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Family History of Hypertension, Gender, and Cardiovascular Reactivity and Stereotypy During Stress

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Thirty subjects with a family history of hypertension and 28 subjects without such a history performed a Stroop Color-Word Interference task, a mental arithmetic task (serial subtraction of sevens), and a shock avoidance task (repeating digits backward while expecting to be shocked for mistakes). Systolic and diastolic blood pressure and pulse rate were recorded while subjects anticipated, undertook, and recovered from the shock avoidance task and undertook and recovered from the Stroop and mental arithmetic tasks. It was found that compared to nonfamily history subjects, family history subjects manifested reliably greater cardiovascular reactivity during each task and in anticipation of the shock avoidance task. These results are congruent with the notion that excessive sympathetic nervous system reactivity—possibly genetically determined—is involved in the development of some form(s) of essential hypertension. Further, the results indicated that family history subjects manifested greater consistency, or stereotypy, of cardiovascular response across the experimental tasks than nonfamily history subjects. The possible role of cardiovascular stereotypy in the development of essential hypertension is also discussed.

KEY WORDS: family history of hypertension; cardiovascular reactivity; cardiovascular stereotypy; blood pressure; stress.

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INTRODUCTION

Traditionally essential hypertension has been regarded as a disorder of unknown cause (Sellers *et al.,* 1971). Some researchers have suggested that in many cases essential hypertension may be the result of excessive sympathetic nervous system reactivity (Kaplan, 1978; Weiner, 1979) that may be due to genetic or constitutional factors (Folkow *et al.,* 1973; Von Eiff, 1970).

Support for this notion is provided by research which has indicated that there is a greater incidence of hypertension in individuals with a family history of hypertension (Thomas and Cohen, 1955) and that normotensive individuals with a family history of hypertension manifest greater blood pressure responses to various stressful situations (Briggs and Oerting, 1937; Brod, 1960; Dieckmann and Michel, 1935; Hines and Brown, 1936; Shapiro, 1961). However, a few studies have found little or no relationship between blood pressure responses to stress and family history of hypertension (Feldt and Wenstrand, 1942; Russek, 1943; Remington *et al.,* 1960).

At least two factors may account for the discrepant results of research assessing the relation between family history of hypertension and blood pressure responses to stress. First, it is possible that the influence of genetic factors may differ for males and females. Of the studies in which the subjects' gender was reported, females tended to predominate in studies that reported blood pressure response differences between family history groups (Dieckmann and Michel, 1935; Briggs and Oerting, 1937), while males tended to predominate in studies that reported little differences in blood pressure responses between family history groups (Russek, 1943; Feldt and Wenstrand, 1942).[2] These data support the notion that family history males may manifest less sympathetic nervous system reactivity than family history females.

The second factor is the age of the subjects. Of the investigations in which subjects' ages were reported, those studies in which a relationship was found between family history and blood pressure responsiveness tended to employ subjects who were younger (Briggs and Oerting, 1937; Dieckmann and Michel, 1935; Shapiro, 1961), whereas those studies in which little or no relationship was found between family history and blood pressure responsiveness tended to use subjects who were older (Feldt and Wenstrand, 1942; Russek, 1943). This suggests that the relationship between family history of hypertension and blood pressure responses to a stressor is weaker for older than for younger normotensive subjects.

[2]To avoid cumbersome terminology, the terms "family history" and "nonfamily history" will be used in this paper to refer, respectively, to "family history of hypertension" and "no family history of hypertension."

The only study which did not employ older and/or predominantly male subjects and still failed to find blood pressure differences between family history groups was reported by Remington *et al.* (1960). A problem with this study centers on the law of initial values (Wilder, 1968). The law of initial values states that the magnitude of a response to a stimulus is influenced by the level of responding prior to the stimulus. In the Remington *et al.* (1960) study, the investigators neglected to take into consideration the fact that the systolic blood pressure for family history subjects was significantly higher prior to the stressful stimulus (cold pressor) than that for nonfamily history subjects.

