STUDIES IN MOTION SICKNESS

SERIES C

Reports on research administered by Wesleyan University by means of grants-in-aid from the National Research Council Committee on Selection and Training of Aircraft Pilots from funds provided by the Civil Aeronautics Administration.

August 1946

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National Research Council

Committee on Selection and Training of Aircraft Pilots

Executive Subcommittee

M. S. Viteles, Chairman

C. W. Bray	A. I. Hallowell
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LETTER OF TRANSMITTAL

NATIONAL RESEARCH COUNCIL

2101 Constitution Avenue, Washington, D. C.
Division of Anthropology and Psychology

Committee on Selection and Training of Aircraft Pilots

August 14, 1946

Dr. Dean R. Brimhall
Director of Research
Civil Aeronautics Administration
Room 3895, Commerce Building
Washington 25, D. C.

Dear Dr. Brimhall:

Attached is a report entitled Studies in Motion Sickness, Series C, embodying four studies conducted by G. R. Wendt and co-workers. This is submitted by the Committee on Selection and Training of Aircraft Pilots with the recommendation that it be included in the series of Technical Reports of the Division of Research, Civil Aeronautics Administration.

The report is the final one in a series describing investigations on motion sickness administered by Wesleyan University under grants-in-aid from the National Research Council Committee on Selection and Training of Aircraft Pilots from funds made available by the Civil Aeronautics Administration.

Cordially yours,

Morris S. Viteles, Chairman
Committee on Selection and
Training of Aircraft Pilots
National Research Council

MSV:rm

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FOREWORD

This report is the third of a series describing investigations on motion sickness administered by Wesleyan University under grants-in-aid from the National Research Council Committee on Selection and Training of Aircraft Pilots. These studies were designed to investigate and compare certain physiological and psychological characteristics of subjects susceptible and non-susceptible to motion sickness.

Acknowledgment is due to co-workers, students, and others who aided and participated in these investigations.

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CONTENTS (Continued)

STUDIES IN MOTION SICKNESS

Series C

I

CIRCULATORY AND RESPIRATORY RESPONSES TO COLD AND TO BREATH HOLDING IN INDIVIDUALS SUSCEPTIBLE AND NON-SUSCEPTIBLE TO MOTION SICKNESS

by

J. S. Helmick
G. R. Wendt

SUMMARY

This investigation represents one of several experiments carried out at Wesleyan University on the relation of motion-sickness susceptibility to the cold pressor test (immersion of hand or foot in ice water) and to the effects of holding the breath for a short period. Reactivity was measured by blood pressure, pulse rate, and breathing changes. The experiments were conceived to test the hypothesis that susceptibility to motion sickness is a condition resulting from so-called "vasomotor instability." In the present experiment twelve subjects highly susceptible to motion sickness were compared with twelve who had never been motion sick. The present results indicate that there were no significant average differences in reactivity to either cold or breath holding among susceptibles and non-susceptibles according to blood pressure, pulse rate, or breathing rate. Comparisons were made of reactions to cold from immersion of the hand and immersion of the foot. Immersion of the foot was more painful according to the subjects' rankings and yielded somewhat greater blood pressure responses. The test-retest reliability of blood pressure reactions resulting from hand immersion was represented by an $r = .76$ for systolic pressure and .57 for diastolic pressure, while for foot stimulation the corresponding figures were .43 and .59. The correlation between the two methods, hand and foot, were .68 for systolic pressures and .56 for diastolic. There were no significant correlations between blood pressure rises to cold and to breath holding. The obtained correlations were $r = .10$ for systolic pressure rise and .19 for diastolic pressure rise.

These data appeared to be sufficient to reject the hypothesis that there is a relationship between motion susceptibility and responsiveness to cold or breath holding. The data incidentally indicated that, as employed in this study, the cold pressor test was somewhat less reliable than previous reports had indicated, and furthermore that the high correlation claimed between cold pressor and breath holding tests by previous workers was not confirmed.

CIRCULATORY AND RESPIRATORY RESPONSES TO COLD AND TO BREATH HOLDING IN INDIVIDUALS SUSCEPTIBLE AND NON-SUSCEPTIBLE TO MOTION SICKNESS

INTRODUCTION

This report presents the results of an investigation concerned with the relationship of motion-sickness[1] susceptibility to vasomotor instability. The study was conducted by Mr. J. S. Helmick and Dr. G. R. Wendt at Wesleyan University, under the auspices of the National Research Council Committee on Selection and Training of Aircraft Pilots. Differences in reactivity to cold and breath holding in terms of blood pressure, pulse rate, and breathing rate variables for individuals susceptible and non-susceptible to motion sickness were examined.

