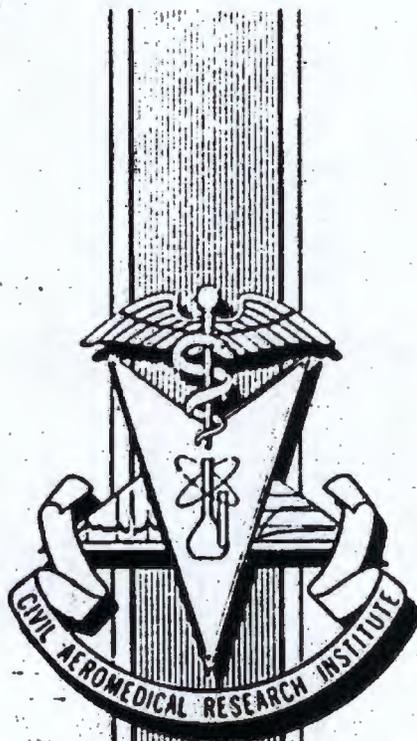


63-14



NYSTAGMUS RESPONSES  
OF THE CAT TO ROTATION  
AND TO  
DIRECTIONALLY EQUIVALENT  
AND  
NON-EQUIVALENT STIMULI  
AFTER UNILATERAL CALORIC  
HABITUATION



63-14

FEDERAL AVIATION AGENCY  
AVIATION MEDICAL SERVICE  
AEROMEDICAL RESEARCH DIVISION  
CIVIL AEROMEDICAL RESEARCH INSTITUTE  
OKLAHOMA CITY, OKLAHOMA

AUGUST 1963

Civil Aeronautical Research Institute, Federal Aviation Agency, Oklahoma City, Oklahoma. CARI Report 63-14. NYSTAGMUS RESPONSES OF THE CAT TO ROTATION AND TO DIRECTIONALLY EQUIVALENT AND NONEQUIVALENT STIMULI AFTER UNILATERAL CALORIC HABITUATION by William E. Collins, August 1963.

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**WILLIAM E. COLLINS, Ph.D.**

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# NYSTAGMUS RESPONSES OF THE CAT TO ROTATION AND TO DIRECTIONALLY EQUIVALENT AND NON-EQUIVALENT STIMULI AFTER UNILATERAL CALORIC HABITUATION<sup>1</sup>

WILLIAM E. COLLINS, Ph.D.

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Cats have demonstrated a decline ("habituation") in the nystagmic response to repeated unilateral caloric irrigation in illumination (Henriksson, Fernandez, & Kohut, 1961; Henriksson, Kohut, & Fernandez, 1962), to repeated rotation in total darkness (Collins, 1963b; Crampton, 1961, 1962a; Crampton & Schwam, 1961), and to rotation with concomitant optokinetic stimulation (Crampton, 1962b). Further, if the elicited nystagmus is limited to a single direction during the habituating trials, there appears to be no transfer of the response decline to vestibularly-induced eye-movements in the opposite direction (Crampton, 1962a; Henriksson, et al., 1962).

The question of transfer involves stimulus modality as well as directional effects. Working with rabbits, Maxwell, Burke, and Reston (1922) and Hood and Pfaltz (1954) reported habituation of rotation-induced nystagmus, but normal responses from the unilateral caloric irrigations which followed the rotatory trials. Collins (1963b) found little transfer in the cat; the frequency of the beats to caloric stimulation was reduced by about one-third after an intervening series of 15 rotations. Dunlap (1925) obtained a marked stimulus transfer by abolishing nystagmus through caloric irrigation of the canals first on one side of the heads of rabbits, and then on the other. He obtained no nystagmus to rotational stimuli after these treatments.

The present study was designed to examine, with cats: (a) the question of transfer of caloric nystagmus habituation to the rotational situation; (b) the manner in which caloric habituation occurs in total darkness; (c) the effects of stimulus repetition upon the secondary nystagmus.

## METHODS

**Apparatus.** Stimulating, restraint, and recording equipment were identical to those reported elsewhere (Collins, 1963b). The rotatory device, described by Guedry and Kletter (1956), was situated in a light-proof room. All testing, including caloric irrigation, was conducted with the animal positioned on the turntable. Restraint was effected according to the technique of Henriksson et al. (1961).

