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Robert S. Kennedy

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LCDR Robert S. Kennedy, MSC, USN

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13. ABSTRACT

To compensate for the low reliability of physiological manifestations of sympathetic nervous system activity two methods are offered. The first method requires a major research program by which a valid criterion of stress would be determined by experimentation, and then predictors of this criterion would be obtained empirically by correlational techniques. These predictors could then be crossvalidated. By using the predictors, the influences of psychological stress and physiological stress could be separated. Whether a functional relationship exists between the magnitude of the response to stress and the probability of its occurrence could then be determined. The second method is similar but less exact. It has been used successfully in motion sickness studies and avoids the necessity of a long exploratory program with numerous pilot studies.

A procedure for the control and the regulation of the perception of the magnitude of the stress to the organism (human and infrahuman) is offered for use with the two methods. The lack of suitable control of this factor is discussed in connection with previous research.

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TWO PROCEDURES FOR APPLIED AND EXPERIMENTAL STUDIES OF STRESS

Robert S. Kennedy

Bureau of Medicine and Surgery
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U. S. Army Aeromedical Research Laboratory

Approved by

Ashton Graybiel, M. D.
Head, Research Department

Released by

Captain M. D. Courtney, MC, USN
Commanding Officer

17 February 1970

NAVAL AEROSPACE MEDICAL INSTITUTE
NAVAL AEROSPACE MEDICAL CENTER
PENSACOLA, FLORIDA 32512

INTRODUCTION

PRECIS

The constellation of autonomic nervous system responses that obtain during stress is well known (20). The validity of these reactions when they occur is generally accepted, but their reliability is low. In this paper a new point of view is suggested whereby, if the reliable assessment of these responses were possible, it would provide investigators with a variety of research strategies. Not the least of these would be the ability to equate different stimuli or responses in the stimulus-response (S-R) paradigm and thus the ability to determine the effects of various treatments (e.g., ablations, drugs, conditioning schedules) within the laboratory as well as to translate these stimulus or response conditions from the laboratory to naturally occurring events.

In the present paper an experimental method is proposed to aid in determining the reliability of these "stress syndrome reactions." Additionally, an alternate but less rigorous procedure is suggested.

BACKGROUND

Reactions to stress involve discharges from the sympathetic nervous system (20). It has been known since 1928 (5) that, when the sympathetic (i.e., adrenergic) nervous system (SNS) discharges, it tends to do so as a whole (5). This total discharge suggested to Bard (5) that the sympathetic nervous system was under some". . . central coordinating mechanism." This same reasoning has led investigators to measure the magnitude of the individual responses of the sympathetic nervous system to try to better understand the central mechanisms(s) involved. Arnold (4) has published a review of the problems associated with this approach, particularly those with regard to emotion (4,331 ff).

In the many textbook accounts of the reactions of the organism to stressful situations, a number of symptoms have been cited (4, 20, 23); these generally include changes in the gastrointestinal, cardiovascular, respiratory, hematological, visceral, and endocrine systems. For the most part, there is agreement among investigators with respect to the direction of the response to stressful conditions, e.g., increased heart rate but decreased gastric motility, vasoconstriction but pupillary dilation (20, p. 404), and that these responses are largely under the control of the autonomic nervous system (ANS) by direction of the hypophysis (24) and its attendant hypothalamic nuclei (viz, supraoptic nucleus and paraventricular nucleus). Ochs (24) also wrote, "Stress agents via the CNS increase the activity of the hypothalamus where a hormone, corticotrophin-releasing factor (CRF), is released in the portal circulation to gain entrance to the anterior pituitary and in turn, release ACTH" (p. 543).

Koelle (20) considered the subsequent release of epinephrine and norepinephrine from the adrenal medulla to be under cholinergic control and also reported evidence for the presence of acetylcholine (ACh) and cholinesterase (AChE) in the "hypothalmico-neurohypophyseal tract" (p. 421). That an adrenergic system may be under cholinergic initiation is further testimony to its complexity (see also Bovard, 6). The question of whether the hypothalamic initiation of hypophyseal release is adrenergic or cholinergic is far from settled. Yet, it appears to be clear cut that the responses of the organism during stress are adrenergic. There may be some exceptions to this generality; for example, when the onset of the stressful situation is rapid, with subsequent loss of sphincter control, and in motion sickness when some of the organism's responses are cholinergic (e.g., watery saliva, vasovagal syncope, decreased heart rate) (12).

