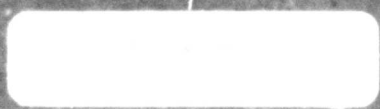




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THE CHANGING PARAMETERS OF THE HABITUATING VESTIBULAR SYSTEM

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FOREWORD

This work was accomplished in the Vestibular Unit of the ENT Branch, under task No. 775003, between June 1964 and January 1967. The paper was submitted for publication on 27 June 1967.

The authors express their thanks to Donald B. Helms, who served as subject in this experiment.

This report has been reviewed and is approved.



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ABSTRACT

Nystagmic responses to a Coriolis stimulation were recorded from a human subject over a period of ten sessions of four stimuli each. The response can be approximated by simple negative exponential growth and decay functions. Repeated exposure results in a reduction of the subject's sensitivity to the stimulus. At the same time the dynamic characteristics of the system mediating the response change so as to provide a more rapid recovery from the stimulus. Both of these changes are beneficial to a pilot, as they improve his resistance to some forms of spatial disorientation.

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I. INTRODUCTION

The vestibular organ in the pilot's inner ear is inescapably an instrument of flight and provides an input to his central nervous system. This input, which is too frequently erroneous, and inputs from the instruments on his panel all undergo central processing and then are read out in the activity we call spatial orientation.

In order adequately to understand and ultimately to control the errors generated by the vestibular system, it is necessary to be able to describe its performance in the ever-changing dynamic environment of flight and to be able to account for changes in the pilot himself.

The decay of the response of the cupula or of some system under control of the cupula can be approximated by the equation:

$$R_t = R_0 e^{-\beta t} \quad (1)$$

in which R_t = the response at t seconds after cessation of the acceleratory stimulus; R_0 = response at $t = 0$; and β is a dynamic factor related to the rate of decay.

Inferentially,

$$R_0 = a S (1 - e^{-\beta t_a}) \quad (2)$$

in which α = the intensity of the acceleratory stimulus; S = the system's sensitivity; and t_a = the duration of the stimulus.

The present experiment deals with a constant α and t_a and was undertaken to determine changes in the response as a result of changes in S and in β as the subject experienced repeated stimulation over a period of days. The

acceleration was generated by a Coriolis stimulus in which the subject was rotated at constant velocity about a vertical axis and was tilted in the frontal plane. This stimulus elicits a sensation of tumbling in the sagittal plane and a vertical nystagmus.

II. PROCEDURE

The subject used in this experiment was a healthy, 23-year-old male, who was selected because of his intelligence, motivation, and sophistication in the procedures of this experiment.

After the subject was seated in the biaxial stimulator, he was instructed to maintain visual fixation on an imaginary point in front of and below him. A stiff, specially constructed pillow was rested on his shoulders, and his head was placed between four stiff prongs jutting from the back of the pillow. The subject was blindfolded with a skin diver's mask made opaque for the purpose, and a masking noise was presented to him through earphones. The chair was tilted 30 degrees to the subject's right, and the main shaft velocity was brought to 18 r.p.m. One minute after constant velocity was reached, the chair was tilted through the vertical to 30 degrees to the subject's left; the time required for this 60-degree tilt was 3 seconds. Alternate tilts were presented at 1-minute intervals without changing the velocity of the main shaft until a total of eight tilts had been presented. The chair was then stopped and the subject was released until the next training period. Two training periods, one in the morning and one in the afternoon, were given each day for five successive days.

III. RESULTS

Electronystagmograms of the recovery from stimulation were analyzed for each of the four right-to-left tilts for all trials except for the fifth and ninth in which electrical noise artifacts rendered the tracings unintelligible. This stimulus caused a vertical nystagmus with the slow phase down. The slow phase velocity and time of occurrence of each nystagmic beat was determined; results from the four stimuli were lumped together, and the values of R_0 and β were obtained from the best fitting straight line determined by the least squares method

(fig. 1). Values of R_0 in millimeters per second were divided by the reference signal to provide R_0 in arbitrary units per second. The coefficient αS was determined for each trial by substitution in equation 2. Values of R_0 and αS are presented in table I and figure 2.