The recording device, an Offner Type T Electroencephalograph, employed a 1.4 sec RC time constant in amplification. Needle electrodes were positioned by the outer canthi for the recording of horizontal components of nystagmus. An indifferent electrode was located on the crown near the mid-line of the skull. Signals were led to a terminal box, through slip-rings, to the recorder located in an adjoining room.

**Procedure.** The test room was in total darkness during all trials. The habituation series consisted of 15 consecutive caloric irrigations of the right ear of each animal. Water temperature was kept at 23.5° C ( $\pm 0.5^\circ$  C). The tests of transfer (pre- and post-tests) consisted of above-threshold CCW accelerations (4.15°/sec<sup>2</sup> for 13 sec) and sub-threshold decelerations (0.19°/sec<sup>2</sup> for 333 sec) with the animal's head

<sup>1</sup> Data collected with the technical assistance of Kenneth E. Swain while the author was at the U. S. Army Medical Research Laboratory, Fort Knox, Ky. The assistance of Joseph E. Duchon and Mary Jayne Capps in the process of data reduction is gratefully acknowledged.

positioned at the center of rotation. The rotation schedule comprised: (a) 30 sec at a constant velocity of 1 rpm; (b) acceleration; (c) 60 sec at a constant velocity of 10 rpm; (d) deceleration to zero velocity. The combination of CCW threshold accelerations and sub-threshold decelerations, and irrigation of the right ear with cool water, was designed to limit the elicitation of primary nystagmus to a single direction, *viz.*, with the fast phase to the left. Stimulation always began within 10 sec of the onset of total darkness. Rest intervals of 12-15 minutes separated trials.

Data from 6 of 10 cats are presented here. The four discarded records were due to: (a) interruption of recording by loss of electrode contact (1 animal); (b) responses to the pre-test or to the first irrigation were too poor to be quantified (3 animals). To obtain further data from the same set of 6 animals, additional trials were conducted following the post-test. Two animals each were stimulated with: (a) warm water (53.5° C) in the untested (left) ear (to elicit nystagmus in the same direction as that occasioned during habituation); (b) warm water (53.5° C) in the tested (right) ear; (c) cool water (23.5° C) in the untested

(left) ear. The latter two conditions each produced nystagmus in the opposite direction from that elicited during the habituation trials. Thus the question of directional transfer could also be examined. A procedural outline appears in Table 1.

## RESULTS

Measurements of slow-phase displacement, frequency, and duration of nystagmus were obtained from each animal. Scoring for the primary response began with the onset of acceleration in the pre- and post-tests, and with the termination of irrigation in the caloric series. Secondary nystagmus (a nystagmus which follows and beats in a direction opposite to that of a declining primary response, in the apparent absence of physical stimulation) was scored from the point of its onset.

Examples of recorded nystagmus responses appear in Figure 1. A clear decline in the vigor of the caloric reaction as a result of repeated elicitation is evident for both of the animals represented. The post-test acceleration records show only minor changes from the pre-test: durations for primary responses are somewhat shorter, the beats seem more regular and the

TABLE 1  
THE PROCEDURAL CONDITIONS EMPLOYED

Cats	Trials	No. of Trials	Conditions	Fast-Phase Direction
All	Pre-test	1	4.15°/sec <sup>2</sup> CCW accel for 13 sec; sub-threshold decel	Left
All	Habituation	15	23.5° C water to right ear for 30 sec	Left
All	Post-test	1	4.15°/sec <sup>2</sup> CCW accel for 13 sec; sub-threshold decel	Left
1 & 2	Directional transfer	1	53.5° C water to left ear for 30 sec	Left
3 & 4	Directional transfer	1	53.5° C water to right ear for 30 sec	Right
5 & 6	Directional transfer	1	23.5° C water to left ear for 30 sec	Right