Although most investigators are in agreement regarding the direction a particular stress response will take, experimental analyses are complicated because not all responses occur in all stressful situations. Additionally, the relative magnitude of a given set of responses may be different for different people (21), and even in the same person with repeated trials. In other words, the adrenergic responses lack reliability that is due to either exteroceptive or interoceptive variables. The former would include such variables as the validity and reliability of measuring devices and differences in experimental design. The interoceptive variables appear to derive chiefly from the lability of the response systems and from individual differences and response styles. Of the variables mentioned, the inadequacies of measurement are the most resistant to statistical control. The method offered in this report is one in which multiple regression (14) is used to improve reliability and validity of assessment.

APPLICATION

The principle aim of all science is prediction and control, and specificially prediction to the individual case. To this end, the present proposal attempts to provide an approach that will result in a suitable criterion for determining the presence of stress, and reliable indices for predicting its magnitude. If the aim is realized, the following may prove to be profitable avenues of investigation:

1) Since concordance between physiological and psychological responses to stress is expected, persons with excessive ANS responses that are accompanied by performance decrements may be considered to be stress susceptible. However, separate hypotheses can be offered regarding individuals in whom these responses are discordant: a) short-term stress resistance where there is excessive ANS outflow but good performance at high cost physiologically, and b) the converse (ANS response but performance is poor) may indicate generally low drive or low motivation.

2) If a generalized syndrome can be identified, then stress reactivity could be predicted from laboratory exposure to stress.

3) Structures within the organism could be ablated or stimulated to assess their role in stress (e.g., dynamogenic zone of Hess (1)).

4) Different laboratory situations (i.e., stimuli) could be equated on the basis of response equivalence.

5) The effects on behavior of different treatments, drugs, conditioning schedules, and the like could be studied.

6) Possible links among stress, emotionality, drive hierarchy, anxiety, and similar behavioral manifestations could be studied better.

7) Laboratory procedures could be related to naturally occurring events to identify and perhaps modify stressful situations and other circumstances that result in "expense" or "cost" to the organism.

8) An index similar to the intelligence quotient (I.Q) can be obtained that could be related to success in certain kinds of stressful occupations, e. g., aviation.

9) Better understanding of the mechanisms involved in such stress-related phenomena as cardiovascular disease, peptic ulcers, migraine, and hysteria may be provided.

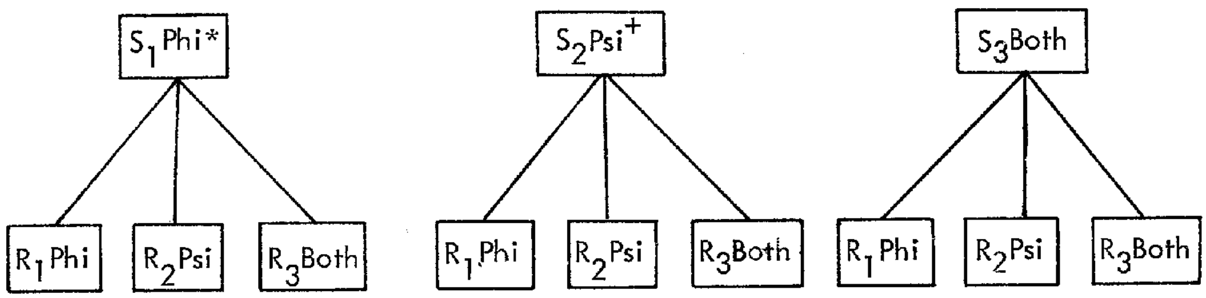
APPROACH

Two of the concepts frequently used in connection with stress are "emotion" and "fight/flight reaction" (cf. No. 6), and synonyms for these terms are implicitly included. Each term entails special somatic visceral changes as a function of the stimulus condition, but the central mechanisms may not be the same for each. Emotion is a vague term, and fight/flight reaction is similarly imprecise. When they are used within the context of stress, their meanings converge, and it is difficult to distinguish between them. Perhaps these distinctions are artificial; thus, one term, "stress," has been selected for exposition in this paper. However, an approach that proves feasible for research into stress is also appropriate, with slight modification, for studies of emotionality and similar phenomena.