The least squares fit showed β to vary with practice according to the function:

$$\beta = 0.193e^{-0.0404T} \text{ sec.}^{-1}, \text{ and}$$

$$\frac{d\beta}{dT} = 0.0078e^{-0.0404T} \text{ sec.}^{-1}/T$$

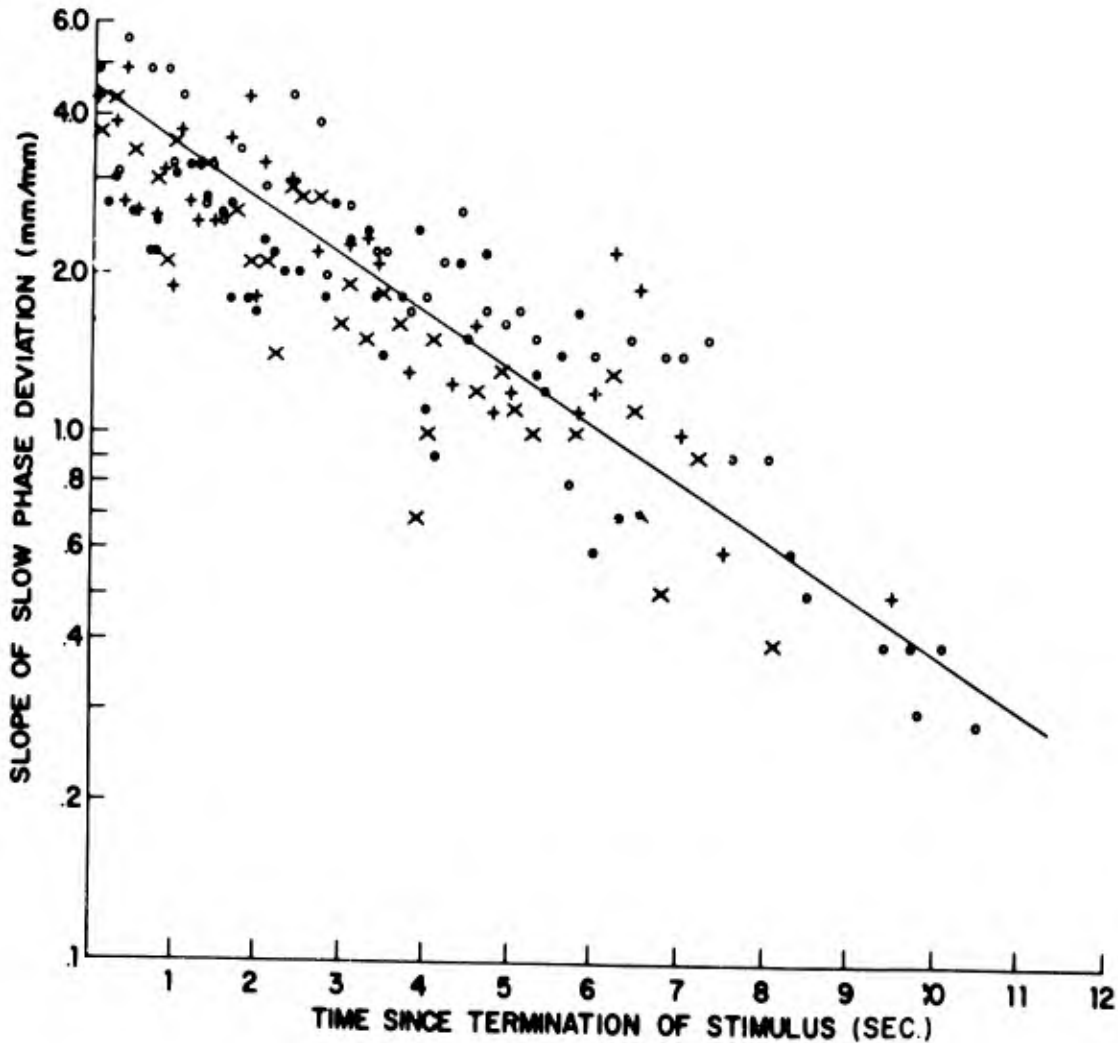


FIGURE 1

Slope of slow phase of nystagmic beats during recovery from Coriolis stimulation. • • = stimulus 1; ○ ○ = stimulus 3; × × = stimulus 5; + + = stimulus 7.

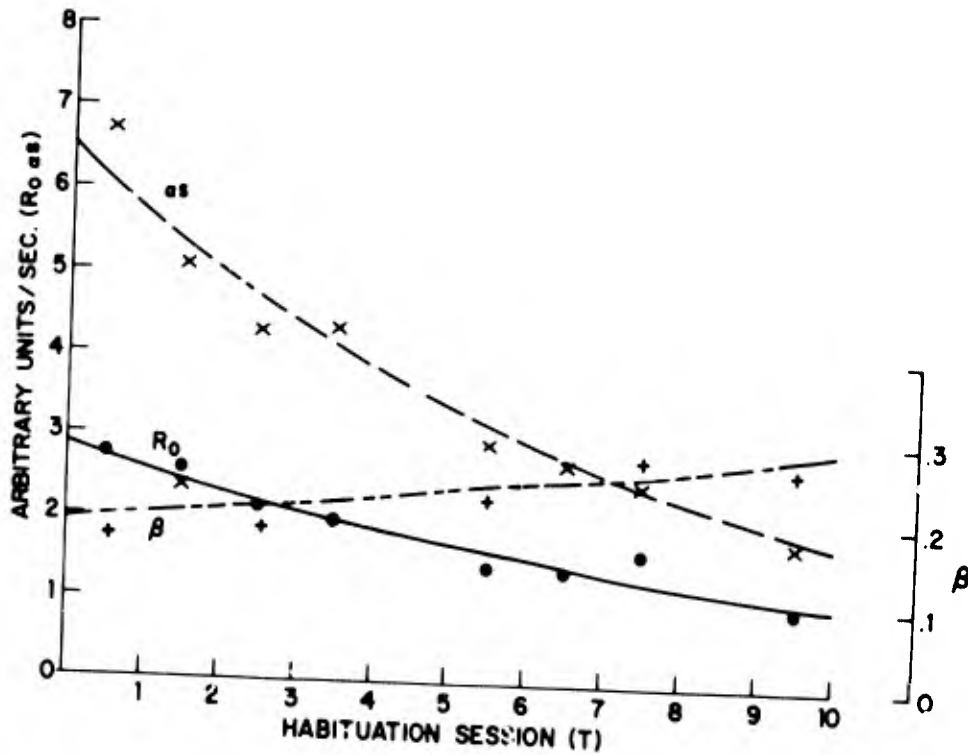


FIGURE 2

Variation of the parameters, β , R_0 , αS , as habituation proceeds. Lines are drawn to least squares fits (see "Results"). ++, experimental values for β , •• for R_0 , × ×, derived values for αS .

TABLE I
Variation of parameters

Session	β	R_0	αS
I	.173	2.74	6.69
II	.239	2.59	5.07
III	.229	2.14	4.28
IV	.196	1.94	4.31
V	—	—	—
VI	.227	1.41	2.88
VII	.269	1.40	2.50
VIII	.264	1.62	2.95
IX	—	—	—
X	.276	0.96	1.72

That is, β increases as the number of exposure sessions, T , increases. In a similar manner, R_0 and αS were found to vary as

$$R_0 = 2.88e^{-.1073T} \text{ arbitrary units/sec.}$$

$$\frac{dR_0}{dT} = -0.309e^{-.1073T} \text{ arbitrary units/sec./T}$$

$$\alpha S = 6.51e^{-.1843T} \text{ arbitrary units/sec.}$$

$$\frac{d\alpha S}{dT} = -0.873e^{-.1843T} \text{ arbitrary units/sec./T}$$

That is, both of these functions diminish with repeated exposure.