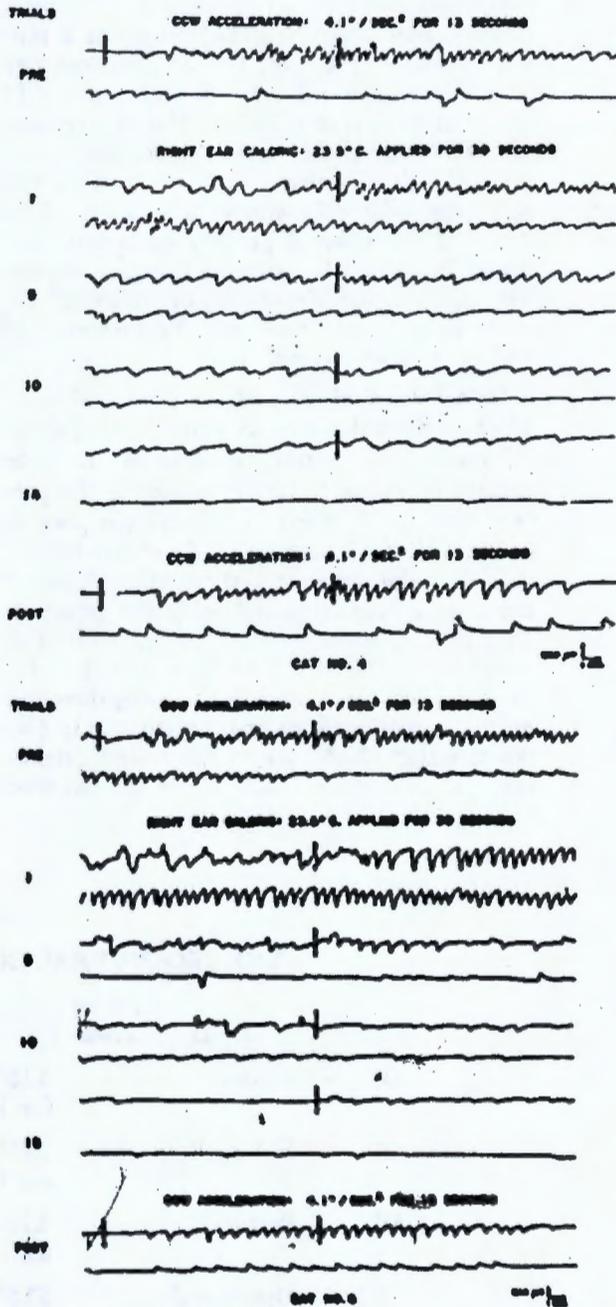


Figure 1. Nystagmus tracings obtained from two cats. Pairs of heavy vertical bars demarcate the acceleration periods. The single vertical bars through the caloric records indicate the termination of irrigation (tracings include the last 14 sec of irrigation). The decline in caloric reactivity is clearly evident. Note the more regular response to acceleration, the drop in frequency, and the earlier onset of secondary nystagmus during the post-test. A secondary reaction is also evidenced in caloric trial 5 for cat 6.

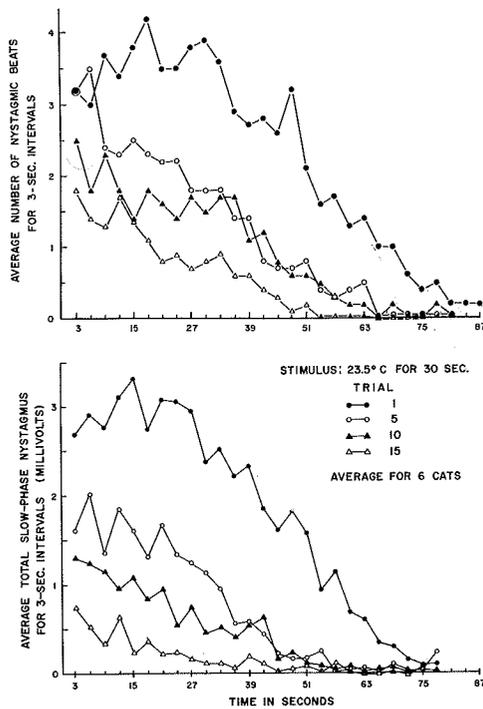


Figure 2. Alterations in the caloric response curve with repeated stimulation. Zero time indicates the termination of irrigation. A considerable reduction in response occurs within the first 5 trials.

