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ADAPTATION TO VESTIBULAR DISORIENTATION: I. VERTIGO AND NYSTAGMUS FOLLOWING REPEATED CLINICAL STIMULATION

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Adaptation to Vestibular Disorientation: I. Vertigo and Nystagmus Following Repeated Clinical Stimulation

Recent studies have been concerned with the effects of repeated unilateral caloric irrigations on human nystagmus and vertigo. Lidvall[1-3] recorded nystagmus from behind closed eyes and reported habituation (a response decline) with as few as 4 repeated stimulations. Number of nystagmic beats and duration of the response both declined, while latency of response and degree of dysrhythmia increased. In addition, subjective responses (vertigo) declined markedly. Fluur and Mendel [4,5] used the duration of nystagmus recorded with the subjects' eyes closed as their primary measure and obtained a shortening of nystagmus time after 8-12 unilateral irrigations. The latter authors also examined before-and-after responses to stimulation of each ear with warm and with cool water and reported that subjects fell into two groups: (1) those who exhibited a directional preponderance in the unhabituated direction, and (2) those who showed reduced responses in both directions.[4] A later study indicated that the directional preponderance following a habituation series could be reversed by then habituating the opposite direction.[5]

Forssman, Henriksson, and Dolowitz[6] kept subjects in total darkness, and Forssman[7] later used an illuminated environment to investigate the effects of repeated unilateral calorizations on nystagmus, laterotorsion, and vertigo. Results for the two studies were similar. Twelve stimulations produced declines in vertigo in excess of 80%, laterotorsion declined about 40%, and the maximum eye-velocity and the duration of nystagmus were reduced by 55% and 25%, respectively.

The importance of alertness or arousal on the process of habituation was noted in several of the above studies e.g. [3,8] and has received extensive attention elsewhere. [9-11] It has been demonstrated that nystagmic output[9] and evidence of dysrhythmia in records of nystagmus can be readily manipulated by instructions given to the subjects. Subjective states of arousal result in brisk nystagmic responses. Thus, in this study, efforts were made to control for the arousal factor.

The present study was designed to examine the effects on nystagmus and subjective experience of repeated unilateral caloric irrigations administered under conditions of total darkness and of visual fixation. Tasks were assigned to subjects in an attempt to control mental states. Pre- and posttests comprised stimuli which elicited unilateral and bilateral nystagmic responses in both directions.

METHOD

Subjects. Subjects were 20 males between the ages of 21-29. All were experimentally naive and were free of any history of ear difficulties, dizziness, loss of consciousness, or unusual reactions to linear and angular accelerations. On each day, prior to testing, subjects' ears were examined and cleaned.

Apparatus. Two water baths were equipped with Bronwill constant temperature circulators. Tubing from each bath terminated in its own plastic nozzle which was to be inserted in the external auditory meatus. Water temperature was maintained such that it was 30° C from one bath, and 44° C from the other, upon introduction to the ear.

Horizontal components of eye-movements were obtained by means of an Offner Type TC recorder. A 3-sec RC time constant was employed in amplification. Signals were picked up from electrodes taped near the outer canthi. An indifferent electrode was located on the forehead. All recordings of nystagmus were obtained in total darkness with the subjects' eyes open. Subjective reactions were signalled by means of a buzzer manually controlled by the subject.

A special device (Caloric Irrigation Receptacle) to collect return flow of water from the ear in a convenient fashion was a rectangular plastic basin into which the subject's head was placed and anteverted approximately 30° by means of a head rest. A drain was located at the back of the basin. A tube extended from the drain into a large water receptacle placed underneath the examining table. A large number of irrigations could thus be performed without any discomfort to the subjects and without concern for collecting the water.

Procedure. Subjects were divided into two groups of 10 each. Both groups were tested on 7 occasions. Six of these occasions were on consecutive days; the seventh was one month later. The first, sixth, and seventh days were termed pretest, post-1 and post-2 tests respectively, and each comprised 6 trials, the order of which was varied as indicated in Table I.

TABLE I

THE ORDER OF STIMULUS PRESENTATION. R AND L REFER TO THE RIGHT AND THE LEFT EAR; c AND w INDICATE COOL (30°C) AND WARM (44°C) STIMULI. BILATERAL STIMULI WERE ADMINISTERED FOR 15 SEC, UNILATERAL STIMULI FOR 30 SEC. ALL PRE AND POST TESTS WERE CONDUCTED IN TOTAL DARKNESS.