The major purpose of the present study was to further evaluate the hypothesis that individuals with a family history of hypertension manifest greater sympathetic nervous system reactivity than individuals without such a history. The study was conducted taking into consideration the factors described above that may have influenced the outcome of the previous studies. First, the gender of the subjects was included as a factor in the study, and therefore the possibility of gender differences was studied directly. Second, the study was conducted with relatively young individuals, viz., those of college age. Finally, the data from the study were analyzed in such a fashion to rule out the influence of the law of initial values.

On the basis of previous research, it was predicted that family history subjects would show a greater cardiovascular response in anticipation of a stressful task (Remington *et al.,* 1960) and during the task (Brod, 1960) and a slower recovery after the task (Brod, 1960) than nonfamily history subjects. Three stressful tasks were investigated that are similar to tasks used in previous studies of cardiovascular activity: the Stroop Color – Word Interference Test (see Shapiro, 1961), mental arithmetic (serial subtraction of sevens; see Brod *et al.,* 1959), and a difficult shock avoidance task (see Manuck *et al.,* 1978; Obrist *et al.,* 1978). In the latter task, subjects expected to receive electric shocks if they made mistakes in repeating digits backward. In sum, the subjects' reactivity to stressful task situations was assessed during anticipatory (for the shock avoidance task only) and recovery periods as well as while the subjects were actually working on the task.

If family history individuals have greater sympathetic nervous system reactivity, they may experience more intense emotional arousal in a stressful situation as well as more intense and/or more frequent emotional arousal in their daily lives than individuals without such a history (see, for example, Harris *et al.,* 1953). These possibilities were evaluated in the present study by obtaining a measure of the subject's apprehension during the shock avoidance task as well as a measure of subjects' general anxiety [viz., the Manifest Anxiety Scale (MAS); Taylor, 1953]. It was expected that family history subjects would obtain higher apprehension scores for the shock

avoidance task as well as higher general anxiety scores than nonfamily subjects.

Genetically determined hyperreactivity of the sympathetic nervous system may, by itself, not be sufficient to predispose people to essential hypertension. It may be that an individual's reactivity has to be channeled into blood pressure responses in order for pathological changes to eventually occur in that system, rather than some other system (e.g., the gastrointestinal system). It is possible, then, that family history individuals may consistently respond to various stressful situations primarily with elevated blood pressure. In other words, they may manifest blood pressure response specificity or stereotypy (see Sternbach, 1966). Blood pressure response stereotypy may in turn contribute to the development of essential hypertension. Support for this notion comes from a study by Engel and Bickford (1961) in which patients with essential hypertension reacted to a variety of stimuli primarily in terms of blood pressure rather than in terms of other modalities such as heart rate, skin temperature, and galvanic skin response.

The final purpose of the present study, then, was to investigate whether family history individuals manifest blood pressure response stereotypy. This question was evaluated in the present study by comparing the family history group to the nonfamily history group in terms of the consistency of their blood pressure responses across the stressful tasks.

METHOD

Subjects

At the beginning of the semester, the Taylor Manifest Anxiety Scale and a "health inventory" were administered to 717 students of general psychology at the University of Kansas. The health inventory elicited health-relevant information about the students themselves and their relatives.

Individuals were regarded as having a family history if they reported having at least one nondiabetic hypertensive parent. The absence of diabetes in a hypertensive parent was used as a criterion in an attempt to eliminate from consideration individuals whose parent's (or parents') hypertension was secondary rather than primary or essential (Conn and Horowitz, 1971, p. 1290). Individuals were regarded as not having a family history if they reported that none of their first-degree relatives had hypertension. Individuals who indicated that they did not know the relevant health status of their relatives were excluded as potential subjects in the

study. Further, to be considered as potential subjects in the study, all individuals had to meet the following criteria: (1) not having diabetes and/or heart disease; (2) not having hypertension;[3] and (3) not frequently using a relaxation technique such as meditation, deep breathing exercises, muscle relaxation, yoga, or prayer. The purpose of the latter criterion was to eliminate individuals who might be able to exert control over their cardiovascular responses during the study.

