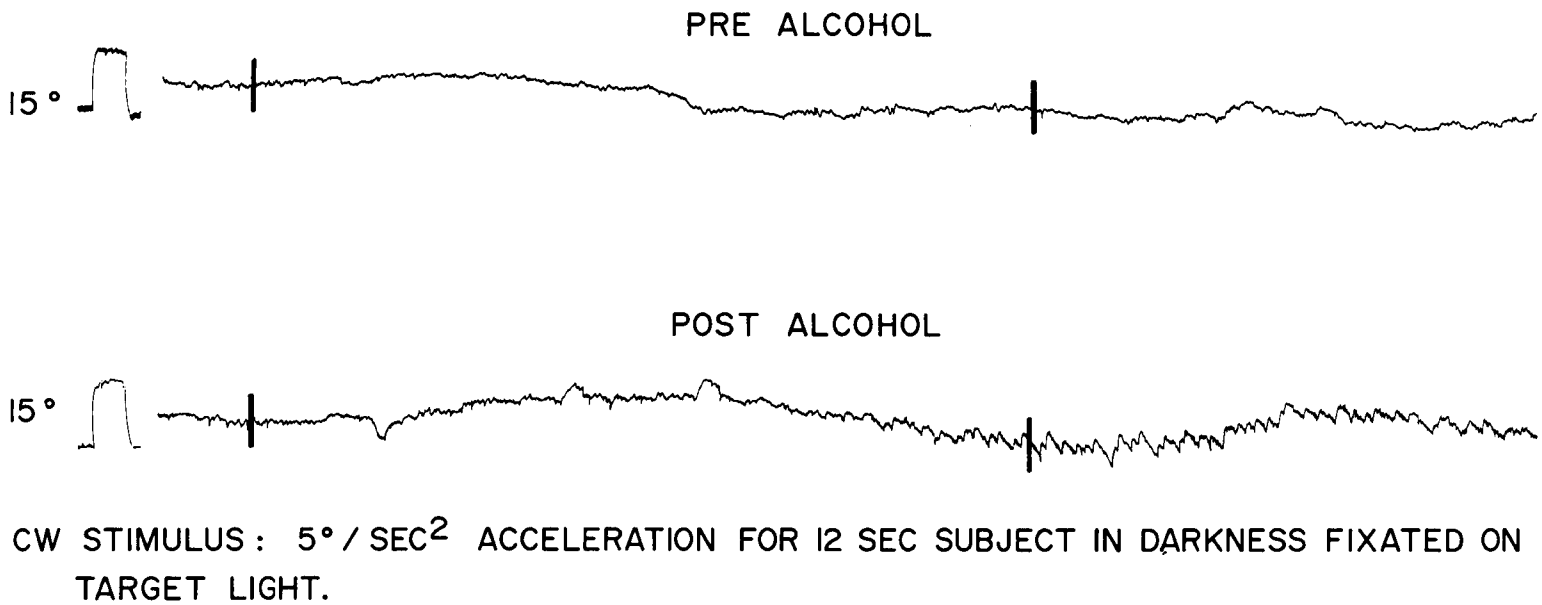

FIGURE 11. A portion of the tracings of the nystagmic response of a subject (DS) to a 30-second Lc calorization. The caloric irrigation was administered with the room lights on while the subject fixated on the target. The vertical bar marks the end of the stimulus period. The calibration appearing before each of the trials represents 20° of eye movement.

tracing of a subject's response before and after the ingestion of alcohol is presented in Figure 2. These findings support the report of Bochenek and Ormerod[4] but are contrary to results presented by Manz[16], Schwab and Ey[22 23], and Rauschke[20] who indicated that alcohol enhanced caloric nystagmus. The data presented in the following section offer a means of resolving these differences.

Caloric Nystagmus in Room Illumination. These subjects were administered caloric irrigations while attempting to fixate on a target. Under the non-alcohol condition the subjects were able, through visual fixation, to suppress markedly the nystagmic response to the Lc caloric irrigations (see Figure 11). However, following the ingestion of alcohol, a low-amplitude, high-frequency nystagmus was obtained (Figure 11) and the subjects reported difficulty in maintaining fixation.