Groups	SUBJECTS									
Dark	RY	PH	RA	BE	GR	JB	HL	JL	BM	JG
Fixation	TV	FN	GP	FS	CW	DM	FG	FK	RV	VV
Pre Tests	R_cL_w	R_wL_c	R_cL_w	R_wL_c	R_cL_w	R_wL_c	R_cL_w	R_wL_c	R_cL_w	R_wL_c
	R_wL_c	R_cL_w	R_wL_c	R_cL_w	R_wL_c	R_cL_w	R_wL_c	R_cL_w	R_wL_c	R_cL_w
	L_c	L_c	R_c	L_c	R_c	L_w	R_w	L_w	R_w	L_w
	R_w	R_c	L_c	L_w	R_w	R_w	L_w	R_c	R_c	L_c
	L_w	L_w	R_w	P_c	L_c	L_c	R_c	L_c	L_c	R_w
	R_c	R_w	L_w	R_w	L_w	R_c	L_c	R_w	L_w	R_c
Habituation Tests	Dark group: 10 unilateral trials (all R_c) per day for 4 days. All trials in total darkness.									
	Fixation group: 10 unilateral trials (all R_c) per day for 4 days. Trials 1 and 10 on each day in total darkness. All other trials in illumination with visual fixation.									
Post-1 and Post-2 Tests	L_c	L_c	R_c	L_c	L_c	L_w	R_w	L_w	R_w	L_w
	R_w	R_c	L_c	L_w	R_w	R_w	L_w	R_c	R_c	L_c
	L_w	L_w	R_w	R_c	L_c	L_c	R_c	L_c	L_c	R_w
	R_c	R_w	L_w	R_w	L_w	R_c	L_c	R_w	L_w	R_c
	R_cL_w	R_wL_c	R_cL_w	R_wL_c	R_cL_w	R_wL_c	R_cL_w	R_wL_c	R_cL_w	R_wL_c
	R_wL_c	R_cL_w	R_wL_c	R_cL_w	R_wL_c	R_cL_w	R_wL_c	R_cL_w	R_wL_c	R_cL_w

Two of the 6 trials were bilateral irrigations (warm water to one ear and cool water to the other delivered simultaneously). The remaining 4 trials consisted of unilateral irrigations (a warm or a cool stimulus applied to each ear separately). Days 2 through 4 consisted of 10 daily habituation trials. In all 40 of the latter, a unilateral stimulus of 30° C was applied to the right ear. Twenty to 30 minutes of rest occurred between successive stimulations.

The two groups of subjects were differentiated on the basis of the habituation trials. The Dark Group received all trials in total darkness. The Visual Fixation Group was given all pre- and posttests in total darkness, but in the habituation series only trials 1 and 10 on each day were in darkness. The remaining daily trials for the Visual Fixation Group were in illumination with the subjects actively fixating on the center marker of the calibration device on the ceiling and consciously trying thereby to reduce and prevent the nystagmic movement. Thus, the Dark Group received a total of 40 habituation trials in total darkness while the Visual Fixation Group received 8 habituation trials in total darkness and 32 under conditions of visual fixation.

During all "total darkness" trials, the irrigation period was also in the dark. The rate of flow of the water was relatively high, approximately 15cc/sec, to permit ready monitoring of the irrigation by touch alone. Irrigation time was 15 sec for bilateral and 30 sec for unilateral stimuli.

Tests were conducted in the following manner: Subjects assumed a supine position on the examining table with their heads elevated and anteverted approximately 30°. Prior to each trial, eye-movement calibrations were obtained by means of a ceiling panel with a center and two lateral markers. For all pre- and posttests, subjects signalled the onset, point of maximum intensity (defined as the point at which the sensation no longer increased), and cessation of their subjective vestibular experiences by means of a manually operated microswitch. Several seconds after their "cessation of sensation" signal, subjects were given mental arithmetic (MA) problems (continuous division) to perform throughout the remainder of the trial. The MA task was used purely as an alerting technique.[9-11] At the conclusion of each pre- and post-trial, subjects described their sensations and rated them.

Subjective ratings were made in the following fashion. During the pretest, the first two trials for all subjects were bilateral irrigations. Each subject was asked which of the two bilateral stimulations produced the most intense subjective experience. His selection was then given a rating of 100 and all other subjective ratings were made with the "100 intensity" experience as a reference point.

During the habituation trials in total darkness, several tasks were presented to the subjects in accordance with the schedule in Table II. All used the microswitch as a signalling device. The tasks included:

1) Reaction time (RT) – Subjects responded to a series of 500 cps tones of 1/10 sec duration by depressing the microswitch as quickly as possible at the onset of each tone.

2) Temporal Estimation of Sound-Filled Intervals (FI) – The 500 cps tone was sounded for periods ranging between 0.5 and 6.5 sec. At the conclusion of a tone, subjects attempted to reproduce its duration by depressing the microswitch for the same length of time as that occupied by the tone.

3) Temporal Estimation of Sound-Bounded Intervals (BI) – The 500 cps tone was sounded for 1/10 sec to indicate the start and end of an intervening period of silence. Silent periods between the two brief tones ranged from 0.5-6.5 sec. After each pair of tones, subjects depressed the microswitch for a length of time which they considered to be equal to that of the period of silence between tones.

4) Temporal Comparison of Sound-Filled Intervals (FIC) – Pairs of 500 cps tones were successively presented for comparison. A given tone would be of a duration ranging from 0.5-6.5 sec. Its companion tone would differ by no more than 2 sec. Subjects indicated which tone of the pair was longer in duration by signaling with either one or two depressions of the microswitch.