According to Selye (25), the term stress received its modern connotation from him (cf. 5), and his original definition of stress was" . . . the sum of all nonspecific changes caused by functions or damage" (25, p. 311). He later defined it as ". . . the state manifested by a specific syndrome which consists of all the nonspecifically induced changes within a biologic system" (25, p. 54). In this view, stress may be likened to the term "adaptation," in that adaptation refers to a change but may be either an increase or decrease in threshold; however, it is more commonly associated with an in-increase. Stress, by Selye's definition, may also represent a change that is either inimical to, or accordant with, the integrity of the organism; yet, again the former is usually intended. Arnold (4) mentioned the obvious shortcomings of Selye's definition and reported the comments of others, notably of Beach, who felt that the concept was too broad, and of Smith, who concluded that dreamless sleep was the only stressless activity available to man (4, p. 240).

THE MODEL

For the purposes of this paper, I propose to think of stress as "an insult received by the organism that results in a departure from homeostatis." By insult I mean a negative, adverse, or non-adaptive stimulus. This definition is not an addition to the multiple meanings of stress, but merely adds directionality to Selye's postulate or theory and has more practical usefulness. The stressor or agent that provides the insult may be physical (as with electric shock) or psychological (as with loss of prestige). The latter I will refer to, as have others (3, 22), as "psychological stress." The departure from homeostasis may be in the form of physiological (heart rate) or psychological (number of errors) changes. Two dichotomies plus a combination are diagrammed in a model of stimulus-response possibilities where S represents the stimulus or stressor and R the response or reaction. It is convenient to think of this model in terms of the stimulus-response (S-R) paradigm, and while many more variations are possible, only these nine appear to be meaningful.



*Phi = Physiological
+Psi = Psychological

The other possibilities, which are not listed, may be rejected either because they are more complex and thus less amenable to experimental control, or because they involve S-S or R-R combinations and therefore do not represent the typical case. The nine possibilities diagrammed are not all equally feasible, nor would these approaches provide equally meaningful results. It might be argued that the ideal S-R condition for studies into the nature of stress would be a unitary one where S and R were both either physiological or psychological. However, it does not appear possible to stimulate physiologically without having the stimulus take on some psychological stress properties, except of course on the first trial with a naive animal where it is possible to provide a threat of a physical stimulus without actually applying it. Also, experimental control of a threatening stimulus is very difficult. One of the problems with physiological stimuli, on the other hand, is that the extent to which certain nociceptive stimuli may change the properties of the channels that they are stimulating is not known. It is, therefore, suggested that S_2psi (of the diagram) be considered as a desirable stimulating method.

With regard to the responses that are to be measured, the unity of organisms is such that no situation exists where concommitant physiological and psychological responses do not occur. The stimulus condition proposed here (S_2psi) is similar to one used by Wherry, Jr. and Curran (29) but with some modifications so the same procedure can be used with man and animals.

The main shortcoming of prior research into psychological stress has been that the perceived magnitude of the stress was not controlled. Although the objective stimuli were usually equal, they may have been differentially stressful to different subjects. When this lack of control interacts with the ever-present individual differences in responses, the results are confounded. That these individual differences can be substantial is well known. For example, at the stimulus end, basal heart rate, vital capacity, and eye-blink rate vary over a wide range in a random population; at the response end, a homogeneous sample has responded with comments of pleasure and objection to the same experimental procedure in unusual gravitoinertial force environments (viz, rotation) (2).*

The traditional approach in stress studies is to give all subjects the same objective stimulus and then to measure their responses; yet, no consideration is made of the fact that a given stimulus (whether a comprehensive examination (31) or an airplane ride (7)) is differentially stressful across subjects. For this reason, it appears reasonable to assume that a study has never been conducted where the magnitude of the stressor getting through to the sensorium was controlled and the appropriate responses of the organism adequately assessed. In the study by Curran and Wherry, Jr., (8, 29) a method was devised that attempted to equate the stimulus for all subjects. In their study a painful and a mild shock were demonstrated to the subject; then an ostensibly valid probability generator was introduced, and the subject knew the probability of his receiving a mild or painful shock. In general, the results of that study were as would be predicted; i.e., the more noxious conditions (high probability, painful shock, and receiving it) were more disruptive of performance.