Alcohol, therefore, interfered with the ability of the subjects to fixate. What earlier investigators had described as an enhancing effect of alcohol on vestibular responses, can now be more accurately attributed to the depressive effect of alcohol on the ability of the subject to maintain visual fixation. Since the visual fixation mechanism was depressed, the nystagmic response to vestibular stimulation was more evident. (Similar results were obtained when using rotatory stimulation.[21]) Jatho[14], by indicating that alcohol ingestion interfered with the recovery movements of the eyes following brisk head movements, provides additional support to this view of the action of alcohol.

The interfering effect of alcohol on fixation is similar to the effect noted by Rashbass and Russell[19] for a barbiturate (sodium amytal). Under dark conditions, the drug had little effect on caloric nystagmus. In the light without the drug, the subject was able to suppress the nystagmic response through visual fixation. However, following drug administration, Rashbass and Russell[19] reported that the nystagmic response was vigorous and nearly as strong as that obtained under conditions of total darkness. Thus, there is a strong similarity between the actions of sodium amytal and alcohol on the ability of the subject to fixate visually while undergoing caloric vestibular stimulation.

Optokinetic Data. The results from the optokinetic trials offer further evidence concerning the depressive effect of alcohol on the oculomotor system. This depressive effect is evident in the means (Tables 15 and 16) and mean response curves (Figures 12–16) for the slow phase displacement and frequency measures. The results of the analyses of variance and t tests are presented in Tables 17 and 18. Throughout the Post I and Post II testing sessions, the responses of the control group remained very near their Pre levels (Tables 15 and 16). In contrast, both the moderate and high alcohol groups evidenced considerable Pre to Post I declines in both frequency and slow phase eye displacement; the decline for the high alcohol group was much larger (approximately 40% compared to approximately 15% for the moderate alcohol group). The Pre to Post I declines in mean slow phase and frequency scores for the 60-second trials, with the exception of the frequency measure for the 60-second (lights off) trial, were all significant for the moderate alcohol group (Tables 17 and 18). All of the Post I mean values for the high alcohol group were significantly below their Pre levels (Tables 17 and 18). The response evidenced considerable recovery during the Post II testing session, where only three of the means for both alcohol groups were still significantly below their Pre levels (Tables 17 and 18). This depressive effect of alcohol on optokinetic nystagmus supports previous studies[3 12 15 17 24].

The suppression of optokinetic nystagmus by alcohol may be due either to the action of the latter on the eye muscles or its interference with the ability of the subject to fixate. The latter is a definite possibility since ter Braak[6], Rademaker and ter Braak[18], and Honrubia et al.[13] have all shown that optokinetic nystagmus is dependent upon how the subject views the stimulator. A much stronger response is evident when the subject fixates on the surface of the drum rather than fixating in front of or behind the stimulus.

Evidence from earlier studies by Bender and O'Brien[1] and Bergman, Nathanson, and Bender[2] indicate that sodium amytal also interferes with optokinetic nystagmus. The similarity of action of alcohol and this particular barbiturate on optokinetic nystagmus and on the ability of the subject to maintain visual fixation during vestibular stimulation would seem to indicate that they are affecting similar centers.