Of the students (40 females and 28 males) who met the criteria for inclusion in the study and were regarded as having a family history, 30 subjects (16 females and 14 males) agreed to participate and constituted the family history group. Of those potential subjects who met the criteria for inclusion in the study and were regarded as not having a family history, 28 subjects (15 females and 13 males) agreed to participate and constituted the nonfamily history group. All subjects participated as volunteers in partial fulfillment of their general psychology course requirements.

No attempt was made to validate the subjects' report of family health history; however, preliminary results from a study reported by Obrist (1978) suggest that subjects' reports are reasonably accurate. In that study, 87 subjects reported on their parents' history of hypertension and heart disease and were found to be 89.3% accurate in comparison with reports obtained from the parents themselves.

Cardiovascular Measures

The measures of cardiovascular activity obtained were systolic and diastolic blood pressure and pulse rate. They were measured by means of a Narco Bio-Systems Korotkoff Sounds Microphone positioned over the brachial artery in the upper portion of the subject's nondominant arm. The microphone was contained in a standard size occluding cuff that was inflated every 60 sec by a Narco Bio-Systems Automatic Cycling Cuff Pump. Recordings of these measures were made on a Narco Bio-Systems Physiograph Six which was operated by a lab technician. Both the technician and the polygraph were separated from the subject and the rest of the laboratory by a partition.

[3]It is interesting to note that the proportion of students with a family history of hypertension who reported having high blood pressure (10.8%) was reliably greater ($p < .001$) than the proportion of students without a family history of hypertension who reported having high blood pressure (1.6%). This suggests that even by college age, family history of hypertension is exerting a reliable effect on clinical manifestations of this disorder. All students who reported having high blood pressure were eliminated as potential subjects in the present study.

Procedure

Subjects participated individually in sessions conducted by an experimenter (the first author) who was unaware of the subjects' status concerning family history. The experimenter explained to the subjects that the purpose of the study was to determine how certain verbal tasks influence physiological responses. After subjects signed a consent form agreeing to participate, the blood pressure cuff was attached.

The experimental session was divided into nine periods. The first was a baseline period during which baseline measures of physiological activity were obtained. The Stroop task and the mental arithmetic task each were associated with two periods: one period for the task itself and one period for recovery following the task. Finally, the shock avoidance task was associated with four periods: one for determining the subjects' limits for repeating digits backward, one for anticipation of the task, one for performance of the task, and one for recovery following the task. Physiological recordings were made every 60 sec within each period.

During the baseline period, which lasted approximately 10 min, the subject was asked to sit quietly while initial measures of blood pressure and pulse rate were recorded. Next, during the Stroop task period, the subject was given two sheets of standard Stroop stimuli on which to work for 2 min. Specifically, the stimuli were the names of four colors (green, red, orange, and blue), each of which was printed in one of the other three colors; for example, the word "red" might be printed in either green, orange, or blue ink. The subject was instructed to say out loud the color of ink for each word as fast as possible and without making mistakes. To increase the stressfulness of the task, the experimenter conspicuously displayed a stopwatch, and at the end of 1 min he told the subject to hurry.

During a 4-min recovery period following the Stroop task, the subject was instructed to sit quietly while the polygraph ostensibly was recalibrated.

During the mental arithmetic task, the subject was instructed to begin with the number 2194 and serially subtract the number 7 until told to stop. The subject was instructed to make a subtraction out loud at least once every 2 sec, and to make the subject aware of this rate, a metronome was set to click once a second. The subject performed this task for 4 min. To increase the stressfulness of the task, at three points during the task the experimenter told the subject to hurry and/or to be more accurate.

During a 4-min recovery period following the mental arithmetic task, the subject again was instructed to sit quietly.

During the period for determining the subjects' limit for repeating digits backward, each subject was administered the Digits Backward portion of the Digit Span subtest from the Wechsler Adult Intelligence Scale according to standard instructions (Wechsler, 1955, p. 41). Each subject was given digit series of increasing length until he/she reached his/her own

limit, defined as the level at which he/she failed two successive series of a specified number of digits.

