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SOME RELATIONSHIPS BETWEEN BLOOD ALCOHOL,
POSITIONAL ALCOHOL NYSTAGMUS (PAN),
AND POSTURAL EQUILIBRIUM (ATAXIA)

Alfred R. Fregly, Martin Bergstedt, and Ashton Graybiel

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UNITED STATES NAVAL SCHOOL OF AVIATION MEDICINE
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

March 1965

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POSITIONAL ALCOHOL NYSTAGMUS (PAN),
AND POSTURAL EQUILIBRIUM (ATAXIA)*

Alfred R. Fregly, Martin Bergstedt, and Ashton Graybiel

Bureau of Medicine and Surgery
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17 March 1965

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U. S. NAVAL SCHOOL OF AVIATION MEDICINE
U. S. NAVAL AVIATION MEDICAL CENTER
PENSACOLA, FLORIDA

SUMMARY PAGE

THE PROBLEM

To explore quantitative relationships between blood alcohol levels, positional alcohol nystagmus (PAN), and postural equilibrium performances measured with a new quantitative ataxia test battery and with a series of clinical-type ataxia tests.

FINDINGS

Moderate amounts of 80-proof vodka (1 cc per lb. body wt.; 55-100 mg% blood alcohol level) produced appreciable decrements in the postural equilibrium functioning of all thirteen vestibular normal subjects evaluated. Maximum decrements occurred at 60-75 minutes following alcohol intake and were fairly well correlated with the peak blood alcohol levels. But more strikingly, the ataxic responses were in very close agreement with the intensity and duration of the PAN I (intoxication period) responses along the time axis. No systematic relationships between the ataxia test performances and PAN phase II responses were found; rather, the ataxic performances improved to virtually complete, if not complete, recovery during the PAN II period.

Repetition of the experiment two days later with the same subjects under increased stimulation (100-proof vodka in the same dosage) reproduced the findings generally proportional to the increased stimulus.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the assistance of the following: Mr. James K. Colehour for the blood samples; Dr. Reid H. Leonard for the blood alcohol determinations; Dr. Vernon C. Bragg for the audiometric evaluations; Dr. Earl F. Miller, II, for counterrolling evaluations; Lt. Mike E. McLeod, MC USN, for threshold caloric determinations; Mr. James C. Sansing for technical assistance with the ENG apparatus; Miss Edna Marques and Mrs. Susie Everett for help with nystagmus data reduction; Mr. Theron L. Trimble for obtaining the bulk of the ataxia test battery data and for his assistance with data reduction, and to the student aviators and volunteer enlisted personnel who undertook conscientiously their roles as subjects.

INTRODUCTION

Few quantitative data are available on the correlation between alcohol intoxication and ataxia (1), which is the main concern of this investigation. Reliable measurements of ataxia were ensured with the recent development of a multidimensional quantitative test battery (6). Determinations of positional alcohol nystagmus (PAN) were included partly because of its clearly defined relation to alcohol intoxication (4) and partly because its significance in relation to ataxia has yet to be demonstrated. For release of PAN, at least one functioning labyrinth must be present (3) and, in persons with normal labyrinths, the minimal value of alcohol in the blood must be greater than 20 mgm% (5). Following a single intoxicating dose of alcohol, PAN I appears in about thirty minutes and lasts about three hours, which extends into the hangover phase. Approximately 1-1/2 hours after cessation of PAN I, nystagmus reappears, beating then in the opposite direction (PAN II), and lasting five to seven hours (4).

PROCEDURE

SUBJECTS

Thirteen well-motivated, volunteer subjects participated. Five subjects were Naval or Marine Corps student aviators with an age range of 21-23. The remaining nine subjects, ages 18-24, were enlisted Naval personnel in the capacity of full-time research subjects.

All subjects were in excellent health, and medical evaluation revealed no significant abnormality; all were free of any vestibular disturbance and of a significant history of auricular difficulties. In addition to meeting the requirement of average or better postural equilibrium and ataxia test performances, they revealed normal responses to counterrolling (8), threshold caloric testing (7), and audiometric evaluation. Moreover, no subject revealed spontaneous or positional vestibular nystagmus upon examination prior to the experiment.