5) Temporal Comparison of Sound-Bounded Intervals (BIC) – A period of silence was

TABLE II

THE ORDER OF TASK PRESENTATION FOR THE DARK GROUP AND FOR THE VISUAL FIXATION GROUP. RT = REACTION TIME; FI AND BI = TEMPORAL ESTIMATION OF SOUND-FILLED AND OF SOUND-BOUNDED INTERVALS, RESPECTIVELY; FIC AND BIC = TEMPORAL COMPARISON OF SOUND-FILLED INTERVALS AND OF SOUND-BOUNDED INTERVALS, RESPECTIVELY.

	Habituation Sessions			
	I	II	III	IV
Trials	Dark Group			
1	FI	FIC	BI	BIC
2	FI	FIC	BI	BIC
3	FI	FIC	BIC	BI
4	RT	RT	BIC	BI
5	BI	BIC	RT	RT
6	BI	BIC	FIC	FI
7	BI	BIC	FIC	FI
8	RT	RT	RT	RT
9	FI	FIC	FI	FIC
10	BI	BIC	FI	FIC
Trials	Visual Fixation Group			
1	FI	FIC	BI	BIC
2 Through 9	Illumination with Visual Fixation			
10	BI	BIC	FI	FIC

delimited by two 1/10 sec, 500 cps tones and was followed by another pair of tones with an intervening period of silence. Silent periods ranged from 0.5 - 6.5 sec, but in each pair of silent periods the maximum temporal difference did not exceed 2 sec. Subjects depressed the microswitch once or twice to indicate whether the first or second silent period was longer in duration.

For each of the above tasks, a whole series of stimuli were presented throughout a trial. The tasks were used purely to maintain a state of alertness in the subjects. However, subjects were encouraged to perform as accurately and as attentively as possible and were impressed with the fact that their performance was of significance. Records of their signals were obtained.

RESULTS AND DISCUSSION

Nystagmus

Eye-movement recordings (see Figures 1 and 2) were scored and analyzed for duration of nystagmus, slow-phase displacement, and number of nystagmic beats as indicated elsewhere.[11] Mean data for both the Dark Group and the Visual Fixation Group appear in Table III. Percentage data relating the posttest scores to those of the pretest appear in Table IV. In both tables, scores have been rounded off to the nearest whole number.

The data were treated statistically by analyses of variance and t tests (Tables V and VI). In all analyses, as expected, significant differences were obtained among subjects. In addition, "Ears" yielded significant differences for all measures due to the fact that higher scores were consistently obtained for bilateral, as compared with unilateral, irrigations.

TABLE III

MEAN DURATION, NUMBER OF NYSTAGMIC EYE MOVEMENTS, AND SLOW-PHASE DISPLACEMENT OF THE EYES TO PRELIMINARY, POST-1, AND POST-2 TESTS FOR THE TWO GROUPS. EACH VALUE IS A MEAN FOR 10 SUBJECTS.

	Dark Group			Fixation Group		
	Pre	Post-1	Post-2	Pre	Post-1	Post-2
			Duration (Seconds)			
R_cL_w	172	182	173	191	191	172
R_wL_c	168	153	163	193	186	170
R_c	154	152	158	174	169	155
L_w	136	156	147	174	180	163
R_w	123	130	124	172	156	155
L_c	135	139	136	180	179	154
			Number of Beats			
R_cL_w	250	326	285	287	316	291
R_wL_c	215	248	255	272	318	294
R_c	193	231	242	233	242	215
L_w	174	242	223	227	245	218
R_w	136	200	192	223	234	220
L_c	158	177	176	246	249	228
			Slow-Phase Displacement (Degrees)			
R_cL_w	1991	2124	1926	2997	2403	2557
R_wL_c	2016	1644	1847	3000	2629	2374
R_c	1389	1271	1433	2166	1537	1430
L_w	1331	1403	1236	1907	1512	1488
R_w	961	1203	1128	1976	1793	1521
L_c	1196	1150	1071	2174	1920	1525