The major contribution of their study was that it demonstrated a sound, replicable and reliable method for the study of psychological stress. The shortcomings were that it ignored physiological responses and that the procedure was not directly applicable to infrahuman subjects. However, the method resembles both "probability matching" (19, 30) and the partial reinforcement paradigm (18). In probability matching studies the subject responds to one of the two alternative stimuli, A and B. Rewards are programmed so that responses to A are rewarded 80 per cent of the time, and to B 20 per cent. To maximize the reward possibilities, the subject should respond 100 per cent of the time to A; he does not but "matches," so that he responds to the 80 per cent alternative 80 per cent of the time. This results in only a 68-per cent reward (i.e., 80^2 plus $.20^2$). In some partial reinforcement schedules, the subject is rewarded for responding at a variable ratio (VR), and the well-known "scalloping" (18) demonstrates that performance is related to impending reward. Although higher rates of responding result

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*Moreover, evidence exists that a specific pattern of responses occurs to various stressors within individuals, although the particular response within the pattern may be different between individuals (21, 28).

with this schedule, the response is also less resistant to extinction than continuous reinforcement. Both of these methods demonstrate that the probability of receiving a reward (or punishment) influences the animal's behavior.

The stimulus conditions for the present proposal, therefore, should be like those used by Wherry, Jr., and Curran (8, 29) and elsewhere (9) where, in humans, the real probability of receiving a shock is known by the subject. If the subjects are animals, they will be trained by the principles of probability matching and VR schedules so that they expect to be shocked a similar proportion of the time. In both instances physiological and psychological measures would be obtained to determine the effect of the anticipation (threat) of physiological (shock) stress on the subject. Further, data obtained on those trials when the subject did receive a shock would be treated separately from those in which he did not.

The first portion of this paper has been concerned with establishing a point of view in the conduct of an investigation of stress effects. If this approach is granted and if the method is successful in controlling the stimulus variable, then the next consideration is the reliable assessment of the responses, and the determination of which responses to measure.

PROPOSED PROCEDURE

The responses to stress are a constellation of symptoms involuntarily released (20, pp. 399 ff). Not all responses, however, occur at all times to all stressors to the same degree; indeed, sometimes responses do not occur in any degree to some stressors. This type of graded response to stimuli is common in the field of behavioral sciences, and sophisticated statistical operations have been successfully applied to it, particularly in the areas of personnel selection and test construction. Furthermore, the validity of the measures available in such areas is probably less than the face validity of ANS responses in stress research; yet, the reliabilities are sometimes equal. The method customarily used in these areas involves the validation of a measure by determining how those who have qualified respond to it; e.g., obtaining aviator wings "means" success in flight training; selling the most insurance "means" a good salesman. Aspirants who respond similarly to those who are empirically successful are given a better chance of success than those who do not.

As more items are tested and found to be positively related to success, a pool of items accrues, and a greater portion of the variance related to success in this endeavor is thus explained. Further, some items predict success better than others, and these are given extra weight. These weights (beta weights, see reference 14) may be different for subgroups within the main group. For example, although physical fitness, navigation ability, marksmanship, I.Q., and mechanical comprehension may all be positively related to success in flight training, each may possess a different beta weight, and this weight may change whether the prediction is to success as a pilot of single-engine aircraft, multi-engine aircraft, or helicopter. The rationale for statistical operations involved in this procedure appears in many textbooks (14, pp. 392-437). It should be noted that this approach also provides a priori three decisions as to whether an item is to be included into the multiple prediction formula: 1) It must correlate significantly with the criterion. 2) It must add significant predictive ability to the existing method at an acceptable level. 3) It must add unique prediction; i.e., not overlap with other predictions. Statistical formulae are also available which will "shrink" the individual correlations by the amount that they overlap so that unique variance is being predicted (14, p. 401).