IV. DISCUSSION

Ideally, any expression of the relationships between stimulus and response in the vestibular system would be a complex one which would

describe separately the roles of the end-organ and of many parts of the central nervous system; changes in the response should be ascribable to changes in parameters which have well identified anatomic and physiologic correlates. Unfortunately, transfer functions of the brain are now beyond our grasp.

Happily, the two-parameter transfer function based upon cupular mechanics can be used to approximate the relations between stimulus and response, over a fairly wide range of conditions, and changes in the parameters can be ascribed to changes in central function, provided experimental conditions do not violate the invariance of the end-organ (1-7).

It was found in this experiment that changes in response can be ascribed to changes in both parameters, since neither dS/dT nor $d\beta/dT$ is equal to zero. Substitution in the equation

$$\frac{dR_o}{dT} = \frac{\partial R_o}{\partial S} \frac{dS}{dT} + \frac{\partial R_o}{\partial \beta} \frac{d\beta}{dT}$$

shows how changes in R_o are affected by changes in the two parameters (fig. 3). The increasing exponent augments the response during growth; that is, the response tends to become asymptotic more quickly. This effect, however, is more than offset by the great changes in sensitivity, so that R_o is progressively smaller.

It also follows that the residual effect (i.e., the response during recovery from stimulation) is diminished by the reduction in R_o and dissipates more rapidly as β increases with exposure.

These results have some interesting implications for aerospace operations. It must be emphasized again that even though the stimulus was generated by rotation in yaw and angular displacement in the frontal plane, the response occurred in the sagittal plane; hence, it was erroneous not only in magnitude and

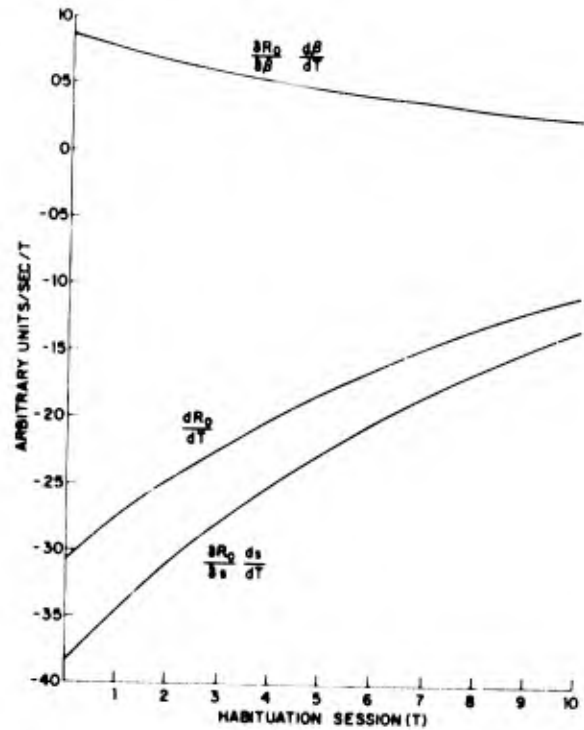


FIGURE 3

Effects of changes in S and in β on R_o .

time, but in plane as well. The best prophylaxis against this error is complete elimination of the response. The error can be quantified in at least three separate ways: the maximum instantaneous error, R_o , the cumulative error extending from the onset of the maneuver to the time at which the response vanishes, which equals $3\alpha S$, and the cumulative residual error extending from the end of the maneuver to the end of the response (R_o/β). Figures 2 and 4 show that these three errors diminish rapidly during the initial exposures and then more slowly with repeated exposure. This is characteristic of most learning functions.