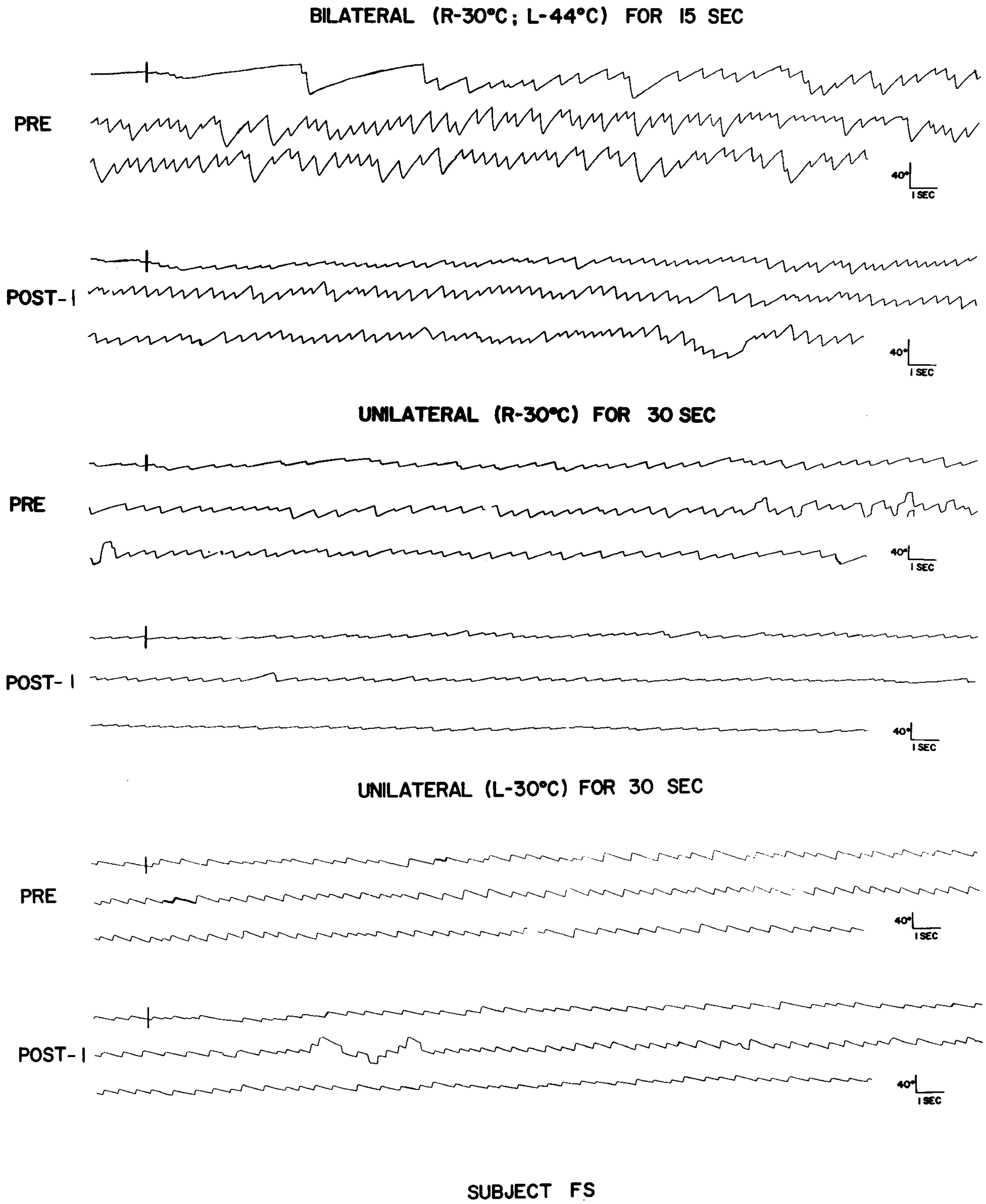

FIGURE 1. Examples of nystagmus recorded from a subject in the Visual Fixation Group. Vertical bars through the records indicate the point at which the irrigation was terminated. Calibration markers appear at the end of each tracing. A clear decline in slow-phase displacement is evident in post-1 tests for the practiced direction (bilateral trial and unilateral R-30° C trial).