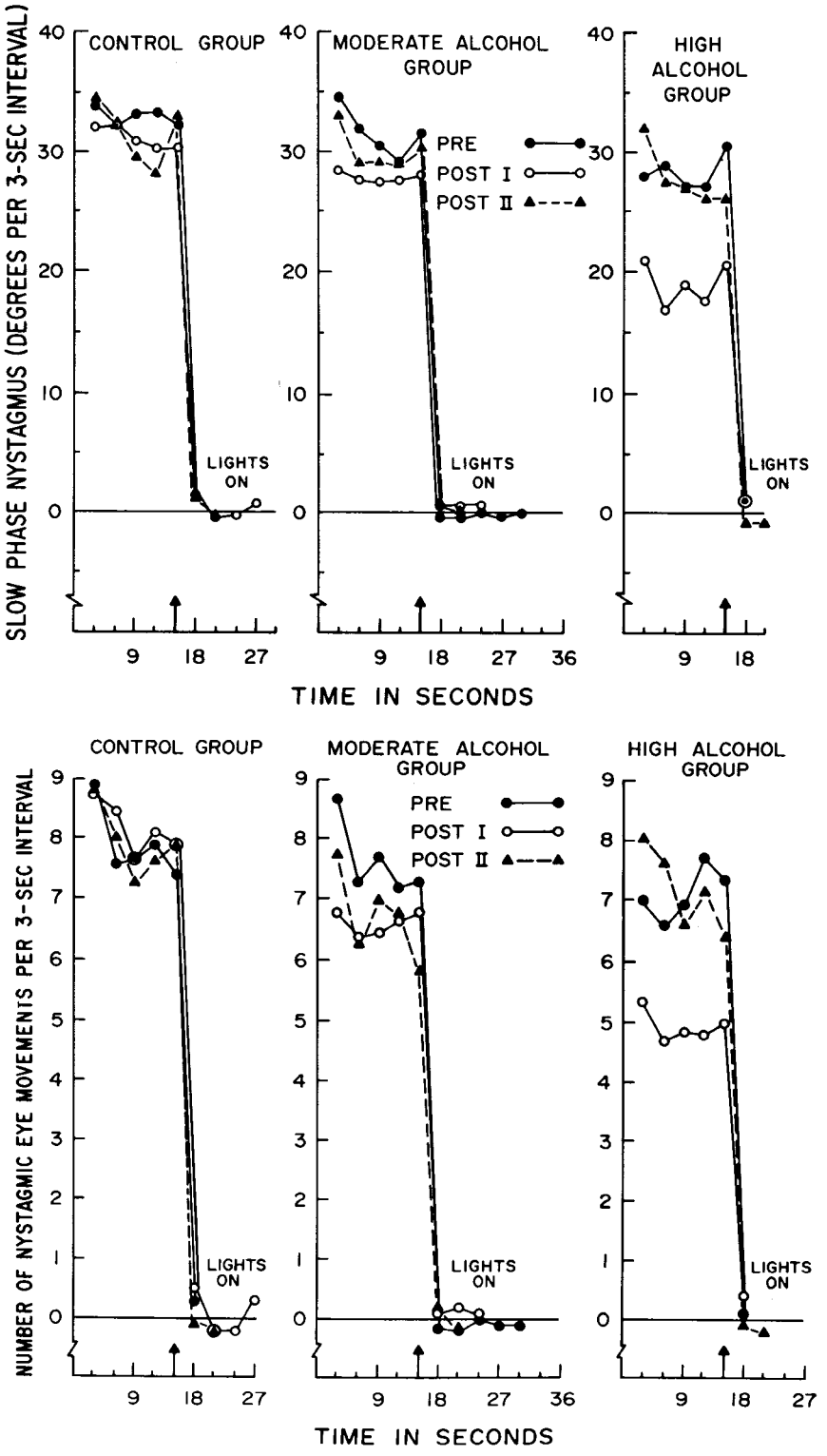

FIGURE 12. Response data for the average number of degrees of slow phase eye movement (upper half) and average number of nystagmic eye movements (lower half) resulting from the 15-second optokinetic trials. Pre refers to the response obtained prior to the ingestion of alcohol, while Post I and Post II refer, respectively, to the data obtained 45 minutes and four hours after ingestion. "Lights on" indicates that the room lights remained on both during and following the stimulus period. The values are plotted in 3-second intervals; each point is a mean of 10 subjects.