A preliminary investigation has been conducted (10) in which the first part of the strategy advocated in this paper was used. The approach is a correlational one, whereby performance is used as a criterion and ANS responses are related to performance to determine the correspondence. A vigilance task served as the indicant of stress resistance, and it was found that norepinephine excretion was the best predictor of signal detection (r = .814). Epinephrine and the 17-hydroxycorticosteroids also were predictive of performance (r = .531, + .565, respectively). The intercorrelation of these variables was moderate (ca r = .40). A multiple prediction equation could be expected to increase the relationship and thus improve predictive ability and amount of variance accounted for. Frazier (10), however, measured other variables (e.g., galvanic skin resistance, pulse pressure, heart rate) and although he does not report the relationships of these variables to performance, multiple regression techniques should have improved prediction of performance decrement. Experimental evidence would also show which response measurements could be avoided in future studies either because a particular response does not correlate with the criterion, or because it correlates too high with another, better predictor of the criterion. Work like Frazier's is very much in keeping with the present proposal and should be pursued. It is unfortunate that additional data were not reported since a multiple prediction equation could have been constructed that would apply to the conditions of his experiment and would have provided valuable leads for future studies.

Although multiple regression has been used successfully in certain applied situations (26), the method is totally predicated on the existence of an objective criterion that may be measured on a "prothetic" (27) continua. In studies of stress, no objectively valid criterion is universally accepted, and certain assumptions will be made here in an effort to obtain one.

That which is maximally stressful leads to death. It is assumed that, within certain limits, with stimuli less than that, graded responses may be obtained from the various response systems (e.g., cardiovascular, endocrine) as a function of the magnitude of the stress. In other words, it is assumed that a monotonic relationship exists between various stressors and responses. Therefore, to obtain a criterion against which to compare other stimuli a unitary stressor will be employed, viz, shock.* Each of the various

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*A more applied criterion would be magnitude of performance degradation.

response systems will be studied individually in a separate, large group of animals. It would be preferable to use primates, but practical considerations might dictate otherwise (e.g., cost). Stimulus values would be selected over a broad range including high, low, and medium shock intensities for each response system. A low-intensity shock would be defined as one that barely elicited a response from that system. A maximal (high) intensity would be at a level above which that response system no longer responds or results in the subject's death. The data for all response systems would be pooled and a stimulus value selected on the basis of two criteria: 1) It is the arithmetic mean of all response systems, and 2) it is capable of eliciting a reaction from all response systems.* This value would serve as the standard shock and be considered the criterion. Values above and below this may be used at a later stage in the program. Next, a group will be exposed to this standard stimulus and the output of all response systems determined. A multiple correlation coefficient will be empirically derived so that each variable contributes unique variance to the prediction of the criterion. The values thus obtained will be used to generate a predicted score for a second sample under identical conditions. This will constitute the crossvalidation of the procedure.

It should be noted that, although with this procedure a linear relationship appears to be assumed between the magnitude of a given stressor and the magnitude of the total organism's responses, the multiple correlation approach may also be used to examine the intercorrelations of the different response systems to this stressor, and to other stressors. If, as Gelhorn (11) suggests, ". . . emotions cannot be explained by considering only the factor of intensity . . . but also of an alteration in the pattern . . ." (p. 412-419)+, it is also possible to detect this relationship by correlational analysis of clusters of interrelationships or, as suggested above, different beta weights of different magnitudes for different stimuli.

In these validation and crossvalidation procedures the probability of receiving the shock was 1.0 and, as such, represented a combined physiological and psychological stress situation (S_3both; R_3both). In subsequent testing, psychological stressors would be used, and the probability of receiving the shock would be varied for different groups of animals. Further, the trials in which a shock was received would be analyzed separately from those in which only the threat of a shock was present. This analysis should provide information regarding the effect of psychological stress when physiological stress has been partialled (subtracted) out. Additionally, the data could be examined to determine whether a monotonic relationship existed for the threat of shock as a function of shock probability.

After this, each of the variables could be changed to make this approach adaptable to other animals, stimulus intensities, and to other stress situations.

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*The second criterion should be used if the first cannot be met.

+Gelhorn was referring specifically to neural discharge, but his intent was more general.