APPARATUS

Electronystagmography

Nystagmus was recorded by means of a direct writing two-channel AC-recorder (Sanborn). The time constant was about two seconds. Electrodes were placed near the lateral canthus of each eye and above and below the left eye. A ground electrode was placed on the forehead. All recordings were made with subjects' eyes closed (5).

Test Battery (Short Version)*

Walk H/T (with eyes open, heel-to-toe) rail and Stand E/O (eyes open) rail: metal construction, 8 feet long, 3/4 inches wide, 1-1/2 inches high above the base (3/4" high and 5-1/2" wide), and sand-blasted top surface (Figure 1).

Stand E/C (eyes closed) rail: pinewood construction, 30 inches long, 2-1/4 inches wide, and one inch above its plywood base (also 3/4" high and 5-1/2" wide) on which it was superimposed (Figure 1).

METHOD

Alcohol Stimulus

On an empty stomach, each subject consumed 80-proof vodka in the first experiment and 100-proof vodka in the second experiment (two days later) mixed with orange juice to suit individual taste (about 4:1) in the amount of 1 cc per pound of body weight. To assure a good and rapid absorption, each subject was allowed exactly fifteen minutes to consume the dosage under the following schedule: During the first five minutes subject was permitted to take only small sips; during the next five minutes subject increased his consumption rate steadily; in the final five minutes he consumed steadily the remaining 50 per cent (approximate).

Blood Samples

On each of the experimental days blood was drawn from the cubital vein of each subject several minutes before he consumed alcohol and again at approximately 30 minutes, 60 minutes, 180 minutes, and 270 minutes following the initiation of alcohol intake. Blood alcohol levels were determined utilizing Natelson's microtechniques (9).

Nourishment

Three and one-half hours after start of alcohol intake during each of the experiments, subjects consumed a light lunch. One to two hours preceding lunch, munching on cheese and crackers was permitted.

Experimental Diary

In the interest of obtaining the changing symptomatology along the time axis of the experiment, subjects maintained a printed diary, or log. They were instructed to use the most appropriate terms and qualifiers, such as slight, moderate, severe, and nil, and to note the exact time of appearance and disappearance of symptoms.

*A Long Version, which employs six rails of varying widths, from which the Short Version evolved, was designed for similar usage and was described fully with the Short Version in a previous publication (6).