Next, subjects were told that in a few minutes they would be asked to again repeat several sets of digits, but that this time shock electrodes would be placed on their hands and they might receive an electric shock each time they made a mistake. Subjects were told that a shock machine which administered shocks on a random basis would be activated each time they made a mistake; hence, the only way to assure that they would not be shocked was to not make any mistakes. Shock electrodes were then attached, and the subjects were asked to sit quietly for 2 min while the shock apparatus ostensibly was readied. These 2 min constituted the anticipation period.

Next, subjects were administered the shock avoidance task, which consisted of repeating six sets of digits, each of which was one digit less than their previously determined limits. Thus, all subjects were asked to perform a task which was roughly equivalent in terms of difficulty level. No shocks were actually administered for subjects' mistakes in order to avoid possible differences in the number of shocks being administered to subjects in the two family history groups which might in turn differentially affect their cardiovascular responses. Not administering shocks did not arouse suspicion since subjects did not expect a shock after each mistake.

A 4-min recovery period followed the shock avoidance task. Following the recovery period, subjects were given a questionnaire which asked them to describe the thoughts and feelings they had had during the shock avoidance task.

RESULTS

As noted earlier, recordings of blood pressure were made every 60 sec during each of the nine experimental periods. Pulse rate was scored by counting the number of beats (i.e., Korotkoff sounds) in a 10-sec interval during each blood pressure recording. For each experimental period, an average score for systolic and diastolic blood pressure and pulse rate was derived in the following manner. For the baseline period, the median of the last three scores obtained during the period was derived for each cardiovascular measure. For the rest of the periods in the experimental session, a mean systolic and diastolic blood pressure score and a mean pulse rate score were derived from the recordings made every 60 sec during each period.[4]

[4]A log transformation was applied to the systolic blood pressure and pulse rate scores to normalize the distributions of these two measures.

In order to eliminate the influence of base-level values on the magnitude of responses given in later periods (i.e., the law of initial values; Wilder, 1968), base-free measures of change are desirable (Benjamin, 1967). Therefore, residualized scores were computed for the three cardiovascular measures (see Cronbach and Furby, 1970). Residualized scores represent the difference between the obtained score for a period and the score predicted by linear regression from the respective baseline period score. Further, to eliminate the effect of level of physiological arousal in one period from influencing the level of arousal during the next period, the scores for each period were adjusted for the last score from the preceding period. (This was not necessary for scores from the Stroop task period since they had already been adjusted for scores from the preceding period, i.e., the baseline period.) This procedure then made the scores for a period independent of the scores from the preceding period.

Analyses of Measures

An analysis of variance was performed on the cardiovascular data for the baseline period with family history group and sex of subject as factors. A repeated-measures analysis of variance with family history group, sex of subject, and periods as factors was performed on the cardiovascular data separately for the stress periods (Stroop task, mental arithmetic task, digits backward limit, shock avoidance anticipation, and shock avoidance task) and the recovery periods (following the Stroop, mental arithmetic, and shock avoidance tasks).

Baseline Period

The analyses for the baseline period data revealed no reliable main or interactive effects for family history group (see data in Tables I and II and Fig. 1).

Stress Periods

The analysis for systolic blood pressure revealed a statistically reliable interaction between family history group and sex of subject [$F(1,54) = 5.43$, $P < 0.024$]. No other main or interaction effect involving family history group and/or sex was reliable. Subsequent analyses revealed that across the stress periods, family history females had a reliably higher systolic blood pressure ($\bar{X} = 126.58$ mm Hg) than nonfamily history females ($\bar{X} = 121.59$ mm Hg) [$F(1,29) = 6.47$, $P < 0.017$]. However, there was no reliable difference in systolic blood pressure across the stress periods

