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ALCOHOL AND DISORIENTATION-RELATED RESPONSES: V. INFLUENCE OF ALCOHOL ON POSITIONAL, ROTATORY, AND CORIOLIS VESTIBULAR RESPONSES OVER 32-HOUR PERIODS

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16. Abstract

There are some indications that the systems most closely associated with disorientation responses--the visual and vestibular systems--may continue to show effects of alcohol ingestion for periods in excess of 24 hours. These effects may be evident both in static vestibular reactions and in dynamic reactions such as those which produce Coriolis vestibular effects. The present study sought to clarify some influences of alcohol on both static and dynamic vestibular responses over 32-hour post-drinking periods. Thirty male subjects were divided into three groups of ten each: Control (no alcohol), Bourbon, and Vodka. Each group underwent eye-movement monitoring for responses to positional, rotational, and Coriolis stimulation. The subjects were tested immediately prior to ingestion of the test or the control beverage and for regular intervals up to 32 hours thereafter. Blood alcohol levels were determined by gas chromatography. The usual PAN I and PAN II nystagmic responses were noted and, additionally, a direction-changing, positional nystagmus was obtained 24-32 hours after the ingestion of alcohol. More spontaneous nystagmus was noted among control subjects than might be expected from previous studies. Responses were generally depressed to angular accelerations and to Coriolis stimulation. There was no differential vestibular effect between congener and non-congener beverages. Implications of the results are discussed with emphasis on long-term vestibular effects of alcohol.

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I. Problem.

The concern that alcohol ingestion compromises the flying ability of pilots is manifest in the recent FAA regulation (FAR 91.11) prohibiting the drinking of alcoholic beverages during the 8-hour period prior to flying. Commercial airline companies have for years imposed a stricter limitation on their pilots in banning the use of alcohol for 24 hours preceding flight-time. However, there are some indications in the literature that the systems most closely associated with disorientation responses—the visual and vestibular systems—may continue to show effects of alcohol ingestion for periods in excess of 24 hours.[22] These effects may be evident both in static vestibular reactions (e.g., positional alcohol nystagmus; a patterned eye-movement response that occurs when the head is placed in certain positions after drinking alcohol) and in dynamic reactions such as those which produce Coriolis vestibular effects. The present study sought to clarify some influences of alcohol on both static and dynamic vestibular responses over 32-hour post-drinking periods.

Static Effects. Aschan, Bergstedt, Goldberg, and Laurell[2] described in detail two types of positional alcohol nystagmus (PAN): Type I, that beating in the direction of the lower ear (when the subject is lying on his side or when the subject rolls his head to one side while lying in a supine position), and Type II, beating in the direction opposite the lower ear. They found PAN I to begin approximately 30 minutes after the ingestion of alcohol and to persist for several hours, followed first by a latency period during which no positional alcohol nystagmus could be demonstrated, and then by PAN II which began about 5–6 hours after ingestion. Aschan et al.[2] reported PAN II to persist for various periods of time up to the fourteenth hour after alcohol ingestion.

Alcohol nystagmus occurring later than 14 hours has rarely been noted in the literature although Plenkers[20] and Walter[31] reported direct observation of the response (subjects wore Frenzel glasses) through 20 and 16 hours, respectively, following alcohol ingestion. In Plenker's study, one patient showed a PAN II response 20 hours after drinking at which time measurable concentrations of alcohol were still in his blood. The 16-hour post-drinking response (PAN II) reported by Walter apparently involved subjects who were allowed to continue drinking for some time after PAN I appeared. More recently, Ryback and Dowd[22] reported PAN II in six subjects 34 hours after the ingestion of alcohol, and Oosterveld[19] found PAN II occurring 44–48 hours after the ingestion of 50cc of whiskey in two subjects exposed to increased gravitation (2.5g).

Dynamic Effects. Alcohol has been reported by some to enhance the nystagmic response to caloric[15 21 26 27] and to simple rotational stimuli[15 25 28 29 30], and by others[6 11 14 16] to inhibit that response. With respect to subjective reactions, Barany[3] noted a weakened "vertigo" response following the ingestion of alcohol. Schroeder[23 24] clarified some of these apparent contradictions by demonstrating that both the "vertigo" and nystagmus occasioned by caloric irrigations or

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angular accelerations are reduced in darkness as a consequence of alcohol; on the other hand, the ability to inhibit nystagmus and "vertigo" by visual fixation in the light is impaired by drinking. However, Ryback and Dowd[22] have reported an increase in both nystagmus and the sensations occasioned by Coriolis vestibular stimulation (apparently in darkness) after the ingestion of alcohol; the authors reported that bourbon produced more pronounced effects in this regard than did vodka.

The present study was designed to evaluate the prolonged effects of two types of alcohol on the vestibular apparatus as evidenced by changes in electronystagmographic recordings and in subjective responses to positional, rotational, and Coriolis stimulation.

II. Method.

Subjects. Thirty male college students, ranging from 21 to 27 years of age, and screened as being either non-drinkers or "light to moderate" drinkers, were randomly assigned to one of three groups of ten subjects each. One group received 100-proof Smirnoff vodka as the test beverage, the second group received 101-proof Wild Turkey bourbon, and the third (control group) was given a non-alcoholic beverage. The beverages were imbibed over a 30-minute period following the administration of preliminary vestibular tests. With the exception of one subject who weighed 124 kg, each alcohol subject was given 2.5 ml/kg of liquor added to orange juice to a total volume of 1100 cc; the heavy subject was given an amount of alcohol equal to that of the heaviest other subject (102 kg). The control subjects imbibed 1100 cc of orange juice, to which a few drops of rum extract were added to give a distinct rum odor and some flavor.

Procedure. The subjects reported at 8:00 a.m. of the first test day after a light breakfast (at about 7:00 a.m.), usually toast or roll and coffee. A blood sample was drawn and electrode placement, instructions, and a practice rotation trial followed. The earliest time that alcohol was administered was 9:30 a.m. The subjects had previously been asked to refrain from drinking alcoholic beverages during the 24 hours prior to testing. All of the subjects denied the use of drugs. The subjects had meals with the research personnel and remained at the Institute overnight for the second day of testing.

Positional testing was done in a totally darkened examination room. The subject assumed a supine position on an examining table, with his eyes open, and his head elevated 30° so that the plane of the horizontal canals was approximately aligned with gravity; testing began with the head in this position (i.e., nose pointed up) for one minute. At signals from the experimenter, the subject turned his head to the left for one minute, rolled it back to upright for another minute, turned it to the right for one minute, and then rolled it upright for a final minute. Throughout the trial, the subject was given mental arithmetic problems to maintain alertness. Positional testing was done before drinking and 1, 2, 4, 6, 8, 10, 24, 27, 30, and 32 hours after drinking.

Rotational and Coriolis vestibular studies were accomplished in a modified Stille-Werner rotating chair (the rotating structure and the subject were totally enclosed). The head was fixed in a head-holder and a bite-block was used to position the horizontal canals approximately in the plane of rotation. The room was in total darkness and the subject was requested to keep his eyes open. The head-holder was adjusted so that the subject could make uniform head tilts of 30° to the left and to the right. The subject was accelerated at an angular rate of 5°/sec² to a constant velocity of 90°/sec; during this time he signalled his turning sensations. After approximately three minutes of constant rotation, the subject was instructed to tilt his head to the right and, later, to return to upright. Each head tilt was made in about one second with a rest period of at least one minute allowed following the end of the response to each tilt and return movement. The chair was then decelerated to a stop at 5°/sec² with the subject's head upright. First CCW (practice) then CW rotations were performed during the pre-alcohol testing. At 1, 2, 4, 8, 24, and 30 hours following alcohol ingestion, CW rotations were used. Throughout each trial, recordings were made of nystagmus and subjective signals.

Recordings. Silver disc electrodes were taped by the outer canthus of each eye to record horizontal components of eye movements. A second pair of electrodes was placed vertically about the left eye, one electrode above the eyebrow and one on the malar area, directly above and below the pupil in straight-ahead gaze. The electrodes

picked up changes in corneo-retinal potential and relayed them through a terminal board to an Offner Type T electroencephalograph. These signals were then amplified, using a three-second time constant, and recorded. Eye-movement calibrations were obtained prior to positional and rotational testing.

Subjective reactions were also recorded. Each subject signalled the start and end of his turning sensation to acceleration stimuli and the beginning and end of his sensations of apparent "climb" or "dive" occasioned by his head movements during constant velocity; he also rated the intensity of the sensations arising from the head movements. The stronger of the initial two head movements (a tilt and a return) was rated as 100%; all subsequent effects were rated by each subject with reference to his 100% "standard."

Blood Samples. Prior to the drinking period, a venous blood sample was drawn from all subjects. Other venous samples were obtained from the two alcohol groups at 1, 2, 4, 8, and 24 hours after the drinking period; a 6-hour sample was also drawn from most subjects. Only pre-drinking and 24-hour blood samples were obtained from the control group. Gas chromatography was used to determine the blood alcohol levels.

Scoring. Nystagmic responses to the accelerations were scored for duration, frequency of eye movements, and slow-phase displacement. The slow-phase eye movement was scored by measuring in millimeters the amplitude of each nystagmic beat from the peak to baseline; these values were summed for three-second intervals and converted to degrees by using the calibration constant obtained prior to each trial.

Vertical components of nystagmic responses to Coriolis stimulation were scored for duration and frequency. Since these vertical responses are frequently of low amplitude, and since blocking of the recording pens and superimposition of blink reflexes are not unusual effects obtained in recording Coriolis nystagmus, slow-phase displacement measurements were not made.