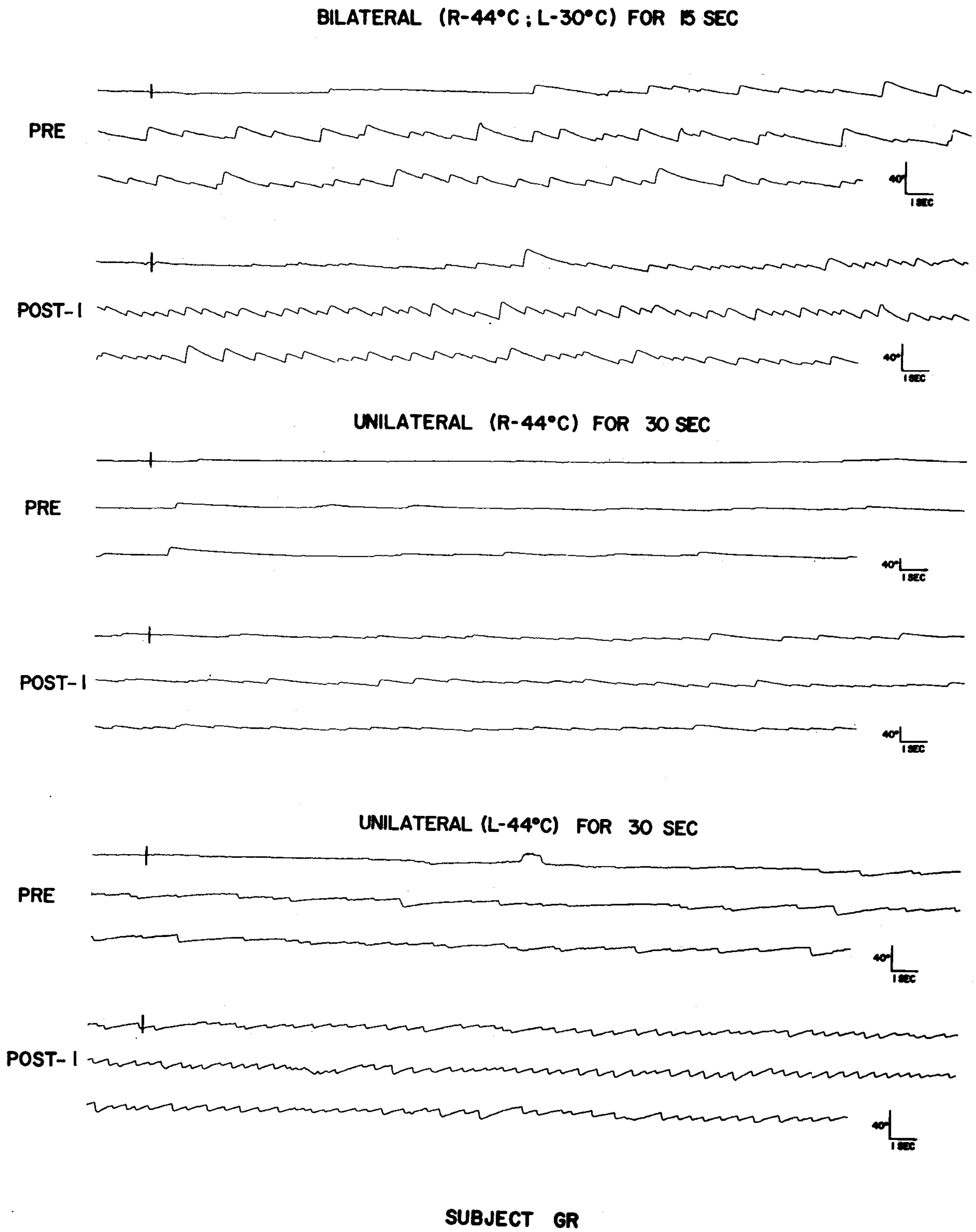

FIGURE 2. Examples of nystagmus recorded from a subject in the Dark Group. Markings are the same as in Figure 1. In pretests, this subject showed remarkably low nystagmic output. The increased number of nystagmic movements in post-1 is especially clear for the practiced direction (unilateral L-44° C).

For the Dark Group, the habituation series produced no statistically significant changes in duration or in slow-phase activity. The number of beats of nystagmus, however, rose significantly from pre- to post-1 and showed no evidence of normalizing after one month with no stimulation (post-2).

The Visual Fixation Group was affected differently. Whereas there was no change in the number of beats of nystagmus from the pre- to the posttests, slow-phase displacement declined significantly from pre- to post-1 and, after one month of rest, the response showed some further decline. The duration of nystagmus for the fixation group showed no pre- to post-1 change, but a statistically significant decline occurred in post-2.

Dysrythmia occurred on a number of occasions during the habituation trials. However, any alerting stimulus would restore a brisk nystagmus. Moreover, based upon observations made both prior to and during the ex-

TABLE IV

RELATION OF DATA FROM POST-1 AND POST-2 TESTS TO PRELIMINARY TEST SCORES. ALL VALUES ARE PERCENTAGES CALCULATED FROM DATA IN TABLE 3.

	Dark Group		Fixation Group	
	Post-1/Pre	Post-2/Pre	Post-1/Pre	Post-2/Pre
Duration				
R_cL_w	106	101	100	90
R_wL_c	91	97	96	88
R_c	99	103	97	89
L_w	115	108	103	94
R_w	106	101	91	90
L_c	103	101	99	86
Number of Beats				
R_cL_w	130	114	110	101
R_wL_c	115	119	117	108
R_c	120	125	104	93
L_w	139	128	108	96
R_w	147	141	105	99
L_c	112	111	101	93
Slow-Phase Displacement				
R_cL_w	107	97	80	85
R_wL_c	82	92	88	79
R_c	92	103	71	66
L_w	105	93	79	78
R_w	125	117	91	77
L_c	96	90	88	70

TABLE V

SUMMARY OF ANALYSES OF VARIANCE (REPEATED MEASUREMENTS DESIGN).