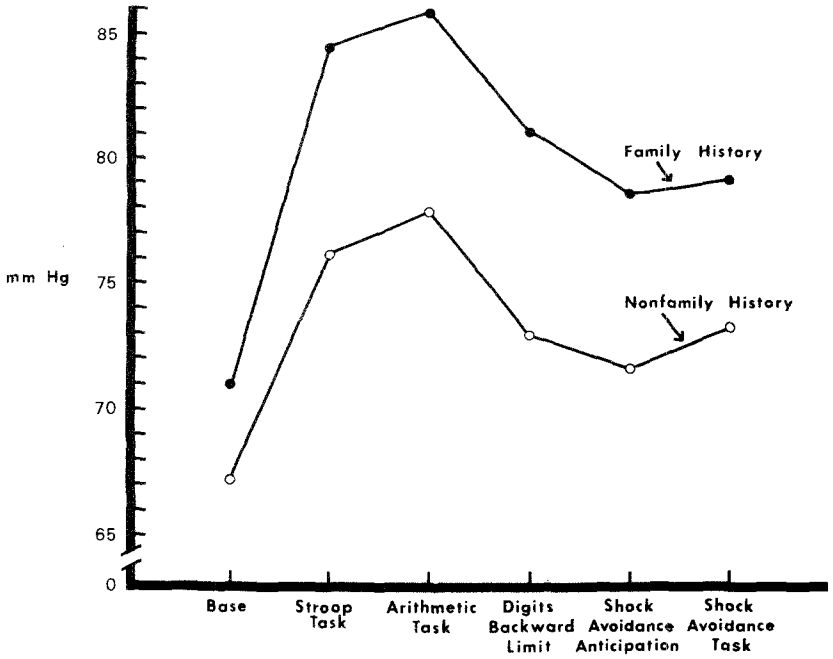

Fig. 1. Mean unadjusted diastolic blood pressure (mm Hg) for baseline and stress periods.

Table I. Mean Systolic Blood Pressure (mm Hg) for Baseline[a] and Stress[b] Periods

	Sex of subject			
	Male		Female	
Experimental period	Family history	No family history	Family history	No family history
Baseline	118.69	118.91	107.67	106.79
Stroop task	128.63	130.44	132.57	126.59
Mental arithmetic task	126.18	129.69	130.40	123.82
Digits backward limit	119.31	120.46	124.99	120.30
Shock avoidance anticipation	117.04	121.95	118.66	115.08
Shock avoidance task	127.19	125.41	126.76	122.47

[a]Unadjusted scores.
[b]Adjusted scores.

Table II. Mean Pulse Rate (Beats Per Minute) for Baseline[a] and Stress[b] Periods

Experimental period	Family history	No family history
Baseline	64.53	63.34
Stroop task	91.74	86.79
Mental arithmetic task	91.75	85.96
Digits backward limit	84.28	81.09
Shock avoidance anticipation	77.76	76.27
Shock avoidance task	98.93	91.57

[a]Unadjusted scores.
[b]Adjusted scores.

between family history males ($\bar{X}$ = 123.58 mm Hg) and nonfamily history males ($\bar{X}$ = 125.52 mm Hg) [$F(1,25) = 0.74$]. (See Table I for individual stress period means.)

The analysis for diastolic blood pressure revealed a reliable main effect for family history group [$F(1,54) = 7.19$, $P < 0.01$], which indicated that across stress periods, family history subjects had a reliably higher diastolic blood pressure ($\bar{X}$ = 80.00 mm Hg) than did nonfamily history subjects ($\bar{X}$ = 76.72 mm Hg). (See Fig. 1 for individual stress period data.) No other main or interaction effect involving family history group and/or sex was statistically reliable.

The analysis for pulse rate revealed a reliable main effect for family history group [$F(1,54) = 4.07$, $P < 0.049$], which indicated that across stress periods, family history subjects had reliably higher pulse rates ($\bar{X}$ = 88.89 bpm) than did nonfamily history subjects ($\bar{X}$ = 84.33 bpm). (See Table II for individual stress period means.) No other main or interaction effect involving family history group and/or sex was statistically reliable.

Recovery Periods

No statistically reliable main or interaction effect involving family history group was found in the analyses of the cardiovascular data across recovery periods.