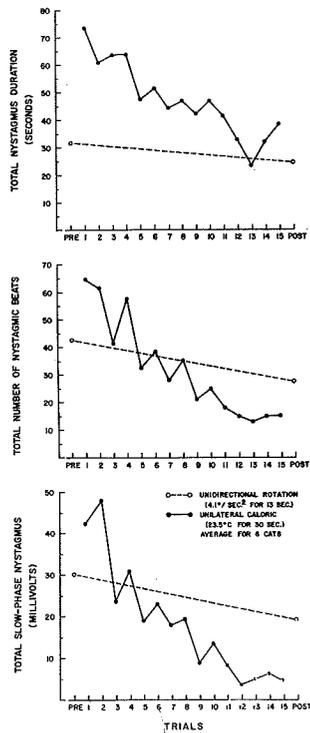


Figure 3. Average slow-phase displacement, duration, and frequency of nystagmic beats for the pre- and post-test responses to angular acceleration and for the 15 caloric trials. Pre- and post-test changes are slight considering the marked drop in the response to caloric stimulation.

secondary nystagmus begins somewhat earlier.

Slow-phase and frequency plots against time were made for caloric trials 1, 5, 10, and 15 (Figure 2). They indicate that: (a) a considerable overall reduction has occurred within the first 5 trials; (b) additional stimulation results in a further overall reduction of the response.

Total response-per-trial measures appear in Figure 3. A decline in all aspects of the response (frequency, slow-phase activity, and duration) is evident for both the caloric and rotatory data. The decline in caloric reactivity

is marked, although less regular than the function obtained for rotation (Collins, 1963b). Duration of the rotation-induced nystagmus only slightly reduced and the drops in frequency and a slow-phase displacement are factors of about one-third.

The time-course of the responses to rotation are plotted in Figure 4. The nystagmus decline affects the entire response curve, showing small, overall depression of ocular activity. For both the pre- and post-tests, the nystagmus continues to build up for a 3-sec period after stimulus termination.

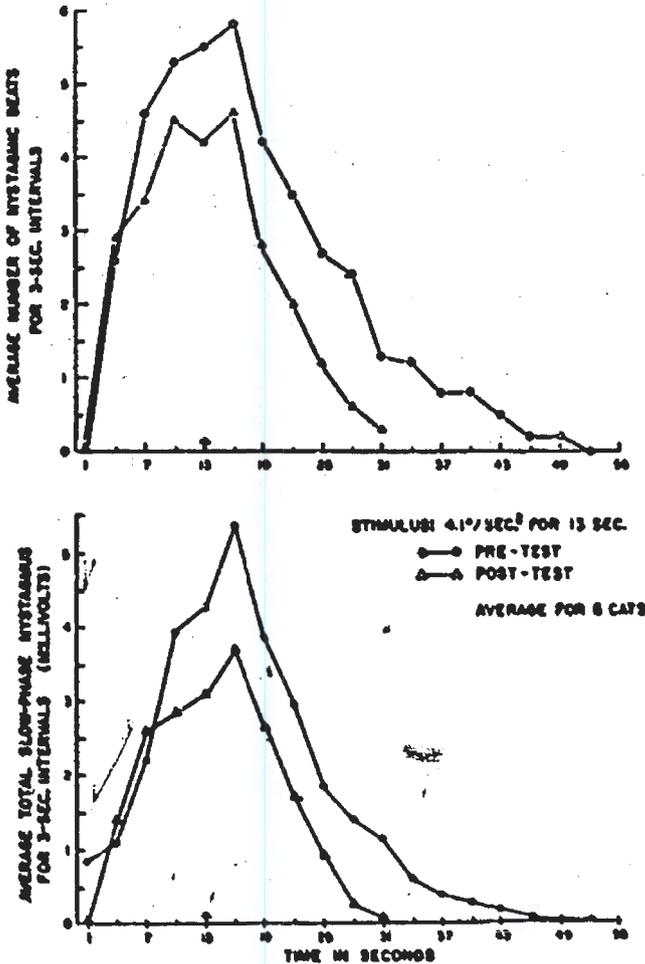


Figure 4. Time-course plots of pre- and post-test rotation-induced nystagmus. Data were plotted in 3-sec intervals with the exception of the first sec. Arrows show point of stimulus termination. Note that in all cases the response "overshoots" the termination of acceleration.