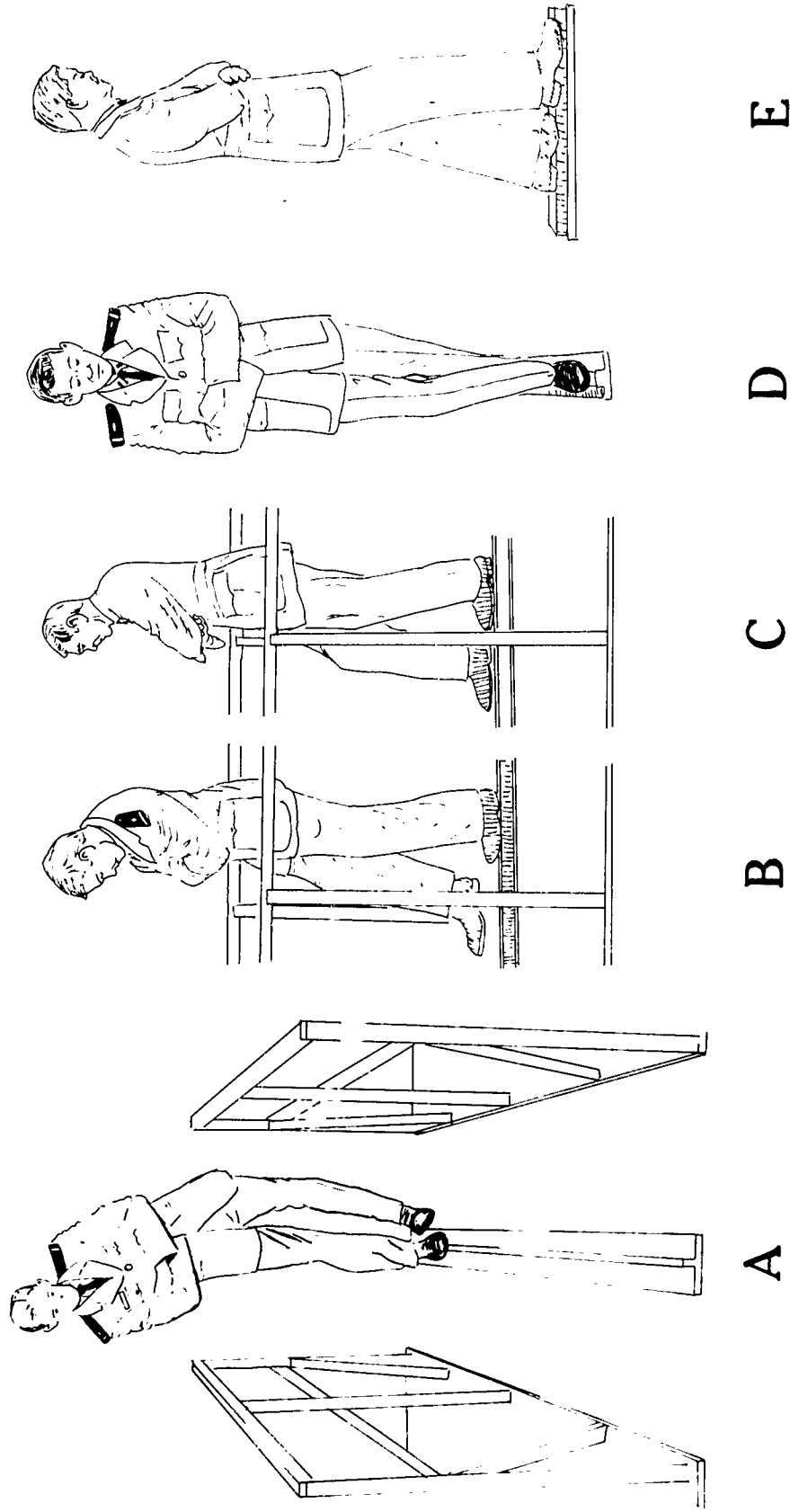


Figure 1

The Test Battery (Short Version): A-B) Walking with eyes open (Walk H/T Test) on the 3/4 inches wide rail;
 C) Standing with eyes open (Stand E/O Test) on the 3/4 inches wide rail; and D-E) Standing with eyes closed
 (Stand E/C Test) on the 2-1/4 inches wide rail.

Positional Alcohol Nystagmus

With subjects lying on a couch in a supine position, control (calibration) recordings preceded and followed each of the serial recordings in the left and right lateral head positions. Each lateral position was maintained for at least two minutes and was repeated twice. Then, immediately after disconnection from the recorder, subjects undertook the ataxia tests. In both the 80- and 100-proof experiments*, PAN was recorded in each subject according to the following schedule: 30, 60, 120, 180, 270, 360, 420, and 480 minutes following alcohol intake.

Nystagmus intensity was measured in terms of degrees of eye movement per second. Usually the mean intensity for a ten-second period was measured when PAN reached a peak, i.e., 20-60 seconds after subject's head was turned (5).

Test Battery (Short Version) and Clinical-Type Ataxia Tests[#]

Shoes were not removed for the test series. Following a combination of written and verbal instructions, all subjects performed all tests in the following sequence:**

1) Sharpened Romberg Test (SR), consisting of standing on the floor with eyes closed for sixty seconds; 2) Test Battery (Short Version) consisting of walking with eyes open (Walk H/T Test) on a 3/4" wide rail; standing with eyes open (Stand E/O Test) on the 3/4" wide rail, and standing with eyes closed (Stand E/C Test) on a 2-1/4" wide rail; 3) standing on one (each) leg for thirty seconds with eyes closed test (SOLEC-R and SOLEC-L); 4) walking a line with eyes closed test (WALEC).