		F-Ratios							
		Total Darkness Group				Visual Fixation Group			
Source	df	Nystagmus Duration	Number of Beats	Slow-Phase Nystagmus	Subjective	Nystagmus Duration	Number of Beats	Slow-Phase Nystagmus	Subjective
Subjects (S)	9	3.42[a]	10.79[c]	7.78[b]	3.89[b]	5.46[b]	3.24[a]	7.84[c]	3.17[a]
Tests (T)	2	0.38	6.56[b]	0.18	1.92	3.63[a]	1.65	6.60[b]	5.59[a]
Directions (D)	1	5.59[a]	10.34[a]	3.21	3.76	0.11	0.01	0.84	14.77[c]
Ears (E)	2	37.97[c]	76.07[c]	6.99[a]	29.04[c]	12.96[c]	83.41[c]	73.20[c]	63.66[c]
S × T	18	1.76[a]	3.23[b]	1.96	2.82[b]	3.92[c]	3.07[b]	2.51[a]	2.79[b]
S × D	9	6.30[c]	4.56[b]	4.83[b]	1.95	3.24[a]	4.29[b]	2.68[a]	0.68
S × E	18	1.06	1.42	1.75	1.85	0.82	0.74	2.06	0.92
T × D	2	1.11	2.82	0.29	7.86[b]	0.61	0.15	2.11	3.45
T × E	4	6.62[c]	2.92[a]	0.90	6.20[c]	0.74	0.83	0.17	0.88
D × E	2	4.02[a]	1.82	0.29	13.48[c]	0.08	0.63	1.26	3.13
S × T × D	18	1.72	1.94[a]	2.87[b]	1.33	0.83	1.67	5.59[c]	0.91
S × T × E	36	0.99	0.71	2.70[b]	1.97[a]	1.44	2.42[b]	8.06[c]	1.20
S × D × E	18	0.82	1.93[a]	2.33[a]	2.08[a]	2.16[a]	2.26[a]	4.78[c]	2.17[a]
T × D × E	4	1.15	1.25	5.66[c]	1.94	0.36	0.59	2.64	3.62[a]
S × T × D × E	36								
	179								

Levels of Significance

a: .05 level

b: .01 level

c: .001 level

TABLE VI

RESULTS OF t TESTS

Dark Group

Measure	Comparison	t	Level of Significance
Frequency (fast-phase to the right)	Pre vs. Post-1	3.67	.01
	Pre vs. Post-2	2.64	.05
	Post-1 vs. Post-2	0.027	——
*Frequency (fast-phase to the left)	Pre vs. Post-1	2.92	.05
	Pre vs. Post-2	2.86	.05
	Post-1 vs. Post-2	0.37	——
Subjective (motion to the right)	Pre vs. Post-1	0.34	——
	Pre vs. Post-2	0.14	——
	Post-1 vs. Post-2	0.41	——
*Subjective (motion to the left)	Pre vs. Post-1	3.80	.01
	Pre vs. Post-2	3.39	.01
	Post-1 vs. Post-2	2.14	——

Visual Fixation Group

Measure	Comparison	t	Level of Significance
Duration	Pre vs. Post-1	0.53	——
	Pre vs. Post-2	1.99	——
	Post-1 vs. Post-2	2.91	.05
Slow-Phase	Pre vs. Post-1	3.58	.01
	Pre vs. Post-2	2.77	.05
	Post-1 vs. Post-2	0.49	——
Subjective (motion to the right)	Pre vs. Post-1	0.75	——
	Pre vs. Post-2	0.13	——
	Post-1 vs. Post-2	1.25	——
*Subjective (motion to the left)	Pre vs. Post-1	6.64	.01
	Pre vs. Post-2	3.01	.05
	Post-1 vs. Post-2	4.53	.01

*Direction stimulated during the 40 habituation trials.

periment, it appeared that some of this dysrhythmia may have been related to the gaze-level of the subjects' eyes. That is, with repeated testing in the dark, there is a tendency not only for alertness to decline, but for some individuals to lower their gaze (and probably half-close their eyelids). At least for some subjects, this appears to produce dysrhythmia. With an "eyes closed" condition, it is suggested that subjects may inadvertently roll up their eyes and occasion a like effect.

Dysrhythmia rarely occurred on the RT trials, perhaps because they were used sparingly (although subjects seemed to respond to them in a particularly attentive fashion), and on only one occasion during the pre- and posttests. It is probable that any task repetitively administered, especially in total darkness, will lose its ability to hold a subject's interest. Responses to timing tasks have been known to become quite automatic and such tasks, though providing relative ease of presentation and the possibility of variation, may not be particularly well suited for prolonged maintenance of alertness.

Subjective Responses

The mean intensity ratings reported by the subjects appear in Table VII. In addition, for both groups, the percentage the posttest ratings were of the pretest are included. For the Dark Group, a statistically significant decline in subjective vestibular experiences was obtained for the direction of response stimulated during the habituation trials. There were no significant pre- to posttest differences for the group of "unpracticed" direction stimuli, although two sets of these responses (to R_w and to L_c) showed higher intensity ratings.

The Visual Fixation Group reported subjective declines for all post-1 stimuli. Further, a directional consistency was evident. The greatest drop occurred to the habituation stimulus (R_c), next to the R_cL_w, and next to the L_w stimuli. The forementioned all produced responses in the same direction as that elicited during the habituation trials and the declines were statistically significant. Although the remaining three stimuli also showed reductions in intensity ratings, the pre- to posttest differences were not significant.

After one month with no intervening tests, recovery of subjective intensity was evident for both groups. Some directional effects were still in evidence.