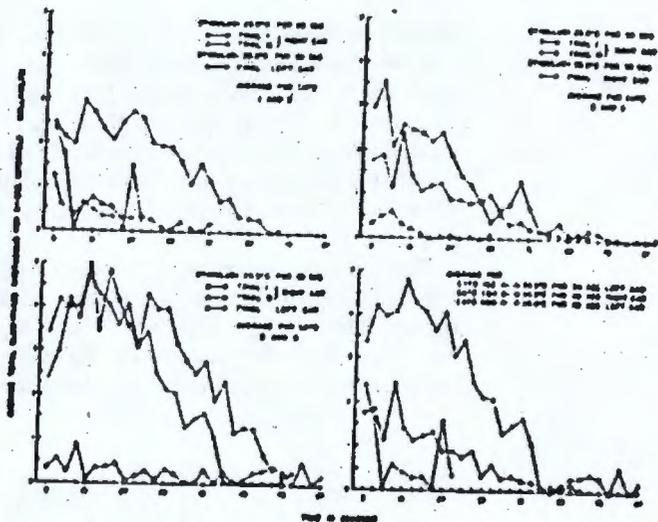


Figure 5. Directional specificity of the caloric response declines in slow-phase output. A directionally equivalent caloric stimulus applied to the opposite ear, after the series of habituating trials, produces a response similar to the last habituation trial (upper left graph, Cats 1 and 2). Caloric stimuli which elicit nystagmus in the direction opposite that of the habituation series produce vigorous responses (upper right graph, Cats 3 and 4, and lower left graph, Cats 5 and 6).

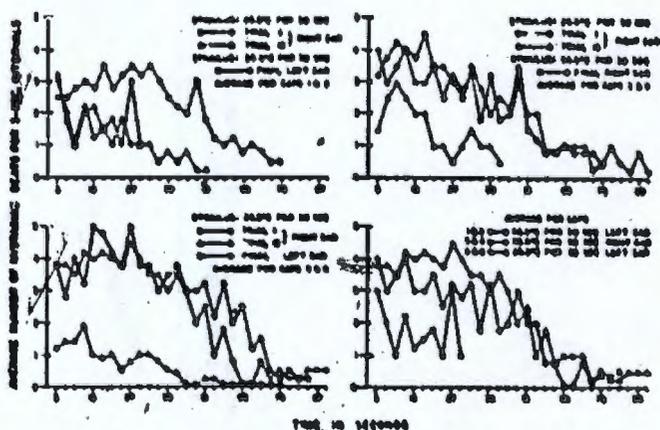


Figure 6. Directional specificity of the caloric response declines in frequency of nystagmus. The data are highly similar to the results presented for slow-phase activity.

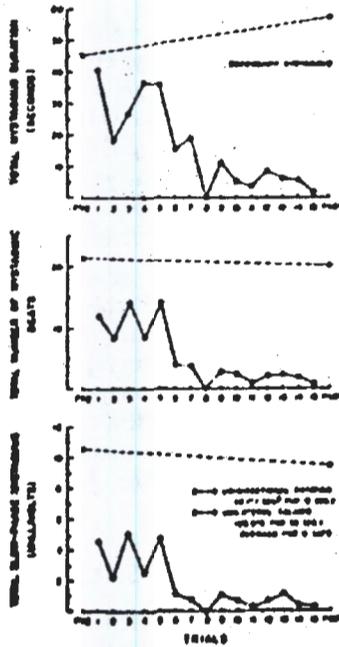


Figure 7. Average slow-phase displacement, duration, and frequency of secondary nystagmus obtained during successive trials. A decline in all aspects of the caloric secondary is evident although animals were not consistent in yielding such responses. All animals demonstrated a secondary to the pre- and post-test accelerations.

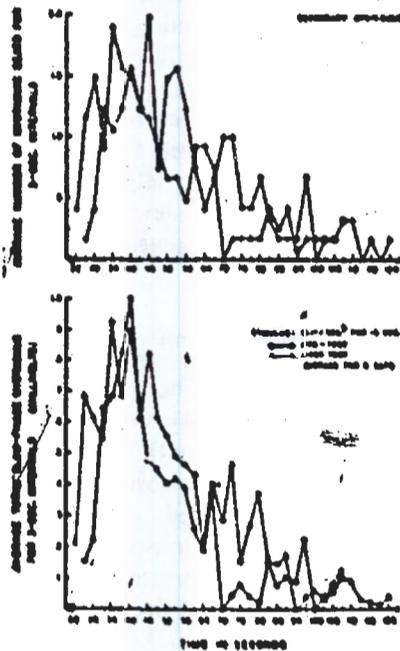


Figure 8. Secondary nystagmus responses to acceleration plotted in 3-sec intervals according to actual time (zero time represents point at which the 13-sec acceleration was initiated). No significant pre- to post-test changes are evident.