The body position for all tests was as follows: a) body erect or nearly erect, b) arms folded against chest, c) feet in heel-to-toe position and tandemly aligned (SOLEC tests excepted).

The best three out of five trials constituted the scoring of the Test Battery (Short Version), weighted scores were used for the SR and SOLEC tests, and the WALEC was scored in terms of the best two out of three trials (best = least deviant from the line). Maximum scores were as follows: SR: 240 (60 x 4) seconds; Walk H/T: 15 (steps); Stand E/O and Stand E/C tests: 180 (seconds); SOLEC: 150 (30 x 5) seconds; WALEC:## O(inches) deviation.

*There were some exceptions, indicated in the results, due to uncontrollable technical difficulties.

#Utmost safety precaution was necessary on the part of the examiner to prevent possible injury of subjects from possible inadvertent falling.

**The administration and scoring procedures utilized have been described in considerable detail previously (6).

##A major limitation of the WALEC procedure is that in notably ataxic individuals the qualitative performance is often more deviant than the individual's score would indicate. Accordingly, the WALEC scores reflected spatial orientation skills more than they reflected ataxia.

Preceding the experiment each subject was retested on each test as often as necessary (usually two to five re-tests) for establishing his peak, or plateau, performance scores. Each subject's best (plateau) performance score on each test (except the WALEC) during pre-experimental testing represents his baseline performance score. The greater variability of the WALEC dictated the use of mean pre-experimental scores of each subject as his baseline performance score.

During the experimental periods subjects undertook these tests at approximately 30, 60, 120, 180, 270, 360, and 420 minutes after the start of alcohol intake.*

RESULTS

BLOOD ALCOHOL LEVELS

A comparison of baseline level with experimental level alcohol concentrations in the blood in the two experimental situations is shown in Figure 2. Maximum mean concentrations of the 80-proof stimulus occurred at about seventy minutes, whereas in the 100-proof experiment maximum mean concentrations occurred earlier, or at sixty minutes following the start of alcohol intake. Moreover, the 80-proof stimulus was sustained in the blood at maximum level only temporarily, whereas the 100-proof was sustained at, or very near, maximum for two hours. Significantly greater concentrations of alcohol in the blood during the 100-proof experiment were evidenced at the 60 minute, 180 minute, and 270 minute periods ($P < .01$, t test).

POSITIONAL ALCOHOL NYSTAGMUS

Before alcohol intake there was no nystagmus in any of the subjects in the three head positions studied, i.e., supine, right lateral, and left lateral.

After alcohol intake all subjects showed positional alcohol nystagmus of varying intensity in right and left lateral positions in accordance with findings reported earlier (4). All subjects also showed the two typical phases of PAN as well as the intermediate period between these two phases.

The mean nystagmus responses are shown in Figure 2A and B, and in terms of the time axis they are similar to the mean responses shown in the remaining figures. Within a given individual there were, however, as has been observed earlier (4), apparent inconsistencies, such as unequal responses and differences in responses both between and within individuals, when the test was repeated. Further variation was found between onset and cessation of a certain phase of nystagmus. Each expected vacillation from zero PAN for a given subject within the PAN I phase was observed. The general pattern of PAN was followed; i.e., PAN I started about one-half hour after alcohol intake and lasted about four hours with nystagmus to the right in the right lateral head position and to the left in the left lateral head position. The supine position produced, usually, either no nystagmus or only single beats ~ ~ ~ ~ ~

*Due to uncontrollable technical difficulties, five subjects were not tested during the sixty-minute period of the 80-proof experiment.