Positional responses were rated independently by the authors on a 0 (no nystagmus) to 4 (vigorous nystagmus) scale. A rating of "0" was given when no positional nystagmus was seen; "1" represented the occurrence of only a few beats of low-amplitude nystagmus; a rating of "2" was assigned when regular-beating nystagmus with a relatively low slow-phase velocity was observed; "3" denoted a high frequency, regular nystagmus; and "4" represented a vigorous response of regular frequency and of high slow-phase velocity. In practice, half-step ratings (e.g., "1.5") were frequently made. An average rating for each head position was obtained for each subject.

III. Results.

Mean blood alcohol levels and their standard deviations were computed by sessions for each group (see Table 1). No measurable ethanol content was obtained from any subject during the Pre-tests or 24 hours after alcohol ingestion. In general, the Bourbon Group showed slightly higher mean blood-alcohol levels than did the Vodka Group, but the differences in no case reached statistical significance at the .05 level.

TABLE 1

Means and standard deviations in per cent for blood alcohol levels derived for the three groups. (N=10 for all calculations unless otherwise indicated.)

Group		Session						
		Pre	1-hr	2-hr	4-hr	6-hr	8-hr	24-hr
Control	Mean	0	No Samples Drawn					0
	SD	0						0
Bourbon	Mean	0	.104	.097	.067	.036*	.002	0
	SD	0	.027	.012	.011	.009	.003	0
Vodka	Mean	0	.092	.088	.065	.032	.005	0
	SD	0	.019	.017	.019	.020	.006	0

* Samples drawn only from four subjects.

Static Tests

Mean ratings of the positional responses appear in Table 2 according to direction of nystagmus and head position. A tabulation of subjects who showed apparent nystagmus in the various head positions is in Table 3.

The data in Tables 2 and 3 provide several points of interest. First, among all three groups, a considerable number of subjects showed some apparent positional responses during the Pre-tests. Second, although nystagmus frequently was not very strong, the number of Control subjects who showed some apparent positional responses varied considerably across the 11 test sessions. For example, rolling the head to the left produced some apparent nystagmus to the

left in 5–6 Controls and to the right in 1–3 subjects, depending upon the test session (see Table 3). Similarly, rolling the head to the right resulted in apparent left-beating responses in 3–6 Control subjects and right-beating responses in 0–5 Controls, again depending upon the test session. As a third point of interest, both groups of alcohol subjects demonstrated clear PAN I during the first four hours following the ingestion of alcohol. During the 6-through-10-hour sessions, PAN II responses were consistently evident. For the 24-through-32-hour sessions, responses in the direction of PAN I were again predominant, although relatively weak.

TABLE 2

Positional Responses:

Mean ratings (0-4 scale) and direction of nystagmus from positional tracings obtained in darkness for upright, left, and right positions of the head during pre- and post-drinking sessions.

		Head Position								
		Control			Bourbon			Vodka		
Session	Direction of Nystagmus	U	L	R	U	L	R	U	L	R
Pre	L	.37	.47	.25	.07	.27	.27	.10	.10	.13
	R	.07	.08	.25	.13	.13	.00	.03	.12	.20
1-hour	L	.30	.72	.25	.10	3.15	.00	.00	3.23	.00
	R	.03	.10	.00	.00	.00	3.08	.13	.00	3.08
2-hour	L	.35	.63	.35	.37	2.90	.00	.10	2.83	.00
	R	.07	.10	.27	.00	.00	2.85	.13	.00	2.68
4-hour	L	.40	.58	.27	.05	1.08	.10	.02	.57	.03
	R	.00	.10	.13	.00	.00	.87	.07	.03	.58
6-hour	L	.18	.45	.37	.13	.10	.78	.03	.00	1.15
	R	.02	.15	.17	.03	.72	.00	.00	.98	.00
8-hour	L	.25	.38	.42	.22	.26	1.03	.08	.00	1.60
	R	.00	.10	.02	.00	.92	.13	.07	1.22	.00
10-hour	L	.28*	.47*	.17*	.07	.00	.78	.20	.00	1.07
	R	.07	.00	.02	.00	.65	.00	.05	.77	.00
24-hour	L	.27	.67	.15	.03	.23	.00	.08	.63	.13
	R	.00	.10	.22	.07	.03	.27	.02	.12	.23
27-hour	L	.33**	.43**	.20**	.07	.33	.10	.05	.50	.05
	R	.00	.00	.07	.00	.05	.30	.08	.00	.35
30-hour	L	.30	.52	.40	.07	.45	.00	.03	.50	.07
	R	.03	.20	.00	.03	.00	.45	.08	.05	.25
32-hour	L	.13**	.38**	.15**	.03	.37	.02	.03	.55	.17
	R	.02	.08	.07	.07	.00	.22	.08	.00	.33

*N = 8 **N = 7

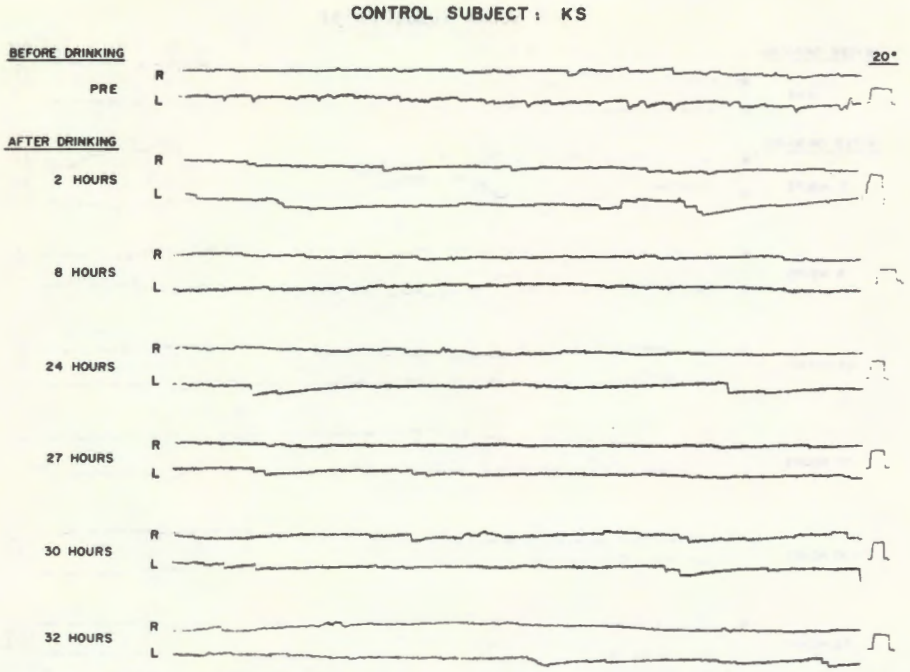

FIGURE 1. Positional nystagmus recorded from a control subject upon rolling his head to the right (R) and to the left (L) prior to drinking (non-alcoholic beverage) and during several post-drinking test sessions. Note differences in the response from session to session.

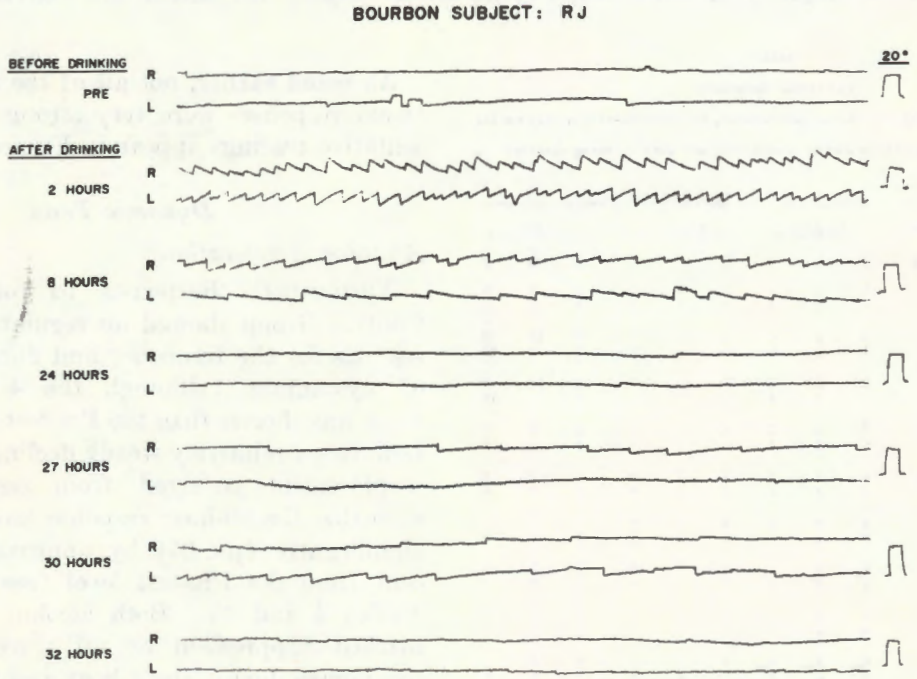

FIGURE 2. Positional nystagmus recorded from a subject in the Bourbon group upon rolling his head to the right (R) and to the left (L) prior to drinking and during several post-drinking test sessions. This subject shows typical PAN I and PAN II responses and, on the second day, gave the strongest positional nystagmus (in the same direction as PAN I) of all alcohol subjects. He is also the only subject, not accounted for by Pre-drinking tests, to show "PAN-II-type" responses on the second day (during the 27-hour test only).