Figures 5 and 8 contain slow-phase displacement and beat-frequency curves obtained by stimulating the right ear with warm water, or the left ear with either warm or cool water. These trials were conducted after the post-test rotations. The data clearly indicate that unilateral caloric habituation is specific to the direction elicited during habituating trials.

Secondary nystagmus data are plotted in Figures 7 and 8. The caloric secondary is extremely irregular in early trials, but shows a definite decline with repeated elicitation (Figure 7). The pre- and post-test (rotation) secondary shows very little change. The one exception is an increase of one-fourth to one-third in duration of the post-test response (Figure 8).

## DISCUSSION

**Primary Nystagmus.** Repeated unilateral caloric irrigation of the cat in total darkness results in a marked decline in slow-phase displacement, frequency, and duration of vestibular nystagmus. These findings are in agreement with caloric data obtained by Henriksson et al. (1962) under conditions of illumination and with results reported by others (Collins, 1963; Crampton, 1961, 1962a; Crampton & Schwam, 1961) for repeated rotational stimulation. The greatest amount of decline occurs during the first 5 trials (Figure 3). This closely parallels the manner in which rotation-induced primary nystagmus habituates (Collins, 1963b).

### *Transfer of Habituation*

**Stimulus transfer.** The pre- and post-test rotation data (Figure 4) show a general, but small decline effected by the intervening calorizations. Of the 3 measures, duration of response is least affected, while the total frequency and the total slow-phase displacement are reduced by approximately one-third (Figure 3). This amount of decline is exceedingly small considering the marked alteration in response to the 15 caloric trials and is equivalent to what might be obtained as a result of only 3 or 4 consecutive rotations (Collins, 1963b).

Perhaps one of the most significant aspects of the pre- and post-test graphs is the fact that the nystagmus, in both cases, shows no decline during the 3-sec period after termination of acceleration. Other data (Collins, 1963b) have indicated that this holds true for only about 4 consecutive trials at this identical stimulus level. With the fifth trial, the response has been shown to drop off sharply from the point of stimulus termination. Thus, the intervening caloric trials, although producing a striking reduction in nystagmus to unilateral irrigation, exercise relatively little effect on responses to rotation.

The question of stimulus transfer in vestibular habituation has received little examination. Maxwell, Burke, and Reston (1922) and Hood and Pfaltz (1954) habituated rabbits to rotational stimuli and then found "normal" responses to caloric irrigation. The former, however, employed no pre-rotation control trial and reported no quantified data while Hood and Pfaltz (1954) based their conclusions primarily upon duration measures. More recently, Collins (1963b) obtained only minor pre- to post-test caloric changes from the cat after habituation to rotation. It should be noted that, in all of these cases, there were apparently considerable differences in the intensities of the habituating and transfer stimuli.

Dunlap (1925) employed conditions somewhat more similar to those reported here. Working with rabbits, he completely abolished nystagmus to unilateral ice-water caloric irrigation first to one ear, and then the other. After this extensive habituation, responses to rotation were absent.

It has been suggested that differences in the relative intensity of rotatory vs. caloric stimulation might have been one cause for the failure to obtain transfer of habituation from rotatory to the caloric situation (Collins, 1963b). The importance of this intensity variable for differences within a stimulus modality has been noted (Griffith, 1920; Cuedry, 1953; Maxwell Burke & Reston, 1922), but has not received intensive investigation. It appears that, after habituation to a given level of stimulation, a more intense stimulus may evoke a brisk response.

A second factor has also been suggested to account for the failure to obtain positive results in transfer tests (Collins, 1963b). Data obtained here lend some support to its possible importance. In the present study, the initial caloric nystagmus output exceeded the rotation response by a considerable amount. Thus the animals were habituated to a stimulus which was initially more intense than that experienced during the pre- and post-tests. This intensity difference would appear to favor a transfer effect. That such transfer did not occur might be accounted for by differences in the neural excitation patterns generated by unilateral and bilateral stimulation. That is, the habituating mechanism may respond with a relative specificity that is related to whether a single horizontal semi-circular canal is stimulated repetitively, or whether both canals are simultaneously activated.