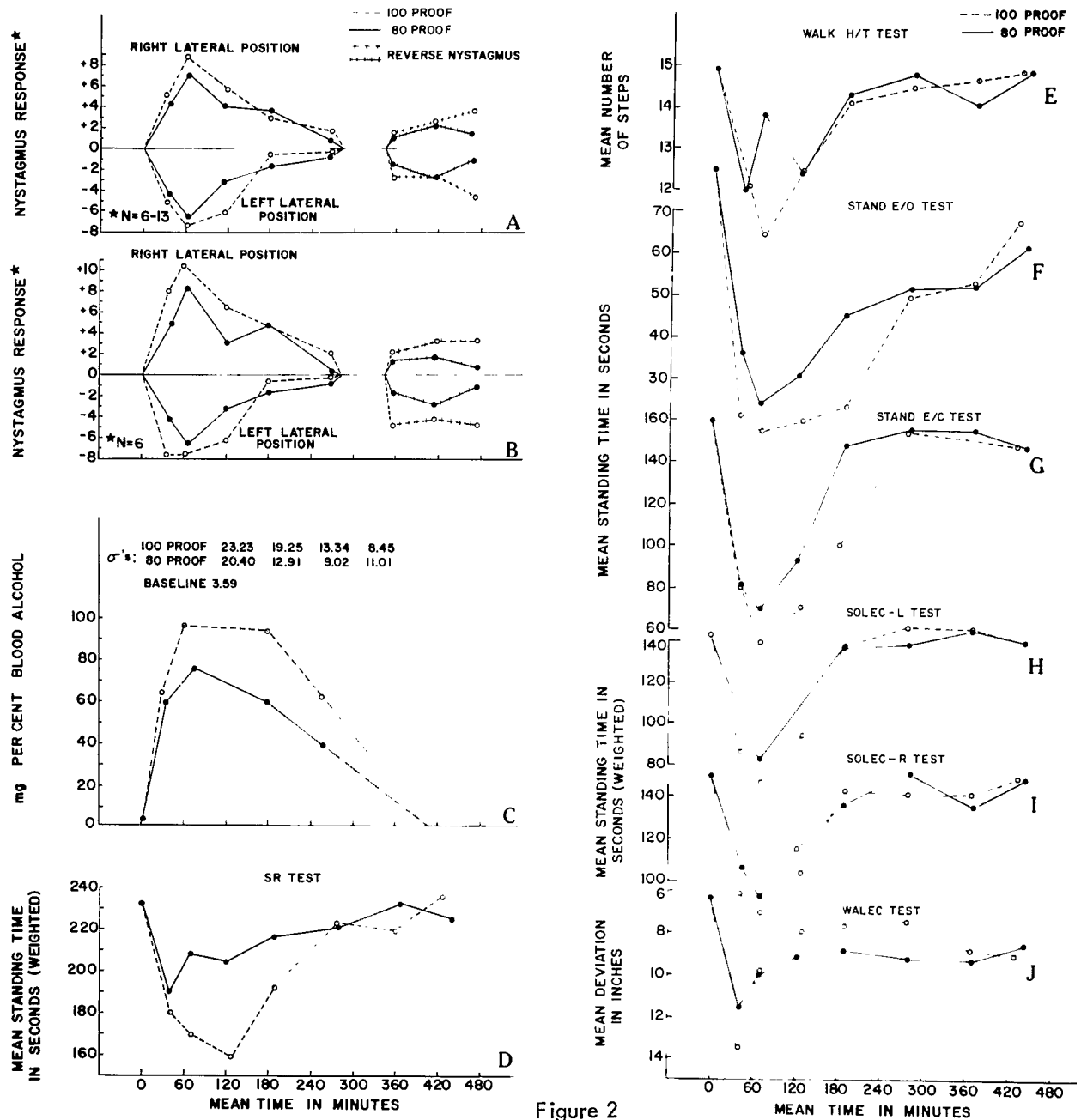


Figure 2

Comparisons of 80-proof with 100-proof alcohol stimulation in thirteen normal male subjects on: A-B) nystagmus intensity; C) blood alcohol level; D) sharpened Romberg test; E) walking with eyes open on a 3/4" wide rail test; F) standing with eyes open on a 3/4" wide rail test; G) standing with eyes closed on a 2-1/4" wide rail test; H-I) standing on one leg with eyes closed-left and right tests; J) walking a line with eyes closed test.