ALTERNATE PROCEDURE

The proposed procedure represents an ambitious research program; therefore, an alternate procedure is offered. Such a procedure is implicitly or unconsciously used as a diagnostic technique in clinical medicine. It has been used experimentally by Graybiel et al. (13) in connection with studies of motion sickness and has been successfully applied in other motion sickness studies (15—17). With this technique the symptoms of a "disease" are first classified and listed as "major," "minor," and "associated or accessory" symptoms. This procedure permits an experienced investigator to classify the symptoms and, at the same time, provides an a priori decision method that others can use. The classification of stress may be as follows: 1) For a given response system stress can be classified on the basis of amount of change; e.g., increase in heart rate of more than 50 per cent constitutes a major symptom, of between 25 per cent and 50 per cent a minor symptom, and less than this, an associated symptom. 2) Separate symptoms may be classified; e.g., presence of thick viscous saliva--a major symptom*, decreased gastric motility--a minor symptom, penile erection--an associated symptom. In general, those response systems easily quantifiable, viz, heart rate, blood pressure, chemical constitution of blood and urine, could receive graded classifications and those less amenable could be placed into one of the three categories. Diagnosis might then be made on a five-point rating scale (16) by which for example:

5 = 2 major symptoms including a pathognomonic symptom

4 = 2 major symptoms not including a pathognomonic symptom
or 1 major symptom and 2 minor symptoms

3 = 1 major or 2 minor or 1 minor and two accessory symptoms

2 = less than a rating of 3 but more than a rating of 1

1 = any subjective symptom or sign usually associated with stress

0 = no observable change

The above scale has been used in the study of motion sickness wherein only six symptoms qualify as major and only five as minor. More may be included in stress reactions. Therefore, it may be necessary to increase the number of major and minor symptoms for each diagnostic category, but the relative magnitudes should remain the same. If this latter extension is employed, it may also provide an expanded and thus more discriminating scale.

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*A further distinction between major symptoms and pathognomonic symptoms may be useful here, greater weight being given to the latter.

CONCLUSIONS

Although the two methods described in this paper have been offered for use in connection with the study of psychological stress, they are also amenable to the investigation of other behavioral events, specifically, the study of emotion, motivation, and drive hierarchy.

In summary, the study of the reactions of organisms to stress is complicated by the lack of reliability of the individual response systems. To resolve this difficulty, two methods are proposed. The first represents a major research program that would define a valid criterion of stress by experimentation and then by correlational techniques empirically obtain predictors of this criterion. At the second stage of the method cross-validation of these predictive variables would be done. By using these standard conditions, the influences of psychological stress could be separated from those of physiological stress at the third stage and determination made as to whether a functional relationship exists between the magnitude of the response to stress and the probability of its occurrence. The second method is less exact, but the immediate implementation of its principles would be possible, and the necessity of a long exploratory program with numerous pilot studies would be avoided.

A procedure for the control and regulation of the magnitude of the stress to the organism is offered for use with the two methods. The lack of suitable control of this factor is discussed in connection with previous research.

REFERENCES

1. Akert, K., Diencephalon. In: Sheer, D. E. (Ed.), Electrical Stimulation of the Brain. Austin, Texas: Texas University Press, 1961. Pp 288-310.

2. Ambler, R. K., and Guedry, F. E., The validity of a brief vestibular disorientation test in screening pilot trainees. Aerospace Med., 37:124-126, 1966.

3. Applezweig, M. H. (Ed.), Psychological stress and related concepts. A bibliography. Technical Report No. 7. New London, Conn.: Connecticut College, 1957.

4. Arnold, M. G., Emotion and Personality. Vol. II. Neurological and Physiological Aspects. New York: Columbia University Press, 1960.

5. Bard, P., A diencephalic mechanism for the expression of rage with special reference to the sympathetic nervous system. Amer. J. Psychol., 84:490-515, 1928.

6. Bovard, E. W., A concept of hypothalamic functioning. Pers. Biol. Med., 5: 52-60, 1961.

7. Colehour, J. K., and Graybiel, A., Excretion of 17-hydroxycorticosteroids, catecholamines, and uropepsin in the urine of normal persons and deaf subjects with bilateral vestibular defects following acrobatic flight stress. Aerospace Med., 35:370-373, 1964.