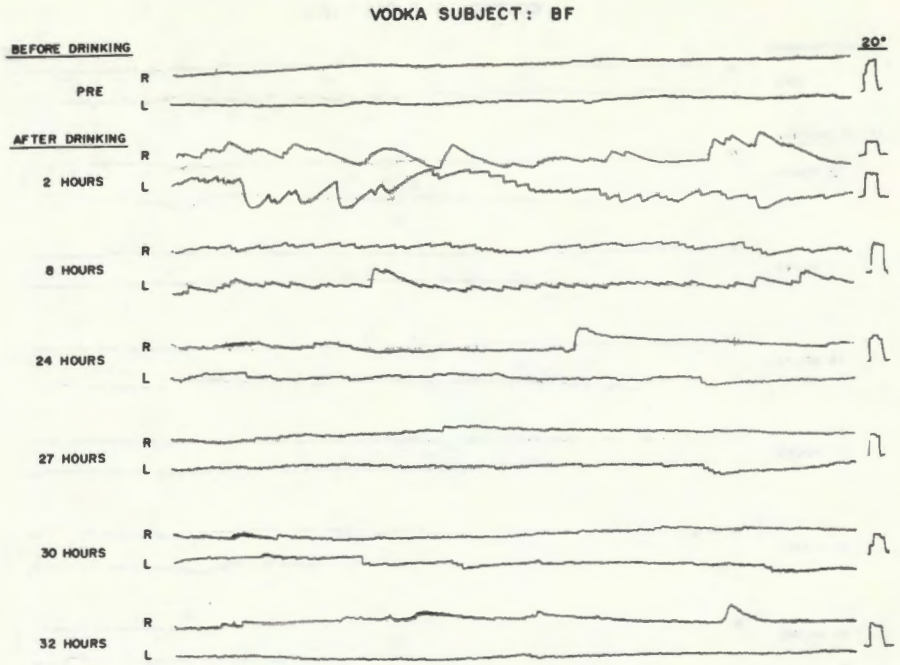

FIGURE 3. Positional nystagmus recorded from a subject in the Vodka group upon rolling his head to the right (R) and to the left (L) prior to drinking and during several post-drinking test sessions. PAN I and PAN II responses are vigorous. The positional nystagmus obtained during the second day is relatively typical, in terms of intensity and frequency, of that exhibited by the several subjects who showed such responses after a night of rest.

TABLE 3

Positional Responses:

The number of subjects who showed left-beating or right-beating nystagmus for the various head positions during static pre- and post-drinking sessions.

		Head Position								
	Direction of	Control			Bourbon			Vodka		
Session	Nystagmus	U	L	R	U	L	R	U	L	R
Pre	L	4	5	3	1	4	5	2	3	4
	R	1	1	5	2	3	0	1	1	3
1-hour	L	5	6	4	3	10	0	0	10	0
	R	1	1	0	0	0	10	2	0	10
2-hour	L	5	6	6	4	10	0	3	10	0
	R	1	1	2	0	0	10	3	0	10
4-hour	L	7	6	5	1	9	1	1	8	1
	R	0	2	2	0	0	7	1	1	7
6-hour	L	4	5	3	2	1	8	1	0	8
	R	1	3	2	1	8	0	0	9	0
8-hour	L	5	5	5	4	2	9	3	0	10
	R	0	1	1	0	8	1	1	10	0
10-hour	L	4*	6*	2*	1	0	10	3	0	10
	R	1*	0*	1*	0	6	0	1	8	0
24-hour	L	5	6	4	1	5	0	2	7	3
	R	0	2	4	1	1	5	1	2	3
27-hour	L	4**	5**	3**	2	5	1	2	6	1
	R	1**	0**	2**	0	2	5	1	0	6
30-hour	L	5	6	4	1	8	0	1	7	1
	R	0	3	0	1	0	5	2	1	3
32-hour	L	3**	5**	2**	1	5	1	1	6	2
	R	1**	1**	1**	1	0	4	1	0	7

* N = 8 ** N = 7

As noted earlier, not all of the apparent positional responses were very strong. Some representative tracings appear in Figures 1–3.

Dynamic Tests

Angular Acceleration

Nystagmus. Responses to rotation by the Control Group showed no regular change across sessions for the frequency and duration measures of nystagmus (although the 4-hour duration score was shorter than the Pre-test score, $p<.05$); however, a relatively steady decline in slow phase displacement occurred from session-to-session, such that the 30-hour response level was reduced significantly ($p<.05$) by approximately 30 per cent from the Pre-test level (see Figure 4 and Tables 4 and 5). Both alcohol groups had a marked suppression of all three measures of nystagmus during the 1-hour and 2-hour sessions ($p<.05-.001$) with substantial recovery evident during the 4-hour session; slow-phase displacement showed the most prolonged reduction (see Table 5). There was somewhat less mean decline

TABLE 4

Angular Accelerations:

Means and standard deviations by session for total slow phase displacement, frequency, and duration of horizontal nystagmus and for the duration of the turning sensation produced by the angular accelerations of $5°/sec^2$ for 18 seconds.

Measure	Group		Session Pre	1-hr	2-hr	4-hr	8-hr	24-hr	30-hr
Slow Phase Nystagmus (Degrees)	Control	Mean	489.6	434.8	421.2	408.4	440.8	389.8	357.1
		SD	241.4	140.7	164.0	173.5	205.0	176.9	164.4
	Bourbon	Mean	643.4	342.1	366.0	455.8	444.7	469.6	453.1
		SD	360.2	112.3	164.5	175.4	167.5	202.1	203.7
	Vodka	Mean	625.2	482.0	414.2	486.9	500.8	512.1	411.8
		SD	152.9	228.5	136.7	155.9	181.9	176.4	137.3
Number of Nystagmic Beats	Control	Mean	70.6	70.8	71.9	68.3	71.0	73.8	69.8
		SD	21.9	22.1	20.3	20.0	20.1	20.0	20.2
	Bourbon	Mean	87.8	57.7	61.8	71.3	75.7	79.3	84.0
		SD	23.3	16.7	21.7	20.4	25.6	31.3	30.1
	Vodka	Mean	87.4	68.5	70.3	81.3	84.5	80.1	84.8
		SD	16.0	16.0	17.6	21.6	24.0	15.6	23.9
Duration of Nystagmus (Seconds)	Control	Mean	52.3	50.3	48.6	48.2	50.9	48.9	49.3
		SD	10.8	11.4	10.4	9.0	11.8	9.3	10.4
	Bourbon	Mean	57.9	43.0	40.0	47.2	55.8	53.8	55.3
		SD	11.8	8.4	5.8	9.2	18.4	15.9	11.6
	Vodka	Mean	58.8	49.3	44.2	53.4	51.6	52.1	52.5
		SD	10.3	8.1	11.8	22.6	11.1	8.5	9.4
Duration of Sensation (Seconds)	Control	Mean	33.6	31.1	31.1	30.6	32.4	34.1	34.0
		SD	10.5	8.3	8.0	8.5	9.2	9.5	8.5
	Bourbon	Mean	35.2	27.0	29.4	34.1	33.5	36.2	37.5
		SD	11.4	8.9	11.1	10.5	11.5	14.4	17.8
	Vodka	Mean	27.1	20.5	21.7	23.3	25.2	25.5	25.7
		SD	7.6	4.6	5.9	4.7	4.8	6.2	5.3

TABLE 5

Angular Accelerations:

Results of statistical evaluations (t tests for correlated data) of the significance of the differences between Pre-drinking measures and those obtained after drinking.

Measure	Group	t for Pre-Drinking Session vs. Post-Drinking Sessions 1-hour	2-hour	4-hour	8-hour	24-hour	30-hour
Slow Phase Nystagmus (Degrees)	Control	1.22	1.29	1.73	0.95	2.08	2.82*
	Bourbon	2.90*	2.99*	2.77*	2.93*	2.15	1.98
	Vodka	2.39*	5.45***	4.33**	2.70*	2.80*	6.61***
Number of Nystagmic Beats	Control	-0.05	-0.22	-0.38	-0.06	-0.54	0.11
	Bourbon	3.88**	3.09*	2.48*	1.68	1.23	0.47
	Vodka	3.96**	3.54**	1.06	0.83	2.51*	0.63
Duration of Nystagmus (Seconds)	Control	1.98	2.10	3.54*	1.44	1.41	1.46
	Bourbon	3.46**	4.36**	2.74*	0.66	1.23	1.29
	Vodka	4.43**	8.58***	1.03	2.80*	2.68*	2.11
Duration of Sensation (Seconds)	Control	1.34	1.83	1.58	0.69	-0.25	-0.12
	Bourbon	3.69**	1.95	0.91	1.27	-0.61	-0.79
	Vodka	3.27**	2.45*	1.59	0.74	0.60	0.69

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

TABLE 6

Angular Accelerations:

Results of statistical evaluations (t tests) of the significance of the differences between groups. Comparisons were made of the percentage of change between Pre-drinking measures and those obtained after drinking for Control (C), Bourbon (B), and Vodka (V) subjects.

Measure	Comparison	t 1-hour	2-hour	4-hour	8-hour	24-hour	30-hour
Slow Phase Nystagmus (Degrees)	C vs. V	1.74	2.06	1.11	1.31	0.41	1.38
	C vs. B	2.64*	1.43	0.61	1.68	0.58	0.04
	V vs. B	0.92	0.16	0.32	0.31	0.26	1.13
Number of Nystagmic Beats	C vs. V	2.83*	2.24*	1.15	1.46	1.68	1.21
	C vs. B	2.97**	2.27*	1.63	1.68	1.58	0.81
	V vs. B	0.77	0.45	0.67	0.62	0.04	0.36
Duration of Nystagmus (Seconds)	C vs. V	3.05**	4.19***	0.50	2.19 *	0.88	0.78
	C vs. B	2.96**	3.32**	1.45	0.28	0.31	0.23
	V vs. B	1.13	0.50	0.61	1.12	0.45	0.96
Duration of Sensation (Seconds)	C vs. V	1.64	1.07	0.11	0.16	0.25	0.50
	C vs. B	2.25*	0.89	0.94	0.39	0.23	0.16
	V vs. B	0.18	0.12	0.65	0.38	0.13	0.40

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

and somewhat more rapid recovery for the Vodka as compared with the Bourbon Group, but these comparative trends were not statistically significant at the .05 level (Table 6). There was no significant "recovery" during the 24-hour session (after a night of rest) probably due to the relatively small changes evident in a comparison of the Pre-session output with that of the 8-hour session.