The intermediate period lasted about one hour. PAN II started about five and one-half to six hours after alcohol intake with nystagmus reversed, i.e., to the left in the right lateral position and to the right in the left lateral head position. The recording of phase II was not followed into cessation. The intention was limited to being certain of a clear period of phase II nystagmus responses for comparison on the time axis with the postural equilibrium (ataxia) test findings.

In both the 80- and 100-proof experiments the intensity and variability of PAN phase II was generally less (not statistically significant) than in phase I (Table I). The general tendency was doubly clear and in good agreement with earlier results (4). The goal of establishing the existence of PAN I and II in each subject for comparison with the alcohol-induced ataxia was realized in this investigation.

TEST BATTERY AND CLINICAL-TYPE ATAXIA TESTS

Comparisons of mean baseline performances with mean performances during the two experimental sessions on the Test Battery (Walk H/T, Stand E/O, and Stand E/C) and on the clinical-type ataxia tests are shown in Table II and in Figure 2 D-2J. Statistically significant declines from baseline performance levels were evidenced on all tests as early as 30-45 minutes after alcohol intake. Generally, peak decrements in performance as a result of the alcohol were observed at 60-75 minutes after alcohol intake, and were strikingly in parallel with peak PAN phase I responses and fairly well correlated with peak blood alcohol levels in both experiments. Results in each of the thirteen subjects were remarkably similar to these group results.

Recovery, or near recovery, to baseline levels of performance was observed as early as 120 minutes (WALEC performance) and as late as some 420 minutes (Stand E/O performance) after alcohol intake. Stand E/C performance recovered at between 180-270 minutes, Walk H/T, SOLEC-R, and SOLEC-L performances recovered at approximately 270 minutes, and SR performance recovered at about 360 minutes after alcohol intake. Generally, the 100-proof vodka produced the greater decrement in performance*, and the slowest recovery to baseline levels of performance. The Test Battery proved to be somewhat more sensitive than the clinical-type tests to alcohol, particularly the Stand E/O Test. Among the clinical-type tests, the SR Test proved to be the most sensitive to the influences of alcohol, although early in each experimental session WALEC Test performances were qualitatively affected considerably more so than the quantitative data indicate. In keeping with expectations, the two dynamic-type or locomotor-influenced tests - Walk H/T and WALEC, were the least influenced by alcohol. Whether or not this finding would hold, however, if a more difficult criterion (e.g., a narrower rail) had been used for the Walk H/T Test and if the qualitatively rich ataxia features of WALEC performance were quantified requires investigation. The progressive recovery of postural equilibrium functioning to virtually complete recovery during the hang-over (PAN phase II) period bore no systematic relationships with PAN phase II responses.

*Only the Stand E/O difference between the 80-proof and 100-proof experiments during Period IV (180 min. after alcohol intake) proved statistically significant ($t = 2.22$, $P.05$).

Table I

Intensity Differences Between 80-Proof and 100-Proof Alcohol-Induced Positional Nystagmus in a
Group of 13 Normal Male Subjects

Test Period	Lateral Head Position	Elapsed Time in Minutes				Nystagmus Response				t of Diff*	
		80-Proof		100-Proof		80-Proof		100-Proof		80-Proof and 100-Proof	
		Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.		
I	R					4.3+	2.50	5.0	4.09	1.68	
	L	37.8	10.26	33.5	4.55	4.2+	2.82	5.1	4.69	1.64	
II	R					7.1#	4.49	8.7	6.22	0.54	
	L	64.1	10.09	60.3	2.23	6.6#	3.95	7.4	4.35	0.11	
III	R					4.0**	3.91	5.7	4.61	1.07	
	L	116.8	7.44	119.2	1.80	3.2**	3.49	6.0	5.81	1.35	
IV	R					3.6	3.53	2.9	3.29	0.09	
	L	181.5	11.37	180.0	0.00	1.7	2.53	0.6	1.09	0.15	
V	R					0.8**	1.40	1.6	1.87	1.57	
	L	263.6	19.08	267.8	2.83	0.8**	1.27	0.3	1.29	0.73	
VI	R					0.9##	1.60	1.4	2.69	0.43	
	L	355.7	3.81	355.5	2.87	<u>1.6</u>	3.34	<u>2.8</u>	3.60	0.52	
VII	R					2.1++	1.55	2.5	2.56	0.89	
	L	415.0	2.41	417.1	4.75	<u>2.9++</u>	2.13	<u>2.8</u>	4.35	0.60	
VIII	R					1.3	2.47	3.5++	2.65	1.40	
	L			470.5	9.07	<u>1.2</u>	4.17	<u>4.6++</u>	3.78	1.06	