The signals made by the subjects to indicate the start, peak, and end of their sensations were also examined. Measurements were made from the end of the irrigation to each signal, converted to seconds of time, and separately averaged for the Dark Group and the Visual Fixation Group (Table VIII). For stimuli eliciting responses in the same direction as the habituation trials (i.e., R_cL_w, R_c, and L_w), the pre- to posttest changes were approximately the same for the two groups. In general, latency increased, maximum intensity was reached earlier, and duration declined.

For stimulation in the direction opposite that of the habituation trials (i.e., R_wL_c, R_w, and L_c), duration of sensation remained approximately constant for both groups from the pre- to posttests. However, for the Visual Fixation Group, latency increased and maximum intensity was reached at about the same point in time while, for the Dark Group, latency declined slightly and the peak intensity occurred earlier. The term "peak" may be misleading. Sensations were relatively rarely reported as building up to a point and then declining. Most often the sensation was reported as reaching an intensity maximum which was maintained for a considerable period of time before the sensation faded away.

There were considerable differences among the sensations reported by the subjects. Apparent angular motion about an earth-vertical axis (including complete revolutions) was a frequent report following bilateral irrigations. The location of the turning axis was either in the stomach-chest area of the body or in the head — never at the lower extremity. The apparent velocity experienced during these turns varied widely and, on two occasions, subjects positively identified motion in the same direction for both the R_cL_w and the R_wL_c stimuli. "Arcing" sensations were frequently reported in which subjects experienced repeated motion through one small angle (say, 45°), usually

TABLE VII

MEAN SCORES FOR THE INTENSITY OF THE SUBJECTIVE EXPERIENCE RESULTING FROM CALORIC IRRIGATION. WHICHEVER OF THE TWO BILATERAL IRRIGATIONS IN THE PRELIMINARY TEST PRODUCED THE STRONGEST SENSATION WAS GIVEN A RATING OF 100. ALL OTHER RATINGS WERE MADE BY COMPARING A NEW SENSATION WITH THE STANDARD OF 100.

	Dark Group			Fixation Group		
	Mean Subjective Rating					
	Pre	Post-1	Post-2	Pre	Post-1	Post-2
R_cL_w	87	41	50	95	47	54
R_wL_c	84	59	113	73	66	75
R_c	36	19	27	31	8	19
L_w	56	39	47	45	29	49
R_w	39	66	53	44	37	46
L_c	30	35	29	48	41	46
	% Post-1 and Post-2 Are of Pre Rating					
		Post-1	Post-2		Post-1	Post-2
R_cL_w		47	57		50	57
R_wL_c		70	135		90	103
R_c		53	75		26	61
L_w		70	84		64	109
R_w		169	136		84	105
L_c		117	97		85	96

without ever experiencing the return movement to the starting position; movement thus appeared always to start from the same point, was repeated through the same angle, but was experienced in only one direction. Other reports included dizziness, "arcing" about a horizontal axis, floating straight up, tilting to one or the other side, and elevation or depression of the feet. Many reports indicated combinations of displacement sensations. On a few occasions subjects noted secondary reactions (e.g., a subject would report an initial sensation of apparent angular motion to the left which, after a time, would give way to apparent motion to the right). The differences in reports did not seem to be related to head position; the same subject in apparently the same position might report a clear turning sensation to one stimulus and, to the next, a clear tilt sensation accompanying the turn.

No sensation was reported for 5 post-1 trials in the Visual Fixation Group (3 R_c and 2 L_w) and for 4 post-1 trials in the Dark Group (2 R_c, 1 L_w, and 1 L_c). During post-2, 3 R_c trials resulted in no reported sensation (1 in the Dark Group and 2 in the Visual Fixation Group).

Of the total of 360 pre- and posttest trials, on only 3 occasions did the subjective experience begin before the onset of nystagmus. Whereas nystagmus was usually in evidence

TABLE VIII

MEAN TIME IN SECONDS FOR ONSET, POINT OF MAXIMUM INTENSITY, AND END OF SUBJECTIVE EXPERIENCE FOR THE TWO GROUPS. TIME WAS CALCULATED FROM THE END OF IRRIGATION TO THE SUBJECTS' SIGNALS. MOTION TO THE LEFT RESULTED FROM R_cL_w, R_c, AND L_w STIMULI, TO THE RIGHT FROM R_wL_c, R_w, AND L_c STIMULI.

		Dark Group			Visual Fixation Group		
Direction of Motion	Test	Onset	Maximum	End	Onset	Maximum	End
	Pre	9.1	42.7	81.1	9.1	42.5	80.1
Left	Post-1	18.4	40.8	65.5	15.8	36.4	67.5
	Post-2	9.9	33.7	63.2	15.5	37.4	73.6
	Pre	9.9	43.5	71.9	8.0	41.3	80.4
Right	Post-1	9.0	34.6	68.9	15.5	39.2	85.3
	Post-2	8.5	32.7	69.1	12.5	39.2	79.6

prior to the end of irrigation (in 226 of 240 unilateral trials and 82 of 120 bilaterial trials), the subjective response rarely began until the irrigation was terminated (in only 22 of the unilateral trials and 5 of the bilateral trials did it occur during the irrigation period). On the average, nystagmus preceded the subjective response by 10.4 - 21.3 sec for bilateral stimuli and by 17.8 - 32.0 sec for unilateral stimuli (see Table IX).