The data of this experiment deal with the habituation of a sensorimotor response to a disorienting stimulus which is closely related to the perceptual response which this stimulus elicits. As yet not much is known of generalization of habituation to other stimuli or to other stimulators, including aircraft; these factors and others must be investigated before

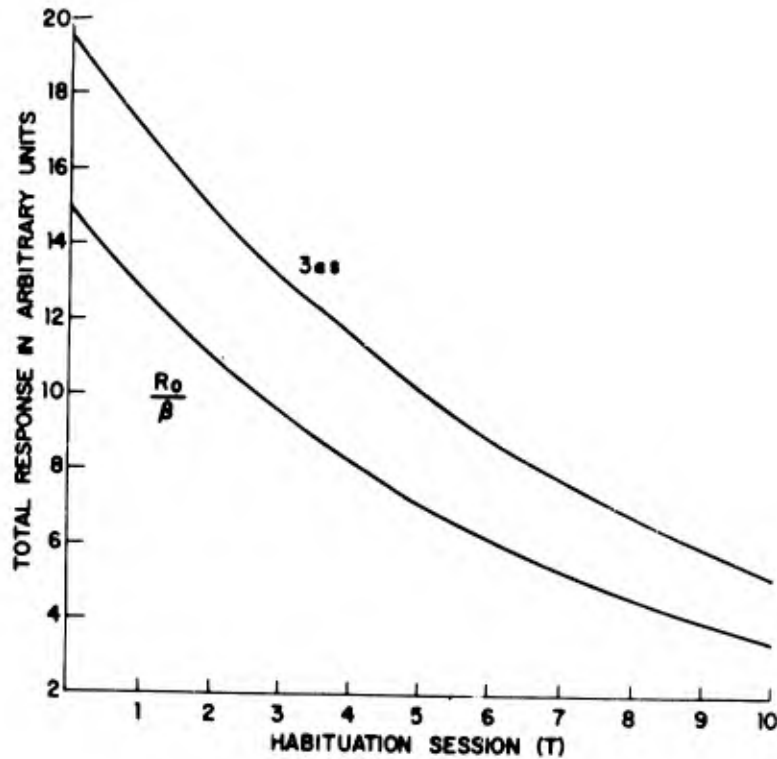


FIGURE 4

Reduction in total error response, $3es$, and in total residual error, R_0/β , by habituation.

a program of training against spatial disorientation is undertaken. Nevertheless, the pronounced changes resulting from relatively few exposures to motion strongly suggest that the

performance of simple exercises on simple and inexpensive equipment can provide protection against some of the disorienting motions encountered in aerospace operations.

REFERENCES

1. Dowd, P. G. Resistance to motion sickness through repeated exposure to Coriolis stimulation. *Aerospace Med.* 36:452-455 (1965).
2. Dowd, P. J., E. W. Moore, and R. L. Cramer. Effects of flying experience on the vestibular system: A comparison between pilots and nonpilots to Coriolis stimulation. *Aerospace Med.* 37:45-47 (1966).
3. Dowd, P. J. Factors affecting vestibular nystagmus in Coriolis stimulation. *Acta Otolaryng.* (Stockholm) 61:228-236 (1966).
4. Dowd, P. J. Speed of recovery from Coriolis stimulation in motion sickness in relation to pilots and nonpilots. SAM-TR-66-63, July 1966.
5. Moore, E. W., and R. L. Cramer. Speed of recovery from Coriolis stimulation and its relationship to motion sickness. Proceedings of the 73d Annual Convention of the American Psychological Association, pp. 41-42 (1965).
6. Moore, E. W., R. L. Cramer, and P. J. Dowd. Effects of motion sickness on the dynamic characteristics of responses to Coriolis stimulation. SAM-TR-65-67, Sept. 1965.
7. Moore, E. W. Responses to Coriolis stimulation in flying personnel with different levels of proficiency. SAM-TR-66-36, Apr. 1966.

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Spatial disorientation						
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