*N = 6; +N = 12; #N = 9; **N = 11; ++N = 10; ## Underlined values indicate reverse nystagmus.

Table II

Comparisons of Means and Standard Deviations of Pre-Experimental with Experimental Test Battery and Clinical-Type Ataxia Test Performances and the Significance Levels of Mean Differences in a Group of Thirteen Normal Male Subjects

80-Proof Alcohol (Vodka)															
Test Battery and Clinical-Type Ataxia Tests	Baseline Mean S.D.	I (42.9) [#]		II (67.9) ⁺		III (120.7)		IV (187.9)		V (278.8)		VI (367.2)		VII (440.5)	
		Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
WALK H/T	14.9 0.85	12.0**	2.45	13.8*	1.09	12.4**	1.60	14.3	1.14	14.8	0.36	14.1	1.49	14.9	0.27
STAND E/O	79.8 40.52	36.1*	43.38	24.3**	22.85	30.4**	37.31	45.1*	33.81	51.6	39.39	52.1	40.24	61.5	51.19
STAND E/C	159.6 38.52	79.9**	46.14	69.0**	49.10	93.3**	56.18	147.5	46.79	154.4	44.99	154.2	46.18	146.2	51.89
SR	232.5 26.11	190.2*	66.25	208.4*	44.20	205.1	64.25	217.1	43.58	221.6	39.33	233.3	16.33	225.8	29.00
SOLEC-R	149.6 1.33	105.8**	39.90	91.1**	47.31	114.4**	35.45	134.7*	28.14	150.0	0.00	134.1*	28.79	147.0	7.17
SOLEC-L	142.5 17.72	102.8**	40.52	82.3**	40.51	105.9**	41.67	135.7	30.76	137.2	23.88	143.2	14.82	136.9	22.12
WALEC	6.3 2.72	11.6*	7.31	10.0	5.81	9.1*	4.57	8.8*	3.98	9.2	4.99	9.3	5.21	8.5	5.62
----- 100-Proof Alcohol (Vodka) -----															
Test Battery and Clinical-Type Ataxia Tests	Baseline Mean S.D.	I (41.1)		II (70.4)		III (128.2)		IV (189.2)		V (276.2)		VI (365.8)		VII (427.5)	
		Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
WALK H/T	14.9 0.85	12.1**	1.98	10.9**	2.37	12.6*	3.20	14.1*	1.38	14.5	1.08	14.7	0.82	14.9	0.27
STAND E/O	79.8 40.52	20.8**	18.60	17.4**	10.25	19.8**	9.29	33.6**	33.33	49.5*	27.61	53.2	36.00	67.5	50.18
STAND E/C	159.6 38.52	82.1**	39.73	53.2**	36.65	70.9**	43.21	99.8**	57.69	154.3	43.24	150.3	48.61	146.8	51.02
SR	232.5 26.11	180.4*	77.21	170.0*	79.59	159.5**	72.95	192.8	74.91	223.4	40.21	220.2	55.29	236.8	9.57
SOLEC-R	149.6 1.33	93.3**	43.69	83.3**	43.69	102.9**	40.10	142.1	9.52	140.2	20.17	139.8	23.16	147.5	5.89
SOLEC-L	142.5 17.72	86.5**	46.47	71.4**	44.88	93.8**	46.57	136.5	24.82	145.2	8.92	143.5	21.81	138.3	19.00
WALEC	6.3 2.72	13.5**	6.81	9.8	8.04	7.9	4.81	7.6	5.75	7.4	4.60	8.8	5.96	9.0	6.91
*P = .05, **P = .01, (by t test), of mean diff. from baseline mean. ^a Mean elapsed time from alcohol intake in minutes.															
+N=8; Baseline x's and o's were: Walk H/T 14.9,0.33; Stand E/O 90.6,43.11; Stand E/C 172.9,12.53; SR 240.0, 0.00;															
SOLEC-R 149.4, 1.65; SOLEC-L 144.3, 15.21; WALEC 5.5, 2.83															