In comparing the groups, only the 1-hour and 2-hour sessions yielded any significant differences in nystagmus measures. During both of those sessions, the two alcohol groups produced shorter durations and fewer beats of nystagmus than did the Control Group. In addition, the Bourbon Group had less slow-phase nystagmus and shorter durations of their turning sensations than did the Control Group during the 1-hour post-drinking session. No other difference among the groups was statistically reliable, and in no case did any of these four measures of responses to angular acceleration yield any significant differences between the Bourbon and the Vodka groups (Table 6).

Time-course comparisons of nystagmus obtained during the Pre-test and at the 2- and 8-hour post-drinking sessions indicated a clear depression of both slow phase and frequency measures (Figures 5 and 6) during the 2-hour

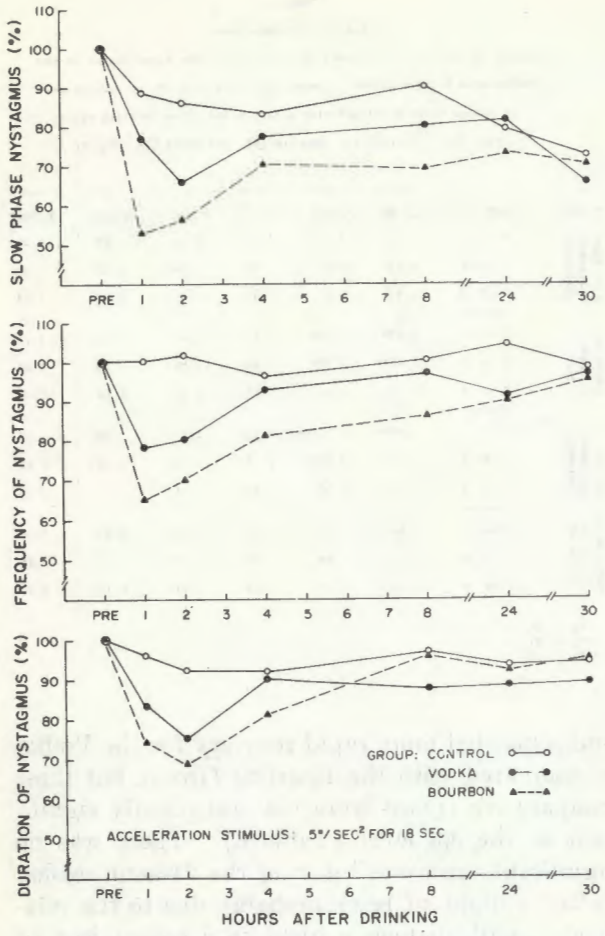

FIGURE 4. Plots of the nystagmic response measures to angular acceleration during several post-drinking test sessions expressed as percentages of the Pre-drinking levels. There is a marked decline in frequency, slow phase displacement, and duration of nystagmus during the first two hours after alcohol ingestion in the Bourbon and Vodka subjects. At no time was any response enhancement evident after alcohol ingestion.

session and some recovery during the 8-hour session for both alcohol groups; Control subjects produced no significant changes. These effects of alcohol on angular-acceleration responses confirm the work of Schroeder.[23] Additional time-course comparisons of nystagmus output appear in Figures 7 and 8 for the Pre, the 24-hour, and the 30-hour sessions. For all three groups of subjects, there was no marked change in frequency measures, but slow phase nystagmus was reduced from the Pre-test levels as a function of repeated stimulation.

Turning Sensation. Plots of the duration of the turning sensation occasioned by the angular accelerations were similar to nystagmus plots, i.e., both alcohol groups showed a drop from the pre-drinking level to the 1-hour post-ingestion session ($p<.01$) and recovery thereafter (Figure 9). The Control Group had no marked change in mean duration across the test sessions (Table 5). There was a slight but general tendency for longer durations (recovery) of the sensation after a night of rest (i.e., during the 24-hour session). Group comparisons yielded only one significant difference: The Bourbon Group reported shorter durations ($p<.05$) than Control subjects one hour after drinking (Table 6).

Coriolis Stimulation

Nystagmus. The duration and the frequency measures of vertical nystagmus yielded fairly consistent group patterns across sessions for the Head Tilts and for the Return-To-Upright head movements considered independently, but apparently different patterns for the two head movements (Figures 10 and 11). Thus, for the Control Group, both measures of nystagmus during Head Tilts increased from Pre levels during the 1- and 2-hour sessions and then declined steadily; the alcohol groups showed a lesser increase or none at all during the 1- and 2-hour post-drinking sessions, and somewhat variable values across the other sessions (Table 7). However, tracings for the alcohol groups were not always readily scorable, especially during the 1- and 2-hour post-ingestion sessions. For example, as indicated in Table 7, only five Vodka subjects provided scorable records for Head Tilts during the first post-drinking test. In some cases, blocking of the recording pens prevented scoring, in others positional nystagmus became superimposed on the Coriolis response and confounded measurement. In general, good tracings were obtained from all groups during the Pre, 8-, 24-, and 30-hour sessions (see Figure 12). Since the 8-hour session showed duration and frequency scores that ranged from 93–110 per cent of Pre-values, no "recovery" was evident during the 24-hour session.

For Return-To-Upright head movements, however, declines for both measures were greater during the first day for both alcohol groups, and all three groups produced a response during the 24-hour session that was elevated from that of the 8-hour session (i.e., some recovery may have occurred). Comparison of Pre-drinking meas-

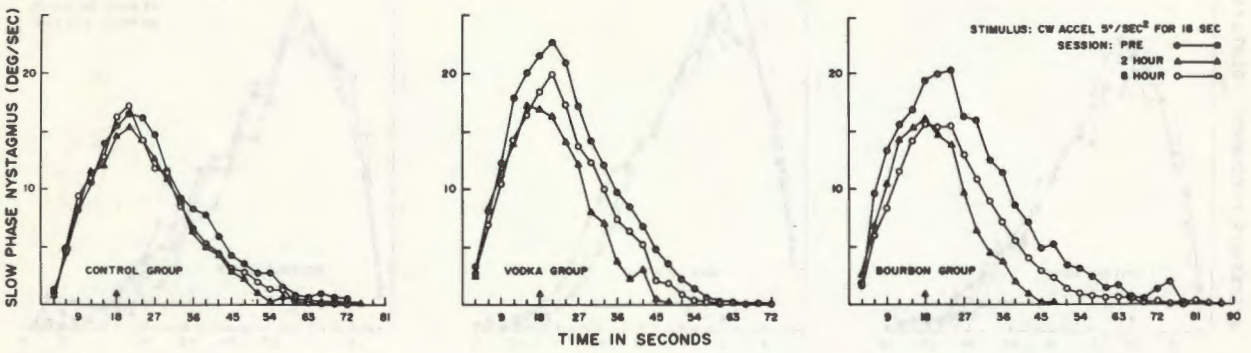

FIGURE 5. Time-course plots of slow phase nystagmus in 3-second intervals for the Pre, 2-hour, and 8-hour angular accelerations. Alcohol depresses nystagmus in darkness.

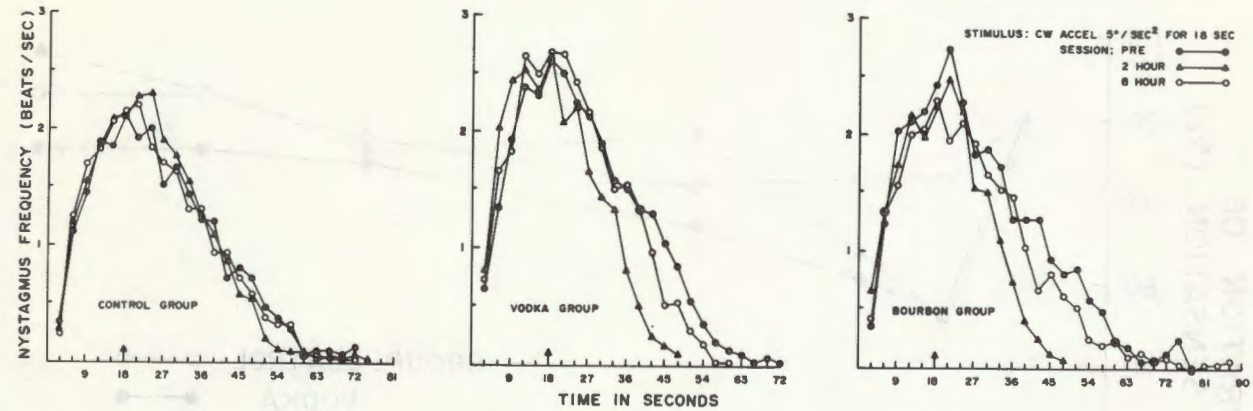

FIGURE 6. Time-course plots of the frequency of nystagmus in 3-second intervals for the Pre, 2-hour, and 8-hour angular accelerations. The alcohol-depressed responses during the 2-hour session show some recovery in the 8-hour session. Compare with Figure 5.