8. Curran, P. M., and Wherry, R. J., Jr., Measure of susceptibility to psychological stress. Aerospace Med., 36:929-933, 1965.

9. Drinkwater, B. L., Flint, M., and Cleland, T. S., Somatic responses and performance levels during anticipatory physical-threat stress. Percept. Mot. Skills, 27: 539-552, 1968.

10. Frazier, T. W., Effects of transitory behavior stress on 17-hydroxycorticosteroid and catecholamine levels. In: Proceedings of the Second Annual Biomedical Research Conference, February 17-18, 1966. Houston, Texas: Manned Spacecraft Center, 1966. Pp 255-279.

11. Gellhorn, E., Prolegomena to a theory of emotions. Pers. Biol. Med., 4:403-436, 1961.

12. Graybiel, A., Clark, B., and Zarriello, J. J., Observations on human subjects living in a "slow rotation" room for periods of two days. Arch. Neurol., 3: 55-73, 1960.

13. Graybiel, A., Wood, C. D., Miller, E. F. II, and Cramer, D. B., Diagnostic criteria for grading the severity of acute motion sickness. Aerospace Med., 39 : 453-455, 1968.

14. Guilford, J. P., Fundamental Statistics in Psychology and Education. New York: McGraw-Hill, 1965.

15. Kellogg, R. S., Kennedy, R. S., and Graybiel, A. Motion sickness symptomatology of labyrinthine defective and normal subjects during zero gravity maneuvers. Aerospace Med., 36: 315-318, 1965.

16. Kennedy, R. S., Tolhurst, G. C., and Graybiel, A., The effects of visual deprivation on adaptation to a rotating environment. NSAM-918. Pensacola, Fla.: Naval School of Aviation Medicine, 1965.

17. Kennedy, R. S., Graybiel, A., McDonough, R. C., and Beckwith, F. D., Symptomatology under storm conditions in the North Atlantic in control subjects and in persons with bilateral labyrinthine defects. Acta otolaryng., Stockh., 66: 533-540, 1968.

18. Kimble, G. A., Hilgard and Marquis' Conditioning and Learning. Second Ed. New York : Appleton-Century-Crofts, 1961.

19. Kirk, K. L., and Bitterman, M.E., Probability-learning by the turtle. Science, 148: 1484-1485, 1965.

20. Koelle, G. B., Neurohumoral transmission and the autonomic nervous system. In: Goodman, L. S., and Gilman, A. (Eds.), The Pharmacological Basis of Therapeutics. Third Ed. New York: Macmillan, 1965. Pp 399-440.

21. Lacey, J. I., and Lacey, B. C., Verification and extension of the principle of autonomic response-stereotype. Amer. J. Psychol., 71:50-73, 1958.

22. Lazarus, R. S., Deese, J., and Osler, S. F., The effects of psychological stress upon performance. Psychol Bull., 49:293-317, 1952.

23. Morgan, C. T., Physiological Psychology. New York: McGraw-Hill, 1965.

24. Ochs, S., Elements of Neurophysiology. New York: Wiley and Sons, 1965.

25. Selye, H., The Stress of Life. New York: McGraw-Hill, 1956.

26. Shoenberger, R. W., Wherry, R. J., Jr., and Berkshire, J. R., Predicting success in aviation training. NSAM-873. Pensacola, Fla.: Naval School of Aviation Medicine, 1963.

27. Stevens, S. S., On the psychophysical law. Psychol. Rev., 64: 153-181, 1957.

28. Vogel, W., Raymond, S., and Lazarus, R. S., Intrinsic motivation and psychological stress. J. Abnorm. Soc. Psychol., 58: 225-233, 1959.

29. Wherry, R. J., Jr., and Curran, P. M., A study of some determiners of psychological stress. NSAM-941. Pensacola, Fla.: Naval School of Aviation Medicine, 1965.

30. Wilson, W. A., Jr., Oscar, M., and Bitterman, M. E., Probability-learning in the monkey. Quart. J. Exp. Psychol., 16: 163-165, 1964.

31. Zlody, R. L., Changes in three blood components as a result of a stress situation. Psychosomatics, 7: 14-18, 1966.