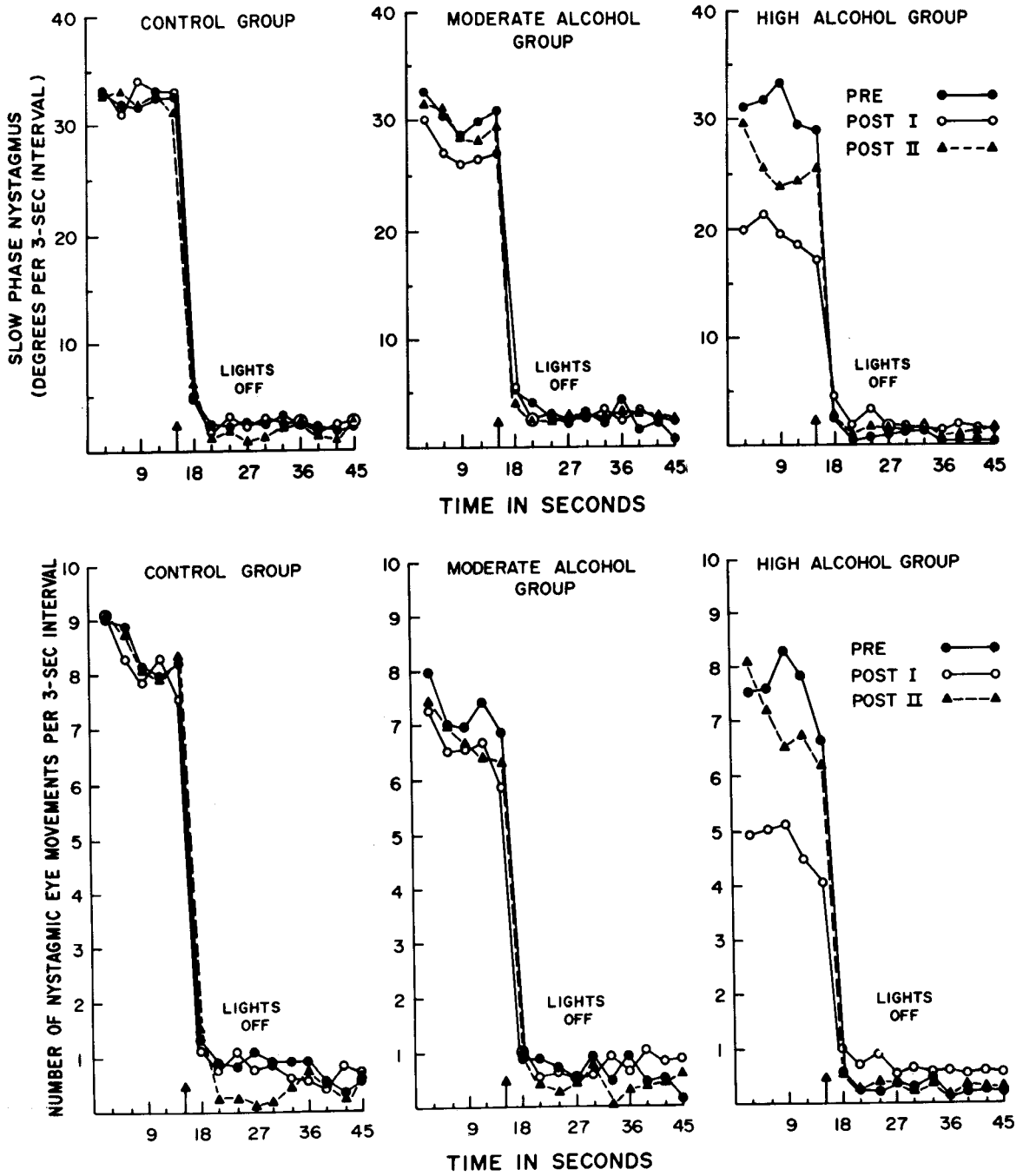

FIGURE 13. Response data for the average number of degrees of slow phase eye movement (upper half) and average number of nystagmic eye movements (lower half) resulting from the 15-second optokinetic trials. "Lights off" indicates that the room lights were turned off immediately after the end of the stimulus. Other symbols and markings are identical to those used in Figure 12.

TABLE 15.—Means and Standard Deviations for the Slow Phase Nystagmus Displacement (in Degrees) Resulting From the Optokinetic Stimuli. Each Group Was Comprised of Ten Subjects.

Group	Condition		15 sec			60 sec		
			Pre	Post I	Post II	Pre	Post I	Post II
Control	Lights On	M	165.1	155.8	158.0	616.7	618.0	604.4
		SD	25.4	29.5	32.4	126.0	78.3	105.5
	Lights Off	M	160.9	163.4	161.3	641.4	641.8	610.4
		SD	15.9	27.1	23.9	79.1	103.6	99.0
Moderate Alcohol	Lights On	M	157.3	138.9	150.3	637.1	518.4	551.4
		SD	15.7	36.6	36.4	75.5	114.4	117.2
	Lights Off	M	151.8	136.2	148.5	620.6	483.0	553.2
		SD	21.0	34.4	28.4	88.3	119.8	132.9
High Alcohol	Lights On	M	141.5	94.6	138.8	540.7	344.6	505.6
		SD	26.9	43.5	34.7	82.8	226.9	154.0
	Lights Off	M	154.6	92.1	129.7	580.6	343.2	511.4
		SD	23.3	58.5	28.4	145.5	260.0	140.7

TABLE 16.—Means and Standard Deviations for the Number of Nystagmic Beats Resulting From the Optokinetic Stimuli. Each Group Was Comprised of Ten Subjects.