The cold pressor test as originally devised by Hines and Brown[2] was designed for the detection of cases of potential hypertension. The test has not ordinarily been applied to differentiate among normal subjects. Previous investigations of its reliability have been concerned mostly with test-retest reliability when applied to diagnosis of normality or abnormality.

The procedure of the test as reported by Hines is to determine the maximum rise of blood pressure produced by a standard cold stimulation, ice water at 4.0° C. applied to the hand for one minute. The subject rests in the supine position for 20-60 minutes during which the blood pressure is taken until it has reached a base line and has apparently ceased to drop. The hand is then placed in ice water to a line just above the wrist while blood pressure readings are taken at 30-second intervals, continuing for two minutes after removal of the hand from ice water. The greatest obtained rises in systolic and diastolic pressures are taken as the index of response. Ordinarily a response of more than 20 mm. Hg. systolic pressure or 15 mm. diastolic pressure is regarded as being hyperreaction. The assumption involved according to Hines is "...that such a rise in blood pressure resulting from a given stimulus is an index of vascular reactivity."[3] Hines and others have presented evidence that a

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[1] For other studies of motion sickness conducted by Dr. G. R. Wendt and co-workers under the auspices of the Committee on Selection and Training of Aircraft Pilots see: Wendt, G. R. Motion sickness in aviation. NRC Division of Anthropology and Psychology, Committee on Selection and Training of Aircraft Pilots, May 1944. Wendt, G. R. Studies in motion sickness. Series A. Washington, D. C.: CAA Division of Research, Report No. 40, December 1944, Wendt, G. R. Studies in motion sickness. Series B. Washington, D. C.: CAA Division of Research, Report No. 60, April 1946.

[2] Hines, E. A., Jr., and Brown, G. E. A standard test for measuring vasomotor reactions. Proc. Staff Meet., Mayo Clinic, 1932, 7, 322-335.

[3] Hines, E. A., Jr., and Brown, G. E. Ibid.

high degree of reactivity so measured is associated with essential hypertension. Children of hypertensive parents tend to be hyperreactors, and hyperreactors tend to develop hypertension. Most hypertensive individuals are hyperreactive.

The breath holding test was devised by Ayman and Goldshine[4] as a test of vascular reactivity believed to be fully equivalent to the cold pressor test. The seated subject was allowed to rest until his blood pressure had ceased to drop. Then without over-breathing, the breath was held voluntarily in exhalation for 20 seconds. Exactly at the end of 20 seconds the systolic blood pressure was taken. After another rest the same process was repeated and the diastolic pressure was taken. Ayman and Goldshine contended that the breath holding and cold pressor tests gave substantially the same results. This result has been confirmed by others.

PROCEDURES

The procedures of the present experiment were designed to duplicate the essential features of the cold pressor and breath holding tests as previously used. However, somewhat more elaborate data were obtained by securing pulse rate and breathing records. Investigation of the stimulation of the foot by cold water was also added. Several changes in technique were introduced in the interest of standardization of procedures and in order to make possible the simultaneous study of cold pressor and breath holding tests. The general procedure was to have each subject rest on a bed for 30 minutes, after which recorders were applied and stimulations given at fixed intervals during a period of 23 minutes. Cold pressor tests were given at 4, 8, 12, and 16 minutes and a breath holding test at 20 minutes. A counterbalanced order of stimulation was used with different subjects so that possible progressive changes were controlled.

A. Order of stimulation and counterbalancing of variables. The procedures were conducted by an experimenter and an assistant. The subjects reclined on beds during the testing. The men came on a staggered time schedule between 7:30 P.M. and 10 P.M., so that while one subject was resting for 30 minutes data were being taken on the other. Toward the end of the rest period the recorders were applied and adjusted. Four minutes of resting record were taken to establish a base line and then the first cold pressor stimulation applied for one minute. This was repeated on hand or foot at 8, 12, and 16 minutes.[5] Breath holding for 20 seconds began at the 20th minute. This test was not repeated.

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[4]Ayman, O., and Goldshine, A. D. The breath holding test: a simple standard stimulus of blood pressure. Arch. Int. Med., 1939, 63, 899-906.