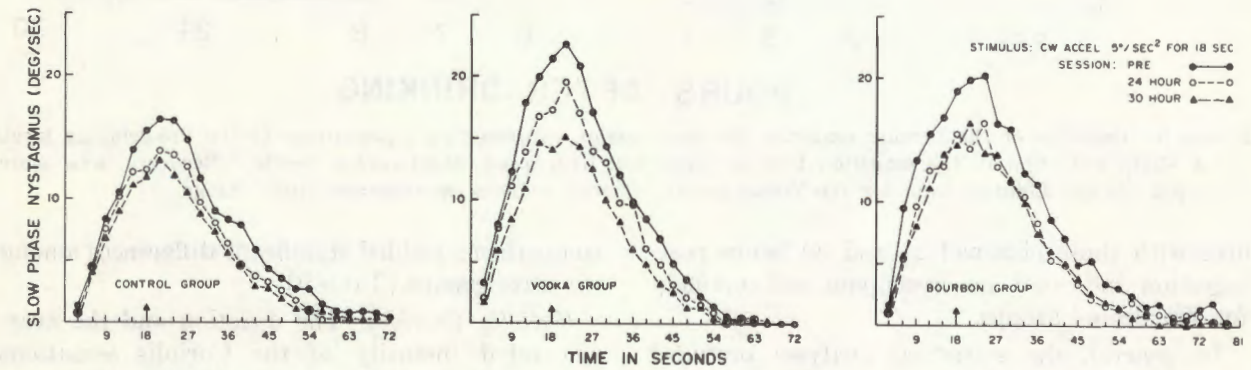

FIGURE 7. Time-course plots of slow phase nystagmus in 3-second intervals for the Pre, 24-hour, and 30-hour angular accelerations. All groups show reduced slow-phase activity as a result of repeated stimulation.

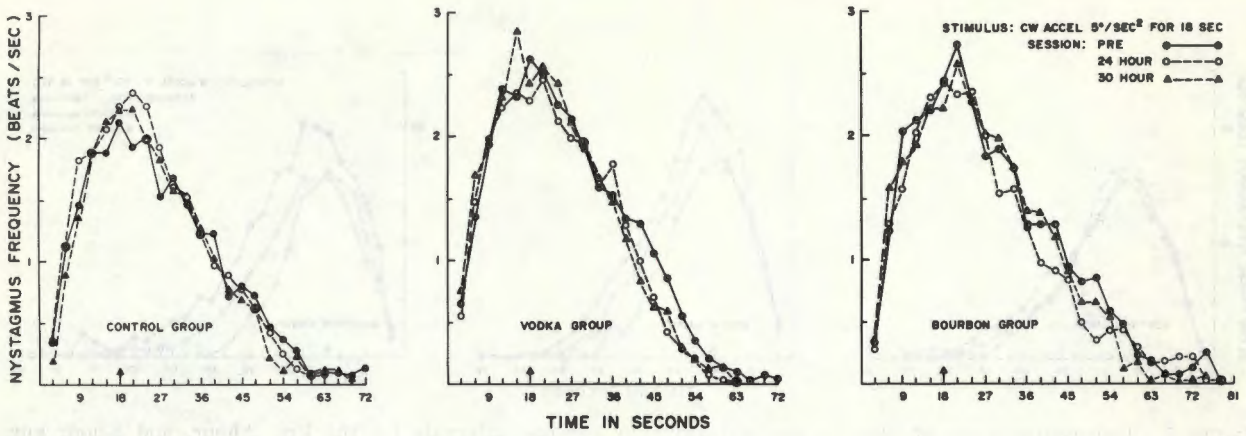

FIGURE 8. Time-course plots of the frequency of nystagmus in 3-second intervals for the Pre, 24-hour, and 30-hour angular accelerations. Eye-movement frequency was not significantly changed by the repeated trials. Compare with Figure 7.

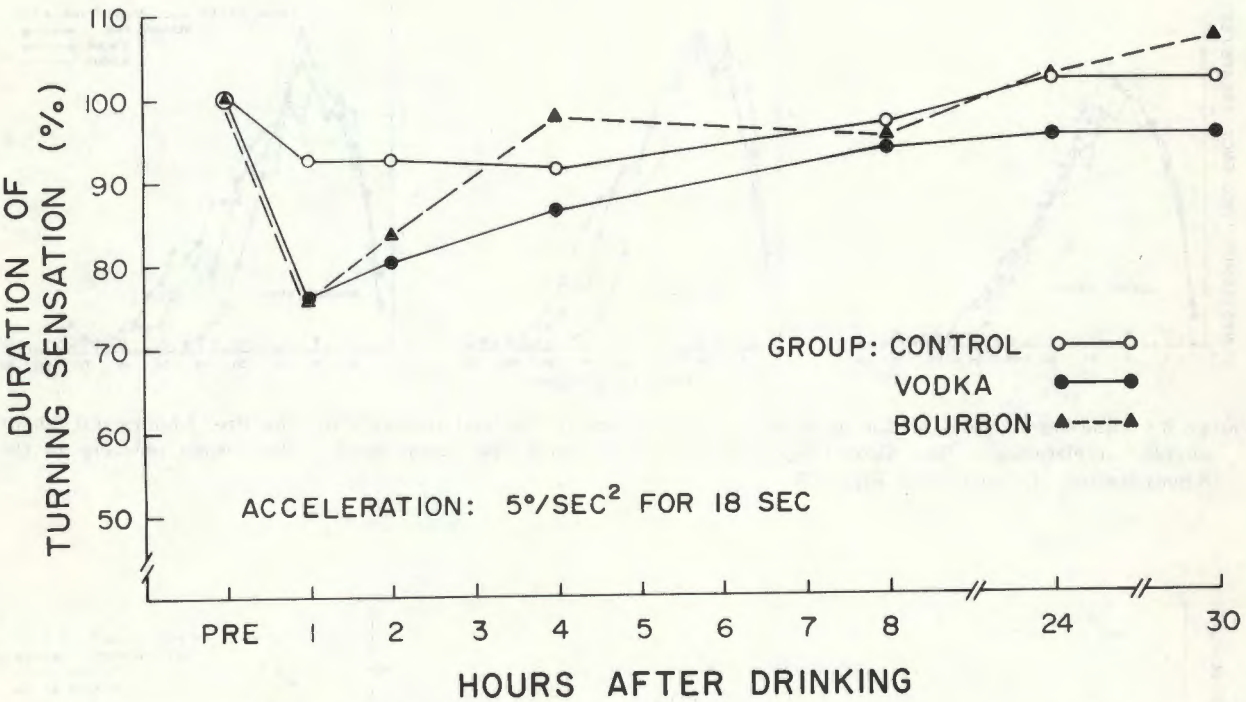

FIGURE 9. Duration of the turning sensation for each session expressed as a percentage of the Pre-drinking level. A sharp reduction in the sensation time is correlated with peak blood-alcohol levels. Recovery was more rapid for the Bourbon than for the Vodka group. Control subjects demonstrated little change.

ures with those obtained 24 and 30 hours post-ingestion indicated no nystagmus enhancement for the alcohol groups.

In general, the statistical analyses provided no evidence for a significant pattern of change across sessions (Table 8), and only two of 72 comparisons yielded significant differences among the three groups (Table 9).

Coriolis Vertigo. The duration and the average rated intensity of the Coriolis sensations were relatively similar for both Tilt and Return movements of the head within each group (see

TABLE 7

Coriolis (Vertical) Nystagmus:

Means and standard deviations by session for the frequency and duration of vertical nystagmus produced by 30° head tilts and return-to-upright head movements during rotation at 15 rpm.

Measure	Group		Session Pre	1-hr	2-hr	4-hr	8-hr	24-hr	30-hr
	HEAD TILTS								
Number of Nystagmic Beats	Control	Mean	14.7	18.9	20.0	16.9	15.4[c]	12.7	13.2
		SD	8.5	11.7	11.3	11.5	10.5	9.2	9.8
	Bourbon	Mean	18.6	20.3	19.6	17.2	18.7	16.3	18.6
		SD	8.7[a]	9.8[a]	7.8[a]	7.0[a]	9.0[a]	6.7[a]	6.8[a]
	Vodka	Mean	17.0	14.6	14.8	15.7	16.2	16.4	16.8
		SD	9.8[a]	3.3[a]	2.9[d]	5.8[c]	7.2[a]	7.7	6.7
Duration of Nystagmus (Seconds)	Control	Mean	14.1	16.5	16.5	14.0	13.5	11.9	10.9
		SD	5.4	5.6	8.0	6.2	5.1[c]	5.4	5.7
	Bourbon	Mean	12.9	12.9	11.3	11.0	14.2	12.0	12.4
		SD	3.6[a]	4.0[a]	4.6[a]	3.0[a]	5.6[a]	3.0[a]	2.6[a]
	Vodka	Mean	13.8	13.5	9.6	11.9	12.9	11.5	11.3
		SD	6.9[a]	4.2[e]	1.0[d]	2.3[c]	5.6[a]	5.2	2.9
	RETURN HEAD MOVEMENTS								
Number of Nystagmic Beats	Control	Mean	15.3	13.3	13.4	14.0	14.8	17.9	12.7
		SD	7.1	6.0	6.4	5.4[a]	6.4	9.6	8.5
	Bourbon	Mean	13.6	9.6	10.7	11.1	11.0	13.6	11.7
		SD	4.4[a]	3.4[b]	5.2[c]	5.8[a]	6.0[a]	5.9[a]	3.7[a]
	Vodka	Mean	15.3	10.1	11.6	9.1	9.0	11.0	12.7
		SD	5.3[a]	5.7[b]	7.6[a]	5.5	3.9	6.8	8.2[a]
Duration of Nystagmus (Seconds)	Control	Mean	11.0	10.0	8.8	9.2	9.3	11.9	8.9
		SD	5.4	3.2	3.1	3.3[a]	2.7	6.5	4.2
	Bourbon	Mean	12.1	8.5	10.6	10.7	7.3	9.1	8.5
		SD	3.6[a]	4.0[b]	3.9[c]	4.3[a]	3.5[a]	2.9[a]	3.3[a]
	Vodka	Mean	10.8	8.0	8.1	9.4	7.0	10.1	9.6
		SD	2.8[a]	3.3[b]	4.0[a]	3.8	1.7	4.0	3.9[a]

(NOTE: N=10 for all means unless otherwise indicated; [a]N=9; [b]N=8; [c]N=7; [d]N=6; [e]N=5.)