The two explanatory factors outlined above are not, of course, mutually exclusive. Further experimentation is required to determine the relative weight of their contributions.

Response transfer. Henriksson et al. (1962) have presented data which show that unilateral caloric nystagmus habituation is specific to the direction of the response elicited during the habituating trials. Data obtained in this study (Figures 5 and 6) provide confirmation of their findings. Thus, after a specific direction of nystagmus has been habituated by repeated unilateral irrigations, a stimulus, applied to the opposite ear, which drives the response in the same direction as that of the habituating trials, shows a marked depression of reaction. On the other hand, stimuli applied unilaterally to either ear, which provoke a response in the direction opposite that of the habituating trials, result in a vigorous nystagmus. Crampton (1962a) has presented data which indicate a similar directional specificity of cat nystagmus habituated by rotation and Aschan (1954) has noted a relationship between directional preponderance of nystagmus in fighter pilots and their choice of direction in "rolling" their aircraft.

Secondary Nystagmus. Only a few studies have been concerned with characteristics of secondary nystagmus (e.g. Aschan & Bergstedt, 1954; Collins, 1962, 1963a,b; Collins & Poe, 1962; Fluor & Mendel, 1962; Hauty & Wendt, 1960). In the cat, the secondary reaction to rotation has been reported to rise, peak, decline, and habituate in a manner highly similar to the primary response (Collins, 1963b). In addition, the slow-phase rotation-induced output of secondary activity in the cat appears to be about one-fourth to one-fifth that of the primary (Collins, 1963b); for man, the factor was reported to be about one-half for 3 selected subjects (Hauty & Wendt, 1960). Some of this inter-species difference may be due to more sustained high levels of arousal in man (Collins & Poe, 1962; Crampton, 1961; Crampton & Schwam, 1961) or to the selection of the human subjects.

In the present study, no consistent relationship between primary and secondary output to the caloric stimulation can be readily expressed. That the secondary declines is clear. The decline, however, is abrupt after trial 5 (Figure 7) and quite irregular. During the first 5 trials, secondary nystagmus alternately declines markedly and returns to its initial level.

All of the animals gave secondary responses to the pre- and post-test rotation trials and to the first caloric irrigation. Thereafter, however, the number of cats producing secondary responses varied from 1 to 5 for trials 2 through 7 — no secondary responses were recorded during trial 8 — and, similarly, from 1 to 5 for trials 9 through 15. Its appearance in a given animal is thus not consistent.

No striking overall change in slow-phase displacement or frequency occurred in the pre- to post-test comparisons of secondary nystagmus. Duration of the response increased, however, during the post-test (Figure 8). Parenthetically, it might be added that the tests employing equivalent (53.5° C to the left ear) and non-equivalent (53.3° C to the right ear and 23.5° C to the left ear) stimuli showed only a few scattered beats of secondary responses.

## SUMMARY

Six cats were exposed to mild angular accelerations before and after an intervening series of 15 caloric irrigations. All trials were in total darkness. Slow-phase displacement of the eyes, beat-frequency, and duration of nystagmus were scored. All 3 measures reflected a decline in both the primary and the secondary caloric measures. Responses to rotation following the caloric habituation showed almost no change, i.e., there was no apparent stimulus generalization. Differences in: (a) the patterns of nervous excitation elicited by unilateral and bilateral stimulation; and (b) intensity, were hypothesized as possible causes for the failure to obtain transfer. Additional unilateral caloric trials confirmed reports that the reduction of nystagmus is specific to the direction elicited during habituation trials.

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Six cats were exposed to mild angular acceleration before and after an intervening series of 15 caloric irrigations. All trials were in total darkness. Slow-phase displacement of the eyes, beat-frequency, and duration of nystagmus were scored. All 3 measures reflected a decline in both the primary and the secondary caloric measures. Responses to rotation following the caloric habituation showed almost no change, i.e., there was no apparent stimulus generalization. Differences in: (a) the patterns of nervous excitation elicited by unilateral and bilateral stimulation; and (b) intensity, were hypothesized as possible causes for the failure to obtain transfer. Additional unilateral caloric trials confirmed reports that the reduction of nystagmus is specific to the direction elicited during habituation trials.

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