[5]Previous experimentation had indicated that three minutes was sufficient time between stimulation periods for all pulse rates and blood pressures to return to their approximate base lines.

Each subject had two cold stimuli presented to the hand and two to the foot. The order of these was predetermined so that susceptibles and non-susceptibles were equally represented in the various stimulus sequences. Two from each group served under each of the six possible combinations of hand, hand, foot, foot; that is, four subjects went through the sessions with the stimulation in the order of hhff, and four under each of the other orders: hfhf; hffh; ffhh; fhfh; and fhhf. In most cases the four subjects used for any one order of stimulations were run in the same evening, two susceptibles and two non-susceptibles, and in general the two groups of subjects were distributed among the various arrival times (7:30, 8, 8:30, and 9).

B. Technique of cold pressor stimulation. As stated above the cold pressor stimulation was begun at a fixed time rather than in relation to a base line judged by the experimenter. This change in the technique of Hines was regarded as essential for proper experimental standardization. In other respects the technique of hand stimulation was the same as theirs. The hand was placed in ice water for one minute, removed, blotted fairly dry, and placed in a sack of turkish toweling. The technique for the foot was similar, the foot being lowered into a pail of ice water at a convenient height beside the bed and immersed up to the ankle, removed after one minute, dried, placed back on the bed, and covered. Water temperatures were recorded. They varied from 2.2° C. to 4.4° C. The average for the hand was 3.6° C. and for the foot 3.1° C.

C. Technique of the breath holding test. The breath holding test was considerably modified from the original procedures of Ayman and Goldshine. The subjects were supine rather than seated. Intrapleural pressure was standardized rather than being allowed to vary. Standardization of pressure was obtained by having the subject blow very slowly after exhalation through a tube connected with a water manometer, keeping it at one inch of pressure for 20 seconds. Each subject was given some practice with this device during the rest period so that the problem-solving aspects of the situation were reduced to a minimum. Such a system used with a very slow leak was easy to maintain at constant pressure and required only a minimum volume of air output for maintenance of the pressure. The procedure in this study appeared to be experimentally more desirable than the original which allowed the subject to determine his own intrapleural pressure.

D. Records. Three classes of records taken were auscultatory measures of systolic and diastolic blood pressure, photokymographic records of pulse rate and breathing, and a ranking by the subject of the relative amount of pain experienced from each of the four cold pressor stimulations.

1. Auscultatory blood pressure measures. A cuff was applied to the opposite arm from that used for cold stimulation. Measures were taken at 30-second intervals throughout the experimental session. Systolic pressure was recorded at the first sound heard and diastolic pressure at the last change in sound from a sharp to a dull beat. Certain difficulties were experienced in reading diastolic pressure since the application of the ice water changed the character of the sounds somewhat in some sub-

jects. In all cases there was about a 20-second lag between the systolic reading and the diastolic reading. Pressure readings were dictated by the experimenter and recorded by the assistant. The timing of readings was such that one set of pressures was recorded slightly before the beginning of the cold stimulations, another about half way through, and a third just at the end of stimulation. The readings for breath holding were so timed that the systolic reading was usually taken about half way through the 20-second period and the diastolic reading about at the end. The timing of these readings was controlled by watching a clock and recorded on the strip of record by electromagnetic signal markers.

2. Photokymographic records. Pulse records were obtained from the leg opposite to that used for cold stimulation. An inflated rubber cuff was fastened around the ankle and its volumetric changes with the pulse recorded on a continuously running photokymograph. Respiration was recorded by a thoracic pneumograph operating a mirror-bearing tambour. A record of the pressure in the blood pressure cuff was made by means of a T-joint in the tube to the cuff whereby the air pressure operated a sylphon bellows whose degree of extension was recorded on the photokymograph paper. Signal magnets were used to indicate the onset of the stimuli and the time of reading systolic and diastolic blood pressures.

E. Subjects. Twenty-four male college students were selected from the total student body of Wesleyan University on the basis of their responses to a motion sickness history inventory.[6] Subjects were selected from the extremes of the population. The susceptibles were those who had experienced recent motion sickness on moving devices. The non-susceptibles were those who had never under any circumstances been motion sick.

RESULTS

A. Cold pressor test. The available data on the cold pressor test were the blood pressure readings, pulse records, breathing records, and subjective reports of relative pain. Each of these will be taken up in turn, indicating the obtained results from susceptibles and non-susceptibles and reliability figures where applicable.