Measures of Apprehension During Shock Avoidance and General Anxiety

The questionnaire administered to subjects following the shock avoidance task were scored on a five-point scale for the amount of apprehension that subjects experienced during the shock avoidance period. The scoring was done by two judges who were unaware of the subjects' cate-

gorization on the family history variable. The correlation between the two judges' ratings was $r(56) = 0.87$, ($P < 0.0001$), indicating a satisfactory degree of interjudge reliability. The mean of the two judges' ratings for each subject was then used in an analysis of variance with family history group and sex of subjects as factors. The analysis revealed a reliable main effect for family history [$F(1,54) = 8.93$, $P < 0.004$], indicating that family history subjects had been more apprehensive during the shock avoidance task ($\bar{X} = 4.07$) than nonfamily subjects ($\bar{X} = 3.09$).

A point biserial correlation was computed between the subjects' grouping on the family history variable and their scores on the Manifest Anxiety Scale. (Scores on the Manifest Anxiety Scale were not available for five of the subjects.) The resulting correlation, $r_{pb}(51) = 0.12$, however, was not statistically reliable. Separate correlations were computed for each sex since sex differences had been expected in this study. The correlation for females was found to be statistically reliable [$r_{pb}(27) = .43$, $P < 0.021$] and indicated that family history females had reliably higher Manifest Anxiety Scale scores than nonfamily history females. However, the correlation for males, although not statistically reliable, was found to be opposite in sign to that of the females, $r_{pb}(22) = -0.24$ (NS).).

In sum, these results indicate that family history subjects experienced more intense apprehension during the shock avoidance task and that family history females, but not males, experience more general anxiety.

Consistency of Cardiovascular Measures

Consistency of cardiovascular responding across stress periods for subjects with and without family history was evaluated in the following manner. Subjects who manifested a greater consistency of response across stressful periods should evidence less variability in their scores across these periods. Thus, for each cardiovascular measure, a standard score was derived for each subject's score for each of the stress periods. Next, for each subject the standard deviation of these standard scores was then calculated. Finally, for each cardiovascular measure a two (Family History) by two (Sex of Subject) analysis of variance was performed on the standard deviations of the subjects' scores across periods. The analysis for diastolic blood pressure revealed a reliable main effect for the family history group [$F(1,54) = 4.29$, $P < 0.043$], indicating that family history subjects evidenced less variability in diastolic blood pressure responses across periods ($\bar{X} = 0.69$) than nonfamily history subjects ($\bar{X} = 0.84$). Further, intraclass correlations computed for diastolic blood pressure across periods were 0.34 and 0.44 for family history males and females, respectively, and 0.18 and 0.11 for nonfamily history males and females, respectively. In sum, both family

history males and family history females manifested a greater consistency of diastolic blood pressure across the stress periods than nonfamily history males and females.

DISCUSSION

The results of the present study indicated that compared to nonfamily history subjects, family history subjects had a reliably higher diastolic blood pressure and pulse rate across the stress periods. In addition, for females but not males, family history subjects had a reliably higher systolic blood pressure across the stress periods than nonfamily history subjects. These results are congruent with the notion that genetically determined, excessive sympathetic nervous system reactivity is involved in the development of essential hypertension. That is, subjects with a family history of hypertension evidenced greater sympathetic nervous system reactivity in response to stressful tasks and in anticipation of an aversive experience than subjects without a family history of hypertension.

It should be noted that the greater cardiovascular reactivity on the part of family history subjects could be due to differences in humoral or hormonal influences rather than differences in sympathetic nervous system reactivity (Weiner, 1979). However, the failure in the present study to find protracted pressor differences between family history groups, for instance, during the recovery periods, points more to a difference in sympathetic nervous system activity than to a difference in more slow-acting humoral or hormonal influences.

There was evidence from the results of this study of greater cardiovascular reactivity in family history females than family history males. This finding is congruent with prior evidence that (a) there is a somewhat greater association for women than men between family history of hypertension and development of hypertension (see Thomas and Cohen, 1955) and (b) constitutional factors play a greater role in influencing blood pressure in women than in men (Mathers *et al.*, 1961). Further, the results of the present study help to reconcile the findings of previous studies. Differences in cardiovascular reactivity between subjects who vary in family history of hypertension are more likely to be found in studies in which males predominate. The possible mechanisms that may account for a sex difference in the familial transmission of a disposition for hypertension are controversial and warrant further inquiry (Thomas and Cohen, 1955).