Group	Condition		15 sec			60 sec		
			Pre	Post I	Post II	Pre	Post I	Post II
Control	Lights On	M	39.4	41.0	39.6	148.0	147.4	151.9
		SD	5.6	6.2	7.8	26.9	18.4	20.5
	Lights Off	M	42.1	41.1	42.2	154.2	158.4	159.9
		SD	4.9	5.9	5.7	14.5	16.4	16.8
Moderate Alcohol	Lights On	M	38.2	33.1	33.7	144.4	124.1	135.1
		SD	7.6	9.3	10.0	34.5	27.2	33.4
	Lights Off	M	36.4	33.0	34.0	136.2	115.3	126.5
		SD	8.1	8.7	8.1	31.1	26.0	30.8
High Alcohol	Lights On	M	35.6	24.7	35.8	141.4	81.7	130.5
		SD	8.0	6.5	6.1	31.3	46.7	22.6
	Lights Off	M	37.9	23.6	34.8	140.2	73.5	124.3
		SD	5.4	11.0	7.4	20.7	55.9	27.3

TABLE 17.—Results of the Analyses of Variance for the Number of Degrees of Slow Phase Nystagmus and Number of Nystagmic Eye Movements Resulting from Optokinetic Stimulation. Stimuli Were of 15 or of 60 Seconds Duration.

Measure	Group	Lights On		Lights Off	
		15-sec	60-sec	15-sec	60-sec
Slow Phase Displacement	Control	0.38	0.05	0.03	0.36
	Moderate Alcohol	0.88	3.46*	0.84	3.57
	High Alcohol	5.45**	4.00*	5.26*	4.12*
Frequency	Control	0.17	0.12	0.12	0.30
	Moderate Alcohol	0.95	1.02	0.44	1.17
	High Alcohol	7.29**	8.27**	8.27**	8.46**

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

TABLE 18.—Results of the Paired t Tests for the Pre vs. Post I and Pre vs. Post II Comparisons of Nystagmic Responses to the Optokinetic Stimuli.

Measure	Group	Comparison	15 second stimulus		60 second stimulus	
			Lights On	Lights Off	Lights On	Lights Off
Slow Phase Displacement	Control	Pre vs. Post I	0.97	0.50	0.05	0.02
		Pre vs. Post II	1.22	0.08	0.31	1.99
	Moderate Alcohol	Pre vs. Post I	2.23	1.72	4.32**	5.80***
		Pre vs. Post II	0.78	0.51	2.52*	2.01
	High Alcohol	Pre vs. Post I	3.10*	3.67**	3.14*	3.65**
		Pre vs. Post II	0.22	3.15*	0.88	1.58
Frequency	Control	Pre vs. Post I	1.11	0.84	0.11	1.11
		Pre vs. Post II	0.09	0.18	0.80	1.78
	Moderate Alcohol	Pre vs. Post I	2.18	1.68	2.17	2.86*
		Pre vs. Post II	1.31	1.99	1.02	1.22
	High Alcohol	Pre vs. Post I	3.28**	3.67**	4.06**	3.60**
		Pre vs. Post II	0.11	2.05	1.70	2.61*