1. Blood pressures. The blood pressure data were handled in two ways, the first, the standard method used by Hines (maximum systolic and diastolic rises); the second, by continuous plotting of systolic and diastolic blood pressure readings. The procedure of the first method was as follows. The base line for each test was taken as the average of the three readings immediately before the beginning of stimulation. The difference between this base line and the highest reading within 30 seconds after stimulation was taken as the maximum rise. The procedure for the second method was the following. The entire record of each subject was first plotted on a con-

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[6] For a copy of this inventory see: Wendt, G. R. Studies in motion sickness. Series B. P. 54.

tinuous graph showing the course of blood pressure throughout the experiment. The levels of successive readings were connected by straight lines. These graphs were then combined into group averages for susceptibles and non-susceptibles. Since the readings for these subjects were not taken at exactly comparable times and were usually not made exactly on the minute or half-minute, it was not feasible to derive group averages directly from the raw data. Instead by reference to the individual graphs the points were determined at which the graph crossed the minute mark and that value used for computation of group averages. This procedure somewhat reduces the average maximum rise from its true value, since the maximum point on the individual's curve seldom fell exactly on the minute mark.

Group average curves of two kinds were derived. The first was, as stated above, plotting sequentially the blood pressure readings. In these curves, shown in Figure 1, each point is determined by readings from six subjects made on the hand and six readings made on the foot. By the second method, the results of which are shown in Figure 2, all of the readings were brought together for the first stimulation of the hand, all for the second stimulation of the hand, for the first stimulation of the foot, and the second stimulation of the foot, so that four separate sets of curves were derived.

The data on maximum rise in systolic and diastolic blood pressure for each subject are shown in Table 1, while the group averages showing continuous readings are shown in Figures 1 and 2. Inspection of the table and the figures appears to justify the following statements about the results.

a. The resting blood pressures of the subjects were between 130-135 mm. Hg. systolic and between 80-85 mm. Hg. diastolic. These base lines are slightly high, which may be either the consequence of chance factors in selection of subjects or may indicate the presence of some apprehension on the part of the subjects. The non-susceptibles show a slightly higher blood pressure than the susceptibles. This is a reversal of the trend characteristically found among such subjects and may be attributed to chance factors in the selection of subjects.

b. Comparison of susceptibles and non-susceptibles in terms of maximum rise shows small and statistically insignificant differences. The non-susceptibles according to mean rises were more reactive. This it will be noted is in a direction contrary to our original hypothesis. For the non-susceptibles the hand stimulation produced systolic and diastolic pressure rises of 8.2 and 11.5 mm. Hg., respectively. The corresponding figures for susceptibles were 8.1 and 10.1. The same set of four figures with the foot were 13.4 and 15.4, 12.6 and 15.1.

c. The reaction to immersion of the foot was greater than that to immersion of the hand. Considering all 24 subjects, the mean systolic pressure rises were 8.1 for the hand and 13.0 for the foot, while the respective mean diastolic pressures were 10.8 and 15.2.