No differences were found between individuals in the two family history groups in terms of cardiovascular recovery following the stressful tasks. This may have been due to the subjects' being youthful and having relatively resilient cardiovascular systems which facilitated a rapid return of

blood pressure to normal levels. Loss of cardiovascular resilience may be necessary before potentially hypertensive individuals will exhibit prolonged blood pressure responses following stress.

The results of the analysis on the measure of apprehension during the shock avoidance task indicated that, as expected, family history subjects experienced more intense emotional arousal during the shock avoidance task than nonfamily history subjects. The results of the analysis of the Manifest Anxiety Scale data suggest that family history females may generally experience more intense and/or more frequent anxiety than nonfamily history females. Why the same relationship was not found for males is unclear. Men with a family history may tend generally to experience some affective state other than anxiety, e.g., anger, more than nonfamily history males.

Finally, the results of the present study revealed reliable differences between family history groups with regard to the consistency of diastolic blood pressure responses across stress periods. Thus there is evidence from this study that individuals who may be regarded as prehypertensive manifest blood pressure response stereotypy.

Further evidence of cardiovascular response specificity in family history individuals comes from a study by Doyle and Fraser (1961), who found that the external administration (injection) of norepinephrine led to a greater reduction in forearm blood flow in sons of hypertensives than in sons of nonhypertensives. This suggests that compared to nonfamily history individuals, family history individuals have a disposition to respond to the hormonal concomitants of stress with greater peripheral vasoconstriction, which could be expected to contribute to greater elevations in blood pressure (Weiner, 1979).

All in all, it appears from this study that individuals who are genetically predisposed to hypertension are characterized by both sympathetic nervous system hyperactivity and blood pressure response stereotypy. Such a combination would ensure that predisposed individuals will manifest sympathetic nervous system hyperreactivity specifically in terms of blood pressure responsivity. Such a combination may be necessary to result in the physiological changes that may be involved in sustained elevated blood pressure (e.g., resetting of arterial baroreceptors, restructuring of resistance vessels, etc.; Weiner, 1979). However, only longitudinal studies will determine whether those who manifest blood pressure response stereotypy and/or sympathetic nervous system hyperreactivity are more likely to develop essential hypertension. Further, there are probably various subvarieties of essential hypertension (Weiner, 1979), and sympathetic nervous system hyperreactivity and/or blood pressure response stereotypy may be involved in the etiologies of only certain subvarieties.

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REFERENCES

Benjamin, L. S. (1967). Facts and artifacts in using analysis of covariance to "undo" the law of initial values. *Psychophysiology* 4: 187-206.

Briggs, J. F., and Oerting, H. (1937). The prognostic value of the cold test in pregnancy. *Minn. Med.* 20: 382-384.

Brod, J. (1960). Essential hypertension: Haemodynamic observations with a bearing on its pathogenesis. *Lancet* 2: 773-778.

Brod, J., Fencl, V., Hejl, Z., Jirka, J., and Ulrych, M. (1959). Circulation changes underlying blood pressure elevation during acute emotional stress (mental arithmetic) in normotensive and hypertensive subjects. *Clin. Sci.* 18: 269-279.

Chesley, L. C., and Chesley, E. R. (1939). The cold pressor test in pregnancy. *Surg. Gynecol. Obstet.* 69: 436-440.

Conn, H. L., Jr., and Horwitz, O. (1971). *Cardiac and Vascular Diseases,* Lea and Febiger, Philadelphia.

Cronbach, L. J., and Furby, L. (1970). How should we measure "change"—or should we? *Psychol. Bull.* 74: 68-80.

Dieckmann, W. J., and Michel, H. L. (1935). Thermal study of vasomotor lability in pregnancy. *Arch. Intern. Med.* 54: 420-430.