*p = .05, **p = .01, (by t test), of mean diff. from baseline mean. [#]Mean elapsed time from alcohol intake in minutes.
⁺N=8; Baseline X's and S.D.s were: Walk H/T 14.9, 0.33; Stand E/O 90.6, 43.11; Stand E/C 172.9, 12.53; SR 240.0, 0.00; SOLEC-R 149.4, 1.65; SOLEC-L 144.3, 15.21; WALEC 5.5, 2.83

SUBJECTIVE SYMPTOMATOLOGY

During both experiments all subjects noted in their logs (diaries) that they experienced thirst, hunger, fatigue, drowsiness, and sleepiness. During the 80-proof experiment subjects noted one or more of the following: vertigo, ataxia, muscular incoordination, thick or slurred speech, blurred vision, numbness, headache, lightheadedness, dullness of sensory awareness, cheerfulness, friendliness, lovingness, detachment, depressed feelings, irritability, aggressiveness, nervousness, physical warmth, sweatiness, sour stomach, and recent memory loss. To this list was added the following in the 100-proof experiment: nausea, increased reaction time, feeling of fullness, and slight burning in the stomach. Without exception, all subjects maintained that they experienced somewhat greater to considerably greater intoxication in the 100-proof experiment. However, no subject vomited nor became ill enough to require medical attention. These testimonials by the subjects themselves were consistent with the examiners' observations. Moreover, the severity of the subject-estimated psychophysiological effects were much in accord with the objective blood alcohol levels, PAN responses, and ataxia test responses.

DISCUSSION

Application of the new quantitative ataxia test battery in the present study served the multiple purpose to a degree not possible with any single subjective or objective ataxia test of assessing locomotor versus "static," visual versus nonvisual, and visual-motor versus vestibulo-motor aspects of ataxia in relation to controlled dosages of alcohol. The appreciable performance decrements observed in response to relatively mild stimuli were reliably uniform to a remarkable extent both within and among individuals. Some hierarchical ataxic effects were observed, but inasmuch as the tests were not equated as to difficulty, this finding must be considered tentative at best despite the marked uniformity of these effects in all subjects.

The ataxia test findings related fairly well to the blood alcohol determinations along the time axis of the experiment. Generally, maximum ataxia was observed somewhat sooner (in 40-60 minutes) than the maximum blood alcohol levels (in 60-70 minutes), and, interestingly, the ataxia test performances were on their way to recovery during the periods in which high blood alcohol concentrations were sustained, suggesting that the maximum changes were a dynamic, dependent either on a rising concentration in the tissues or at least the initial rise to a given level.

The striking parallel relationship found between the ataxic test responses and the PAN phase I responses amidst the absence of systematic ataxia test relationships with PAN phase II responses was a major finding, which suggests the workings not only of a common etiological factor but also a common characteristic of this factor.*

*By employing the technique of maintaining the blood alcohol level, while not changing, thereby, the intensity nor the duration of PAN I responses, with repeated administration of small doses of alcohol during the PAN I period (2), the observed ataxia test relationships to PAN I responses in this study might be elaborated or clarified.

But in man, at least, a full understanding of the underlying mechanisms, particularly the relative importance of central versus peripheral factors, governing the relationships between ataxia and the two phases of PAN awaits further investigation. Further studies employing other toxic agents may contribute inestimably to an understanding of the mechanisms or processes underlying ataxia generally and "vestibular ataxia" in particular.

In such studies as the present, which seek normative standards for later comparisons with less than normal performance standards, the importance of utilizing auricular normal subjects in good physical health and free of pathological drinking patterns cannot be over-emphasized for realization of maximum interpretability of results.

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