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

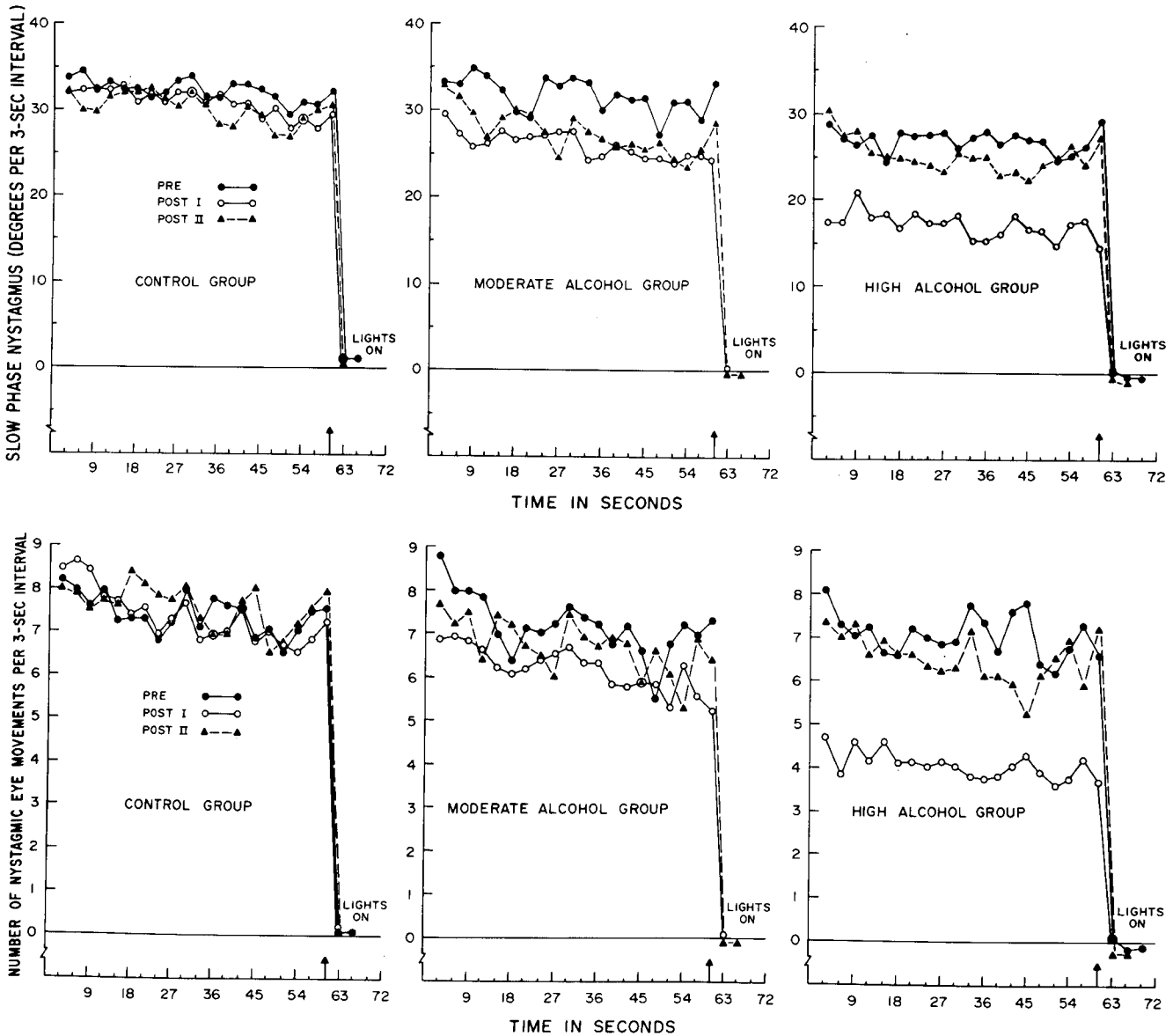

FIGURE 14. Response data for the average number of degrees of slow phase eye movement (upper half) and average number of nystagmic eye movements (lower half) resulting from the 60-second (lights on) optokinetic trials. Symbols and markings are identical to those used in Figure 12.