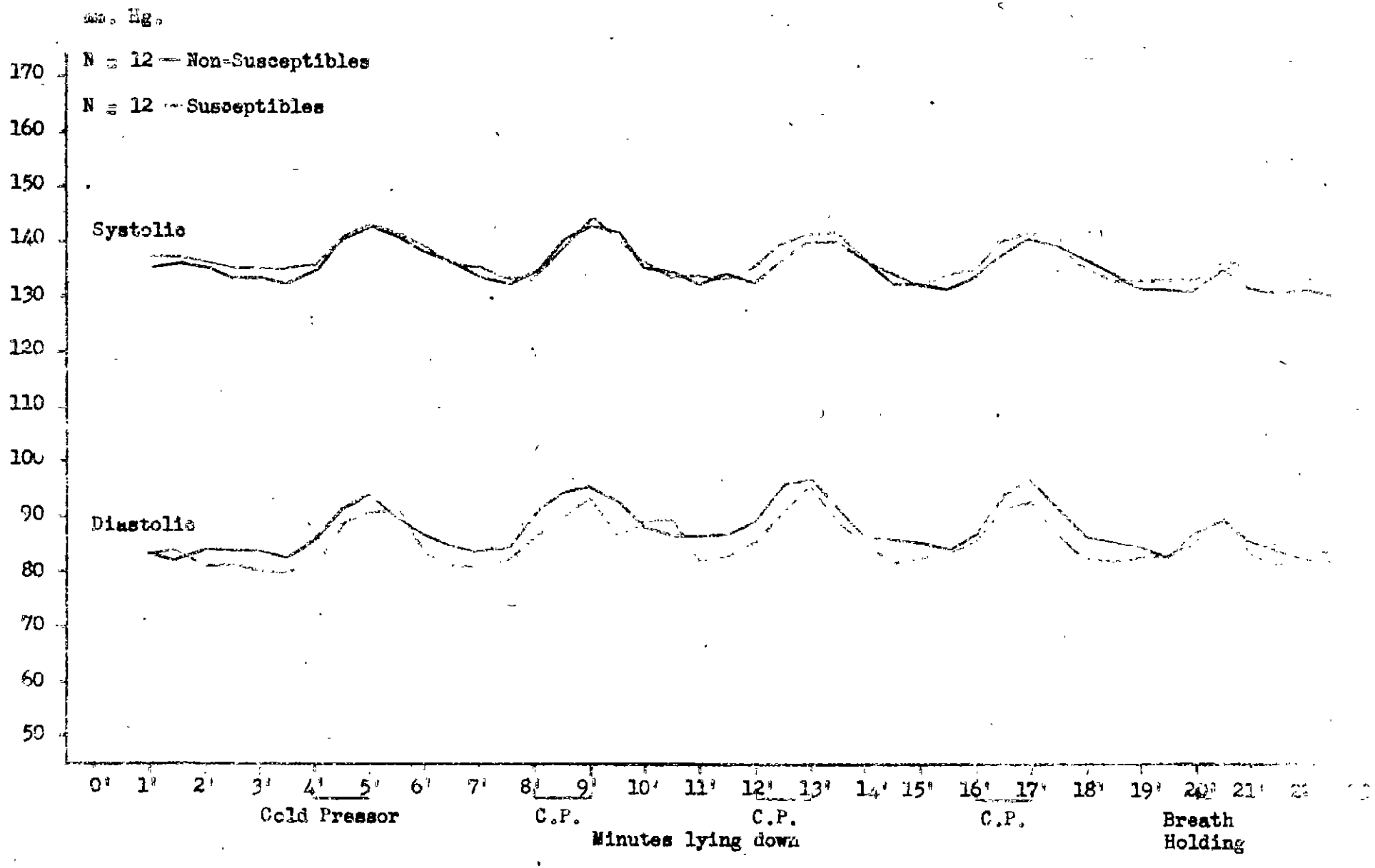

FIGURE 1

BLOOD PRESSURE CURVES (Cold Pressor Test)