TABLE 8

Coriolis (Vertical) Nystagmus:

Results of statistical evaluations (t tests for correlated data) of the significance of the differences between Pre-drinking measures of nystagmus and those obtained after drinking.

Measure	Group	t for Pre-Drinking Session Vs. Post-Drinking Sessions 1-hour	2-hour	4-hour	8-hour	24-hour	30-hour
	HEAD TILTS						
Number of Nystagmic Beats	Control	-2.34*	-2.49*	-1.23	-0.32	1.27	0.84
	Bourbon	-0.40	-0.25	0.47	-0.06	1.12	0
	Vodka	0.08	-0.13	-0.90	0.64	0.16	-0.40
Duration of Nystagmus	Control	-1.69	-1.08	0.08	0.32	1.37	1.26
	Bourbon	-0.01	1.03	1.24	-0.65	0.59	0.37
	Vodka	-0.34	1.86	0.62	1.15	2.83*	1.42
	RETURN HEAD MOVEMENTS						
Number of Nystagmic Beats	Control	1.07	0.98	0.96	0.97	-1.71	1.00
	Bourbon	3.15*	0.79	1.37	1.04	0	1.66
	Vodka	1.52	0.82	1.75	4.54**	1.22	0.77
Duration of Nystagmus	Control	0.90	1.44	0.87	1.54	-0.61	1.38
	Bourbon	1.83	1.42	0.83	2.82*	1.88	2.30
	Vodka	1.43	1.38	1.12	4.28**	0.12	1.29

*p < .05
**p < .01

(NOTE: The N used for the various comparisons can be determined from Table 6.)

TABLE 9

Coriolis (Vertical) Nystagmus:

Results of statistical evaluations (t tests) of the significance of the differences between groups. Comparisons were made of the percentage of change between Pre-drinking measures and those obtained after drinking for Control (C), Bourbon (B), and Vodka (V) subjects.

Measure	Comparison	t 1-hour	2-hour	4-hour	8-hour	24-hour	30-hour
	HEAD TILTS						
Number of Nystagmic Beats	C vs. V	1.17	1.15	0.43	0.76	0.91	1.46
	C vs. B	0.06	0.73	0.65	0.47	0.51	1.07
	V vs. B	0.69	0.58	0.90	0.38	0.31	0.33
Duration of Nystagmus	C vs. V	0.66	1.94	0.50	0.44	0.21	0.33
	C vs. B	0.50	1.75	0.10	0.45	0.81	0.91
	V vs. B	0.07	0.62	0.46	0.85	0.77	0.75
	RETURN HEAD MOVEMENTS						
Number of Nystagmic Beats	C vs. V	0.43	0.08	0.95	2.48*	2.25*	0.01
	C vs. B	1.13	0.12	0.58	0.03	1.08	0.28
	V vs. B	0.28	0.03	0.32	1.05	1.28	0.27
Duration of Nystagmus	C vs. V	0.38	0.14	0.40	1.79	0.72	0.09
	C vs. B	1.80	0.05	0.29	1.86	2.03	1.10
	V vs. B	1.37	0.09	0.09	0.48	1.56	1.16

*p < .05

(NOTE: The N used for the various comparisons can be determined from Table 7.)

Figures 13 and 14). There was a general decline in both measures across sessions during the first day and no striking changes during the following day. There were some apparent differences among the groups, however. For Head Tilts, both the Control and Bourbon subjects showed some declines across sessions for both intensity and duration measures; many of these declines were significantly below Pre levels (see Tables 10 and 11). Only one of the 12 statistical comparisons yielded a significant decline in these same measures for the Vodka group. For Head Returns, there were few statistically significant declines for the two measures of Coriolis sensations, but all of these (four in intensity and one in duration) occurred for the Vodka group. However, in comparing the groups, no statistically significant differences were obtained at any session for the intensity measure and only one of 36 group comparisons yielded a significant difference for the duration measure (Table 12).

IV. Discussion.

Static Effects

Alcohol Subjects. The demonstration of the regular appearance of PAN I and then PAN II during the first ten hours of testing after alcohol

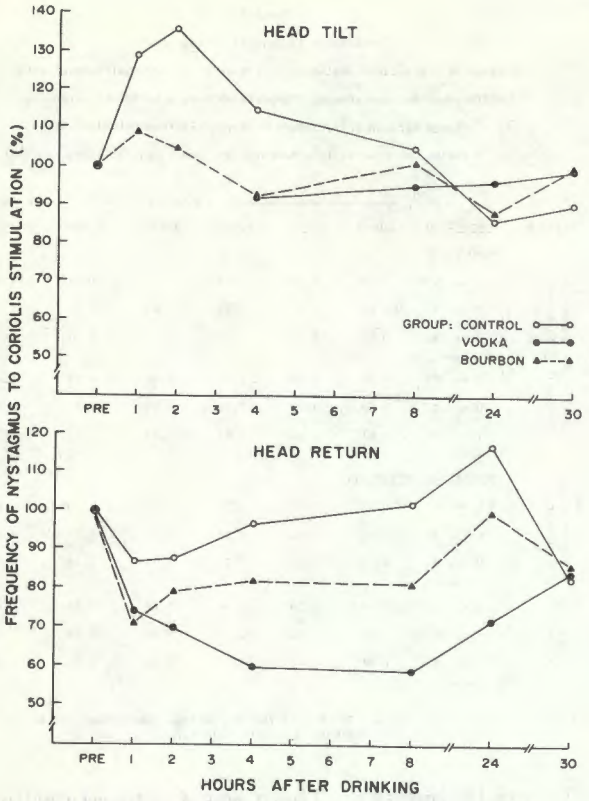

FIGURE 10. Frequency of Coriolis (vertical) nystagmus for each session expressed as a percentage of the Pre-drinking level. Scores for the 1- and 2-hour post-drinking sessions were not plotted for the Vodka group since scorable records were obtained from only a few subjects. In no case did alcohol produce an enhancement of response.

is consistent with the findings of most previous authors.[2 4 5 31] Our finding of the regular conversion of PAN I to PAN II between the fourth and sixth post-ingestion hour is in general agreement with the findings of Walter,[31] Aschan et al.,[2] and Plenkers.[20] Contrary to the findings of the regular appearance of PAN I and PAN II, Ryback and Dowd[22] reported the irregular appearance of PAN I and PAN II 7–15 hours after alcohol ingestion. The latter authors reported PAN I responses from some subjects 7–10 hours after drinking; from the earlier literature, one would expect a PAN II response at this time.

Other authors who have extended the testing period have found PAN II to persist until the 16th to the 20th hour. Plenker's subject,[20] who had PAN II 20 hours after he began drinking, had drunk four liters of beer and eight whiskeys and his blood alcohol was 0.92 mg% at the time of testing. Walter[31] had reported prolongation of PAN II with the prolongation of the drinking period; however, both Walter[31] and Aschan et al.[2] found no influence on the post-ingestion duration of PAN I with extension of the drinking period, i.e., PAN I appeared to last from two to five hours after drinking was completed, regardless of whether the drinking period was of 30 minutes or of two hours duration.

Our results suggest at least one additional phase of PAN well beyond the time limits that might be expected. That phase is the "PAN-I-type" response, observed in some of our subjects, 24–32 hours after alcohol ingestion. Although some of the Control subjects showed apparent positional nystagmus during the same time

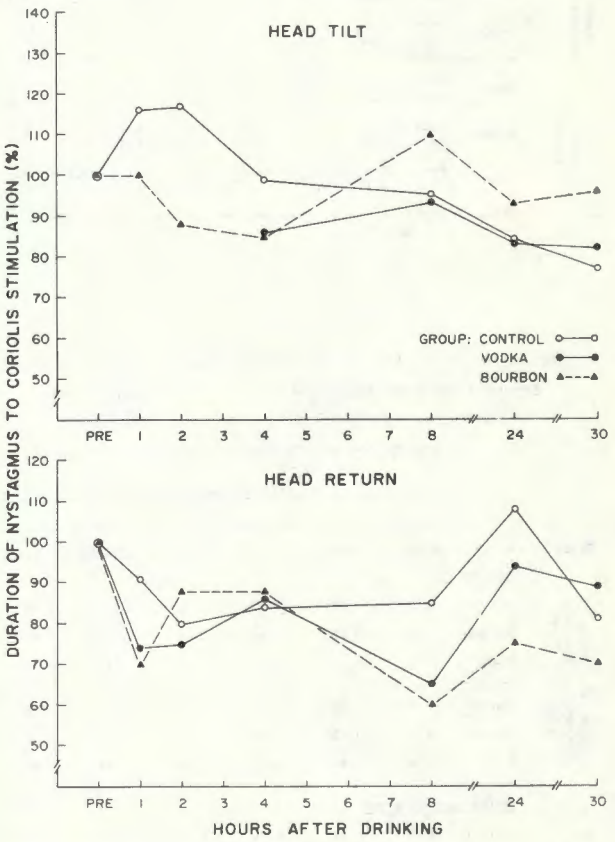

FIGURE 11. Duration of Coriolis (vertical) nystagmus for each session expressed as a percentage of the Pre-drinking response level. Scores for the 1- and 2-hour post-drinking sessions were not plotted for the Vodka group since scorable records were obtained from only a few subjects. In general, the alcohol groups showed some depression of nystagmus during post-drinking sessions.