General Discussion

These findings indicate that, when alertness is maintained, remarkable declines in nystagmic output and duration do not necessarily occur during the course of repeated testing. In fact, an overall increase in number of nystagmic beats may appear as a result of successive trials in total darkness (see also Collins, 1964). It is, then, not always appropriate to consider

TABLE IX

MEAN TIME IN SECONDS BETWEEN START OF NYSTAGMUS AND ONSET OF SUBJECTIVE EXPERIENCE. SUBJECTIVE SIGNALS PRECEDED NYSTAGMUS ON ONLY THREE OCCASIONS.

	Dark Group			Visual Fixation Group		
Trials	Pre	Post-1	Post-2	Pre	Post-1	Post-2
Bilateral	12.8	21.3	18.3	10.4	19.3	12.9
Unilateral	20.7	32.0	26.5	22.4	24.7	17.8

habituation (a response decline) as the only effect of repeated stimulation. The form of the response may change.

The studies cited earlier which used a relatively small number of irrigating stimuli and yet found high rates of nystagmus loss in total darkness (whereas here there were no losses and, in the case of number of beats, a significant response increase) differed in two major respects from the present work: (1) state of arousal was not controlled; (2) data were obtained in darkness with the subject's eyes closed. These two conditions probably interact to lower nystagmic output.

Contrary to data reported by Forssman and his associates,[6,7] the effects of darkness and light on the nystagmic response appear different. Neither duration nor frequency showed any pre- to post-1 decline for the Visual Fixation Group, whereas the slow-phase output dropped significantly. The importance of the light condition is probably not the mere presence of visual objects. It seems most likely that what is required is an active attempt on the part of the subject to control and suppress his eye movements.

In agreement with the previously cited study of the effects on nystagmus of repeated angular accelerations, [11] a one-month rest period did not restore the alterations in the response produced by the repeated stimulation. Thus, for the Dark Group, number of nystagmic movements remained at a higher level than in the preliminary tests and, for the Visual Fixation Group, further declines in slow-phase output and in nystagmus duration were evident, rather than a return toward the preliminary response level.

Although some directionally specific effects are suggested by the nystagmus data, they are neither consistent nor striking. This too agrees with the rotation findings noted above.

Subjective responses showed statistically significant declines only for the practiced direction and insignificant changes for the unpracticed direction for both the total darkness and the visual fixation conditions. However, there was considerably less uniformity in the pre- to posttest changes for the total darkness condition and the marked increase in subjective intensity reported for R_w during the posttests (see Table VII) was accompanied by an enhanced nystagmic output (see Table IV). Unlike the nystagmic response, recovery of subjective intensity is clearly evident following the one-month rest period. These results also agree with our previous rotatory work.[11]

Thus our data indicate that repeated, caloric stimulation results in a modified nystagmic response (which may reflect increased activity rather than a reduction) and that the modification is not capricious; the response shows little or no recovery toward its original form after a month of rest. The changes are bidirectional (although the repeated stimulation was unidirectional) and the nature of the changes seems to depend upon whether the response was repetitively elicited in darkness or with fixation. The subjective response declines for the practiced direction. Subjective reactions to the unpracticed direction, taken as a whole, show no statistically significant change although some declines or increases in intensity may be related to whether the total darkness or the visual fixation condition was present during stimulus repetition. Differential effects of visual fixation and total darkness during repeated testing have been reported for both nystagmic and subjective responses under other conditions of stimulation.[12] Greater reductions were obtained, as in the present study, when visual fixation was employed.

It is sometimes implied that the arousal factor represents a kind of artifact in habituation. Actually, the view propounded by Wendt[13] some years ago seems most appropriate; namely that there can be habituation to the test situation which produces a response decrement when alertness is not controlled. But, by simple instructions designed to relax a subject and reduce his mental activity, the same "response decrement" may be produced on the very first trial.[8] Hence, such a decline is not necessarily related to repeated vestibular stimulation. The changes that do occur as a result of repeated stimulation must be evaluated in terms of arousal level.

SUMMARY

Forty unilateral caloric irrigations were administered in a habituation series to each of two groups of subjects. One group was tested in total darkness. Subjects in the second group were stimulated in illumination and actively attempted to control and suppress their eye movements by means of visual fixation. Pre- and posttests were administered (always in total darkness) in which both directions of response were elicited. In all cases, tasks were assigned to subjects to maintain alertness. The nystagmic reaction was altered as a result of the habituation series, but the change was different for the two groups. After one month of rest, there was no apparent recovery of the response toward the pretest level for either group. Subjective reactions declined in intensity for both groups, but showed recovery after a one-month rest period.

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