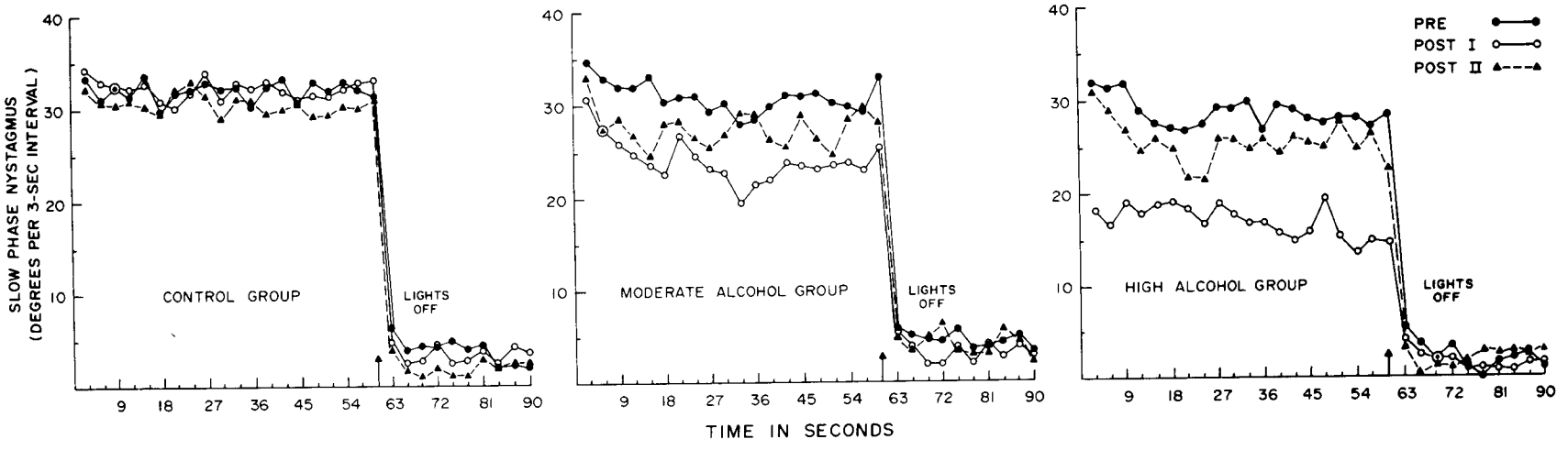

FIGURE 15. Response data for the average number of degrees of slow phase eye movement resulting from the 60-second (lights off) optokinetic trials. Symbols and markings are identical to those used in Figure 12.

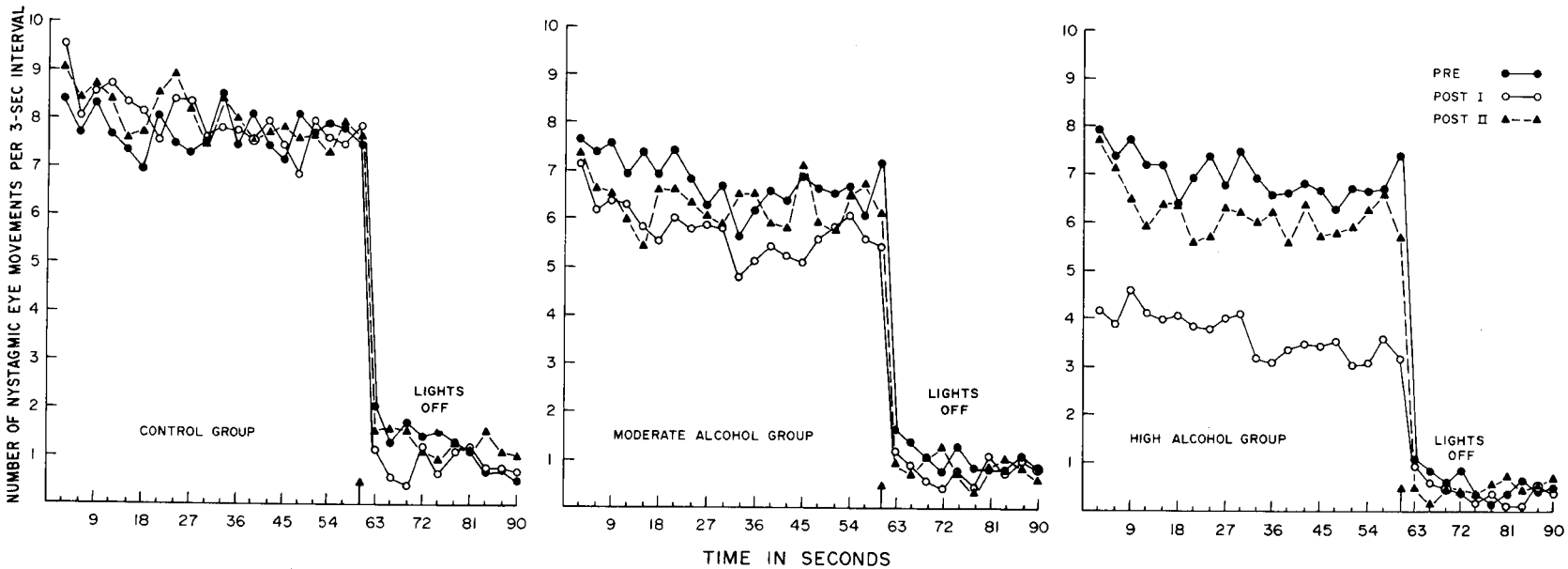

FIGURE 16. Response data for the average number of nystagmic eye movements resulting from the 60-second (lights off) optokinetic trials. Symbols and markings are identical to those used in Figure 12.

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