TABLE 10

Coriolis Sensations:

Means and standard deviations by session for the rated intensity and the duration of the Coriolis sensations (vertigo) produced by 30° head tilts and return-to-upright head movements during rotation at 15 rpm.

Measure	Group		Session Pre	1	2	4	8	24	30
	HEAD TILTS								
Rated Intensity (Per Cent)	Control	Mean	95.0	76.5	71.0	57.0	67.0	58.0	58.0
		SD	12.9	10.6	16.6	26.7	19.9	21.9	24.5
	Bourbon	Mean	87.0	62.0	65.5	55.0	55.3	56.5	48.5
		SD	20.0	21.2	27.9	24.4	21.6	18.1	18.7
	Vodka	Mean	68.5	59.5	58.0	50.5	51.5	48.5	51.0
		SD	33.3	28.4	27.0	24.7	29.2	26.9	27.1
Duration of Vertigo (Seconds)	Control	Mean	9.6	8.8	7.0	6.2	7.3	6.8	6.1
		SD	5.4	5.0	4.5	3.8	4.2	3.5	3.3
	Bourbon	Mean	12.9	11.2	11.0	9.6	8.3	9.7	9.7
		SD	7.8	6.8	5.6	7.6	5.0	7.5	6.9
	Vodka	Mean	8.4	7.3	7.9	6.8	6.2	6.5	6.9
		SD	4.4	2.2	5.2	3.5	3.1	2.9	3.2
	RETURN HEAD MOVEMENTS								
Rated Intensity (Per Cent)	Control	Mean	96.7	97.0	84.0	81.5	82.5	86.5	88.0
		SD	27.9	14.2	20.2	29.3	21.0	23.3	35.6
	Bourbon	Mean	87.0	77.2	71.1	72.3	73.0	76.3	74.5
		SD	25.5	30.2	32.2	29.8	29.0	30.0	32.2
	Vodka	Mean	96.0	83.5	81.9	77.5	71.0	76.5	74.5
		SD	19.4	34.8	37.5	29.7	31.7	26.9	27.2
Duration of Vertigo (Seconds)	Control	Mean	10.3	9.7	8.1	7.2	6.9	8.2	8.0
		SD	11.6	6.3	5.4	4.4	4.5	4.1	7.3
	Bourbon	Mean	13.6	13.0	10.1	11.6	9.1	11.4	10.0
		SD	10.2	8.2	5.1	7.7	5.9	9.0	7.8
	Vodka	Mean	8.5	8.8	8.4	7.5	7.6	6.8	7.3
		SD	3.8	4.4	3.9	3.0	4.1	3.3	3.9

TABLE 11

Coriolis Sensations:

Results of statistical evaluations (t tests for correlated data) of the significance of the differences between Pre-drinking measures and those obtained after drinking.

Measure	Group	t for Pre-Drinking Session vs. Post-Drinking Sessions: 1-hour	2-hour	4-hour	8-hour	24-hour	30-hour
	HEAD TILTS						
Rated Intensity (Per Cent)	Control	3.10*	2.79*	3.86**	3.64**	3.74**	3.44**
	Bourbon	2.98*	2.86*	4.23**	4.14**	3.39**	4.44**
	Vodka	1.66	2.19	2.26	2.05	2.01	2.11
Duration of Vertigo (Seconds)	Control	0.79	3.86**	2.49*	1.99	2.04	2.92*
	Bourbon	2.04	1.15	2.27*	3.66**	2.42*	1.83
	Vodka	1.01	0.70	2.02	1.99	2.30*	1.12
	RETURN HEAD MOVEMENTS						
Rated Intensity (Per Cent)	Control	-0.03	1.25	1.14	1.18	0.83	0.58
	Bourbon	0.56	1.18	1.79	1.67	1.08	1.48
	Vodka	1.12	1.16	2.38*	2.49*	2.35*	2.77*
Duration of Vertigo (Seconds)	Control	0.32	1.05	1.30	1.39	0.71	1.28
	Bourbon	0.34	1.42	1.24	1.48	0.67	1.21
	Vodka	-0.34	0.12	1.57	0.81	3.06*	1.97

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

TABLE 12

Coriolis Sensations:

Results of statistical evaluations (t tests) of the significance of the differences between groups. Comparisons were made of the percentage of change between Pre-drinking measures and those obtained after drinking for Control (C), Bourbon (B), and Vodka (V) subjects.

Measure	Comparison	t: 1-hour	2-hour	4-hour	8-hour	24-hour	30-hour
	HEAD TILTS						
Rated Intensity (Per Cent)	C vs. V	0.95	1.04	1.30	0.45	0.75	0.92
	C vs. B	0.79	0.18	0.09	0.62	0.48	0.32
	V vs. B	1.42	1.25	1.34	0.93	0.47	1.18
Duration of Vertigo (Seconds)	C vs. V	0.05	2.34*	1.12	0.78	0.12	1.32
	C vs. B	0.41	2.02	0.32	0.71	0.10	0.71
	V vs. B	0.41	0.28	1.09	1.50	0.00	0.64
	RETURN HEAD MOVEMENTS						
Rated Intensity (Per Cent)	C vs. V	1.20	0.37	0.76	1.26	1.21	1.39
	C vs. B	0.33	0.31	0.36	0.38	0.19	0.64
	V vs. B	0.58	0.07	0.43	0.85	0.91	0.77
Duration of Vertigo (Seconds)	C vs. V	0.51	0.45	0.25	0.55	1.66	0.27
	C vs. B	0.30	0.39	0.02	0.21	0.31	0.37
	V vs. B	0.09	0.70	0.23	0.69	1.29	0.20

*$p < .05$

period, their responses were direction-fixed. The nystagmus seen in our alcohol subjects was direction-changing (i.e., right-beating when the head was to the right and left-beating when the head was to the left), with the exception of (a) one or two alcohol subjects (depending on the session) who exhibited the same direction-fixed nystagmus which they exhibited during Pre-trial positional testing, and (b) one subject (RJ; see Figure 2) who showed a "PAN-II-type" positional response during the 27-hour session (but not during the 24-, 30-, or 32-hour sessions).

Ryback and Dowd[22] reported PAN II in several of their subjects 34 hours after alcohol ingestion and hypothesized a "recycling" of PAN I and PAN II in spite of the irregular appearance of these responses in their subjects. It may be that our subjects were demonstrating one phase of this "recycling" and Ryback and Dowd's subjects showed the following PAN II phase (since they were tested two hours later than our subjects). However, discrepancies between the approach and results of our and other studies and that of Ryback and Dowd[22] make it difficult, if not impossible, to explain differences in findings. Furthermore, the latter authors showed no electronystagmographic tracings of the 34-