Doyle, A. E., and Fraser, J. R. E. (1961). Vascular reactivity in hypertension. *Circ. Res.* 9: 755-758.

Engel, B. T., and Bickford, A. I. (1961). Response specificity: Stimulus response and individual-response specificity in essential hypertensives. *Arch. Gen. Psychiat.* 5: 478-489.

Feldt, R. H., and Wenstrand, D. E. W. (1942). The cold-pressor test in subjects with normal blood pressure. *Am. Heart J.* 23: 766-771.

Folkow, B., Hallback, M., Lundgren, Y., Silvertsson, R., and Weill, L. (1973). Importance of adaptive changes in vascular design for establishment of primary hypertension, studied in man and in spontaneously hypertensive rats. *Circ. Res.* 32-33 (Suppl. I): 2-16.

Harris, R. E., Sokolow, M., Carpenter, L. G., Jr., Freedman, M., and Hunt, S. P. (1953). Response to psychologic stress in persons who are potentially hypertensive. *Circulation* 7: 874-879.

Hines, E. A., and Brown, G. E. (1936). The cold pressor test for measuring the reactivity of the blood pressure: Data concerning 571 normal and hypertensive subjects. *Am. Heart J.* 11: 1-9.

Kaplan, N. M. (1978). Stress, the sympathetic nervous system and hypertension. *J. Hum. Stress* 4: 29-34.

Manuck, S. B., Harvey, A. H., Lechleiter, S. L., and Neal, K. S. (1978). Effects of coping on blood pressure responses to threat of aversive stimulation. *Psychophysiology* 15: 544-549.

Mathers, J. A. L., Osborne, R. H., and DeGeorge, F. V. (1961). Studies of blood pressure, heart rate, and the electrocardiogram in adult twins. *Am. Heart J.* 63: 634.

Obrist, P. A. (1978). Behavioral–cardiac interactions: Psychosomatic hypothesis. Invited address, 86th Annual Convention of the American Psychological Association, Toronto.

Obrist, P. A., Light, K. C., Langer, A. W., Grignolo, A., and McCubbin, J. A. (1978). Behavioral-cardiac interactions: The psychosomatic hypothesis. *J. Psychosom. Res.* 22: 301-325.

Remington, R. D., Lambarth, B., Moser, M., and Hoobler, S. W. (1960). Circulatory reactions of normotensive and hypertensive subjects and of the children of normotensive and hypertensive parents. *Am. heart J.* 59: 58-70.

Russek, H. I. (1943). The significance of vascular hyperreaction as measured by the cold pressor test. Observations on 200 normal subjects over the age of 40. *Am. Heart J.* 26: 398-404.

Sellers, A. M., Itskovitz, H. D., and Lindauer, M. A. (1971). Systemic arterial hypertension. In Conn, H. L., and Horwitz, O. (eds.), *Cardiac and Vascular Diseases, Vol. 2,* Lea and Febiger, Philadelphia.

Shapiro, A. P. (1961). An experimental study of comparative responses of blood pressure to different noxious stimuli. *J. Chron. Dis.* 13: 293-311.

Sternbach, R. A. (1966). *Principles of Psychophysiology,* Academic Press, New York.

Taylor, J. A. (1953). A personality scale of manifest anxiety. *J. Abnorm. Soc. Psychol.* 48: 285-290.

Thomas, C. B., and Cohen, B. H. (1955). The familial occurrence of hypertension and coronary artery disease with observations concerning obesity and diabetes. *Ann. Intern. Med.* 42: 90-127.

Von Eiff, A. W. (1970). The role of the autonomic nervous systems in the etiology and pathogenesis of essential hypertension. *Jap. Circ. J.* 34: 147-153.

Wechsler, D. (1955). *Manual for the Wechsler Adult Intelligence Scale,* The Psychological Corporation, New York.

Weiner, H. (1979). *Psychobiology of Essential Hypertension,* Elsevier, New York.

Wilder, J. F. (1968). *Stimulus and Response: The Law of Initial Values,* Williams and Wilkins, Baltimore, Md.