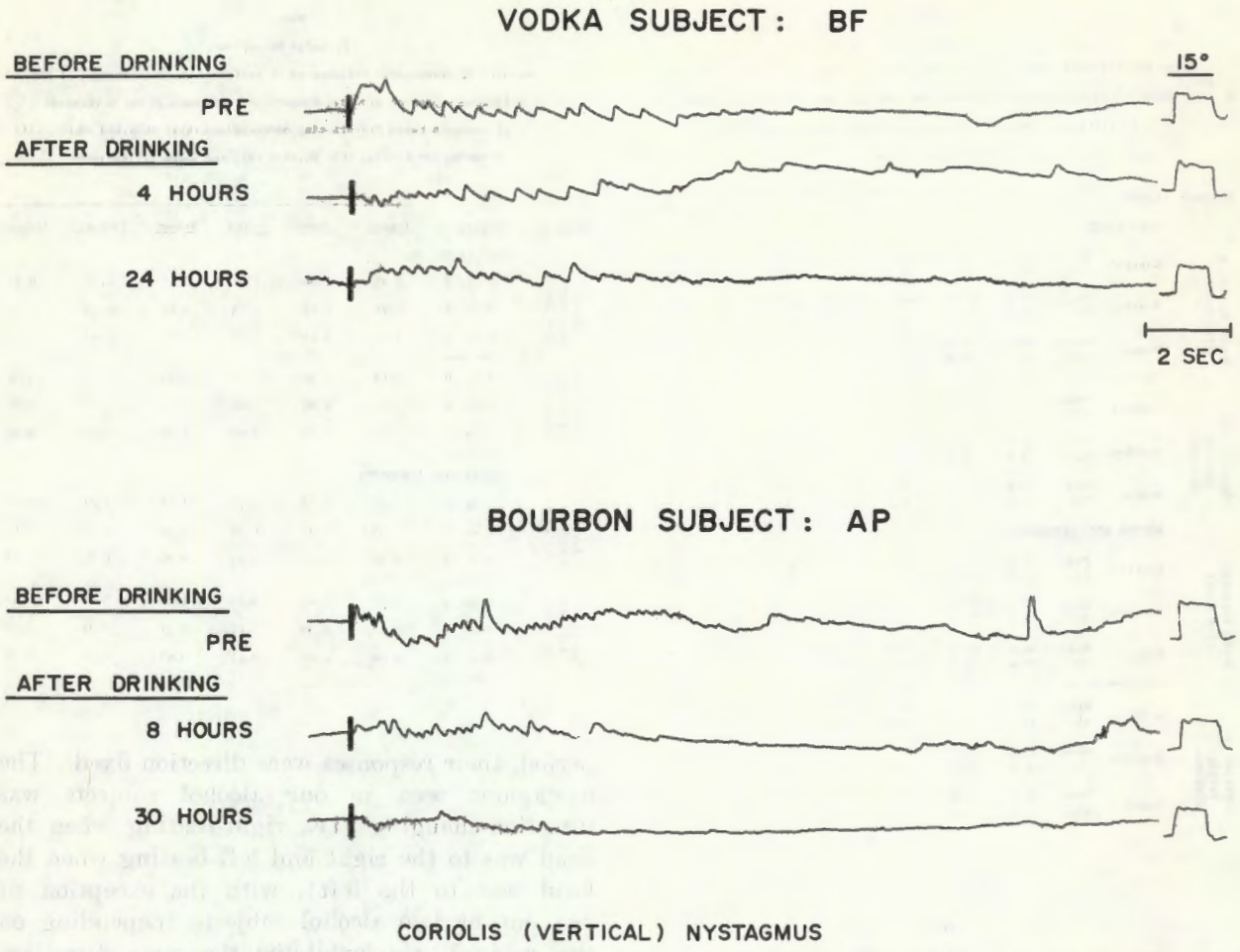

FIGURE 12. Coriolis (vertical) nystagmus recorded from the Head Tilts of a Bourbon and a Vodka subject during several sessions.

hour responses they reported, and the character of these responses cannot, therefore, be compared with our results. Difference in experimental design, types of subjects, and the differing sleep periods may account for many of the differences between the two studies, e.g., our subjects drank over a 30-minute period and the testing was begun one hour later, whereas Ryback and Dowd's subjects drank over a 1½ hour evening period, and were tested the next morning. It can be concluded that our study confirms the regular appearance of PAN I and PAN II during the first ten hours after alcohol ingestion as reported by most earlier authors, and that some subjects demonstrated a "PAN-I-type" response from 24–32 hours after alcohol ingestion.

The genesis of these nystagmic reactions is not clear. However, evidence from studies of animals[17 18] indicates that the semicircular canals of the vestibular system are necessary for PAN. Money, Johnson, and Corlett have concluded that PAN is initiated by the action of gravity on semicircular canal receptors although the site and "mechanism of the action of alcohol remain to be elucidated." [17]

Control Subjects. A second static effect demonstrated by this study was the intermittent appearance of apparent positional nystagmus in the majority of our Control subjects. There was a predominance of left-beating nystagmus throughout the trials. Coats[8 9] and Bochenek, et al.,[7] have demonstrated the appearance of positional nystagmus in 25% and 32% of healthy normal subjects. The latter authors found that, by increasing the gain on the recording amplifier, they could demonstrate nystagmus in subjects who had previously not exhibited any. It is felt that the presence of weak, spontaneous positional

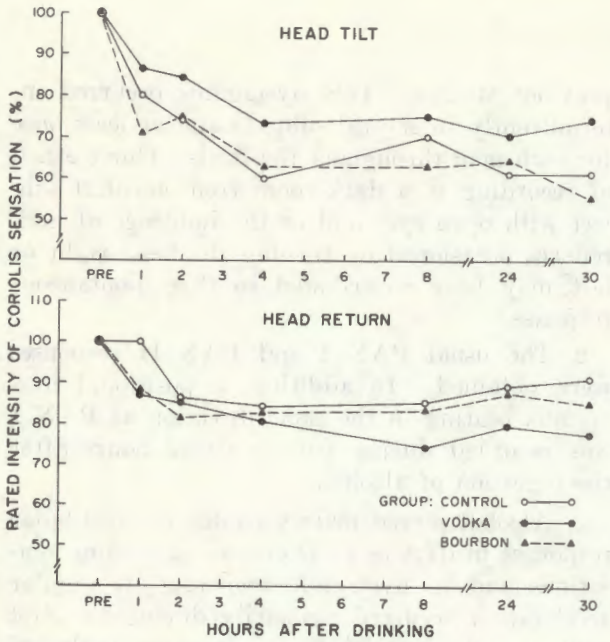

FIGURE 13. Rated intensity of Coriolis sensations for each session expressed as a percentage of the Pre-drinking level. A general decline is evident for all three groups.

responses in such a large percentage of our subjects may reflect, in part, our test procedure which we consider optimal for the detection of nystagmus,[10 12 13] i.e., an electronystagmogram obtained from an alert subject with eyes open in a totally-dark room. However, an additional factor which may have contributed to the large number of weak positional responses which we obtained might have been our procedure of having the subject turn his head, thereby activating neck reflexes. At any rate, our results suggest that, under some conditions, positional nystagmus may be present in a greater number of "normal" subjects than previously reported.

Dynamic Effects

Angular Acceleration. Our finding of a decline in the nystagmic response to angular acceleration in darkness after the ingestion of alcohol confirms the work of Schroeder.[23] This response suppression during the first two hours after drinking was statistically significant for all three measures of nystagmus for both alcohol groups. In general, the response recovered after the first two post-ingestion hours, but some measures (e.g., slow-phase nystagmus for both groups) were still significantly below pre-drinking levels eight or more hours post-ingestion. Authors reporting an enhancement of nystagmus from caloric irrigations or from rotatory stimuli conducted their tests in lighted rooms and were most likely demonstrating a depressant effect of alcohol on the ability of the subject to inhibit nystagmus by fixating his eyes.[23 24] The duration of the turning sensation from the alcohol subjects was shortened during the first hour after drinking, but exhibited recovery during subsequent tests.

Coriolis Stimulation. Our alcohol subjects demonstrated no statistically significant change from pre-drinking levels in number of beats or duration of nystagmus to Coriolis stimulation either during the period of intoxication or the next day. Similarly, there was little effect of alcohol on either the rated intensity or the duration of vertigo. In fact, the 24- and 30-hour post-ingestion responses to Coriolis stimulation were decreased from pre-drinking levels (although not significantly) in both of the alcohol groups. This finding is in contrast to the report by Ryback and Dowd[22] of increased subjective tumbling in both their alcohol groups, an enhancement in duration and frequency of nystagmus from their bourbon subjects, and an increase in frequency (with a decrease in dura-

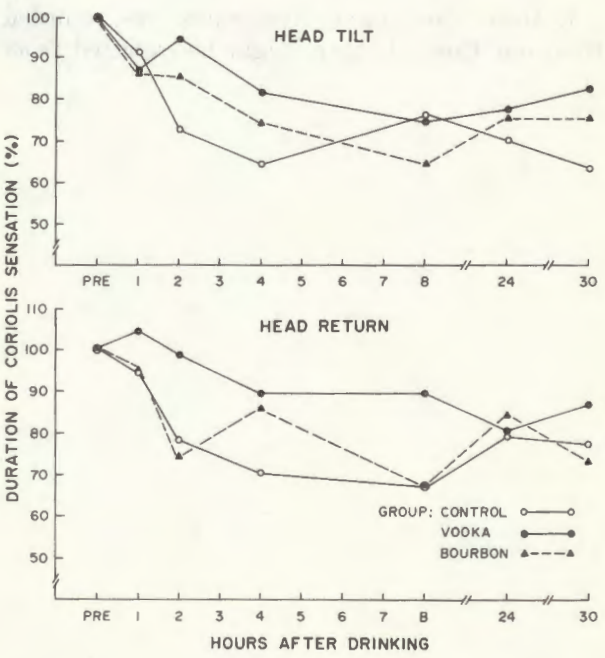

FIGURE 14. Duration of Coriolis sensations for each session expressed as a percentage of the Pre-drinking level. All groups show a decline.

tion) in nystagmus from their vodka subjects, 34 hours after the ingestion of alcohol. A factor possibly affecting the latter authors' findings was their use of some "habituated" subjects; the reported enhancement may conceivably represent release of the central habituating mechanism in those subjects due to the alcohol. (Aschan[1] has presented data, primarily from fighter pilots, which indicate that alcohol may eliminate established response declines to vestibular stimulation.) In addition, our subjects made active head movements (involving neck reflexes), while theirs received passive, whole-body tilts during rotation.

Congeners. Although there were minor differences between the Bourbon and Vodka groups, there were no consistent effects which might indicate more severe or longer-lasting influences on vestibular nystagmus of a congener as opposed to a non-congener beverage. Also, the incidence of headache or hangover as reported by our subjects was somewhat higher for Vodka subjects (non-congener) than for Bourbon subjects (congener).

V. Summary.

1. More spontaneous nystagmus was recorded from our Controls than might be expected from previous studies. This nystagmus occurred intermittently in several subjects and at least once for each man throughout the trials. Our method of recording in a dark room from an alert subject with open eyes and/or the influence of neck reflexes occasioned by turning the head right or left may have contributed to this spontaneous response.

2. The usual PAN I and PAN II responses were obtained. In addition, a positional nystagmus beating in the same direction as PAN I was recorded during periods 24–32 hours after the ingestion of alcohol.

3. Alcohol served mainly to depress vestibular responses in darkness. Decreases in turning sensations and in nystagmic responses to angular acceleration occurred primarily during the first hour or two after drinking. In general, alcohol produced no consistent effects on either the vertical nystagmus or the vertigo produced by Coriolis stimulation. Coriolis responses 24–30 hours after the ingestion of alcohol showed a reduction in both duration and frequency of nystagmus over pre-drinking response levels.

4. There appeared to be no consistent differential vestibular effects between congener and non-congener beverages in our subjects.

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