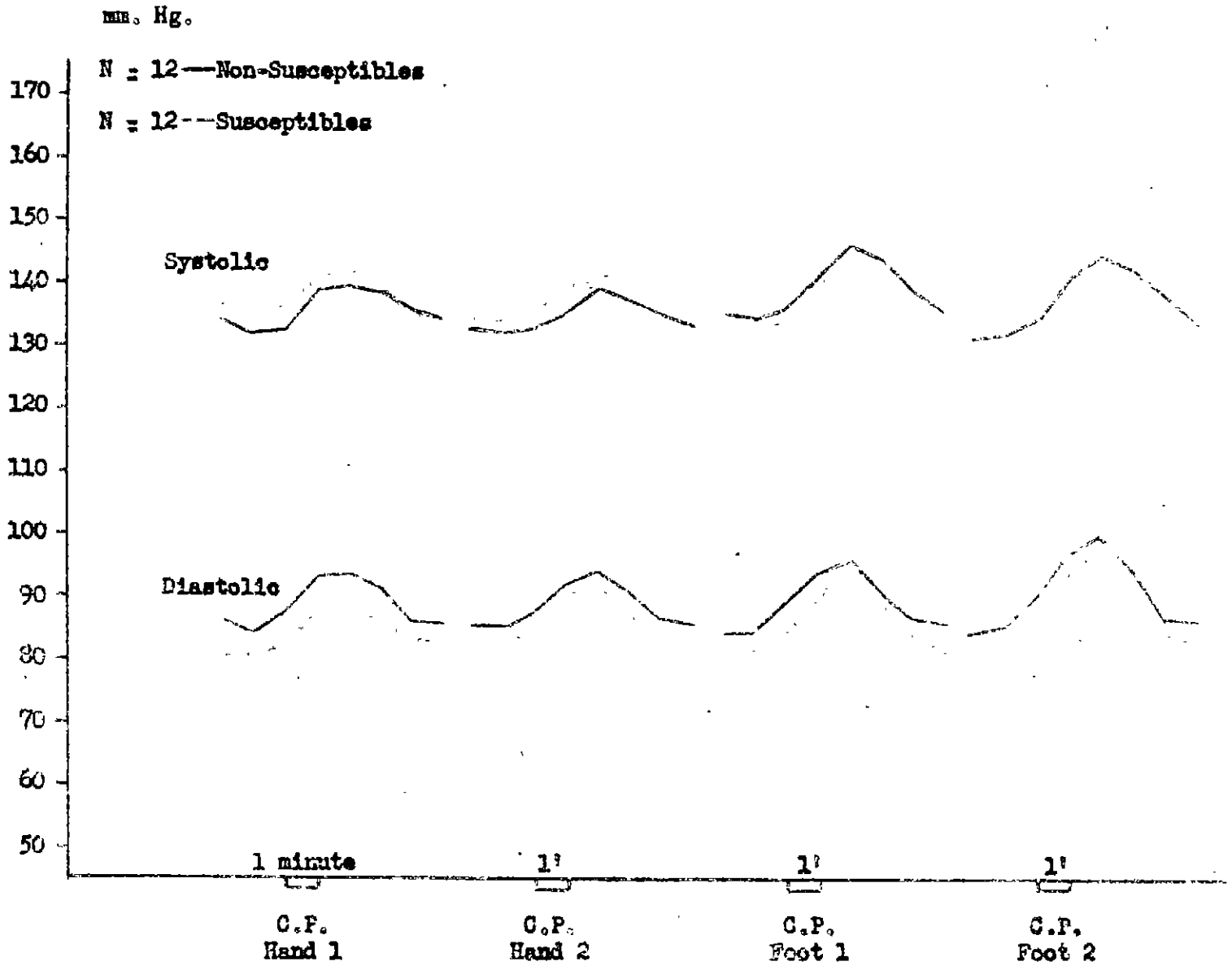

FIGURE 2

BLOOD PRESSURE CURVES (Cold Pressor Test)

TABLE 1

MAXIMUM BLOOD PRESSURE RISES
(Cold Pressor Tests)

	$Hand_1$		$Hand_2$		$Foot_1$		$Foot_2$	
Subject	Sys.	Dias.	Sys.	Dias.	Sys.	Dias.	Sys.	Dias.
Non-Susceptible								
1	8	6	4.7	6.7	6	4.7	11.3	5
2	10	15.3	8.7	6.7	5.3	12.7	11.3	16
3	19.7	26	20.7	28.7	31.3	28	31.3	39.3
4	6	6.7	8	12	12	12	12.7	9.3
5	8.7	12	9.3	11.3	5.3	10	18.7	21.3
6	8.7	8	6	14	8.7	14	10.7	12.7
7	13.3	13.3	13.3	17.3	32.7	31.3	18.7	22
8	5.3	7.3	6.7	4	12	14.7	18	19.3
9	3.3	10	6.7	14	6	9.3	8.7	18
10	10.7	16.7	7.3	7.3	19.3	8.7	15.3	6
11	1.3	10.7	2	14	11.3	12.7	6.7	14
12	3.3	- 2 *	5.3	9.3	5.3	10.7	4	18.7
Av. rise	8.2	10.9	8.2	12.1	12.9	14	13.9	16.8
Susceptible								
13	0	10.7	5.3	15.3	6	16	2.7	10
14	10.7	6.7	8	10.7	21.3	20	22	27.3
15	4.7	5.3	2.7	14.7	18	17.3	10.7	31.3
16	.7	7	8.7	- 4 *	10.7	6	8.7	- 4 *
17	6.7	20	1.3	8	9.3	10.7	8.7	4.7
18	6.7	6.7	2.7	5.3	15.3	14.7	10.7	24.7
19	8	6	13.3	4.7	8.7	12.7	15.3	10.7
20	7.3	4.7	6	6	10	15.3	15.3	12.7
21	3.3	8.7	4.7	6	8.7	9.3	8.7	10
22	14	17.3	15.3	18	7.3	14.7	16.3	22.7
23	17.3	13.3	14	12.7	12.7	21.3	8	10
24	12	12	20.7	22.7	22	22	25.3	18.7
Av. rise	7.6	9.9	8.5	10.3	12.5	14.9	12.7	15.2
Total group Av.	7.9	10.4	8.35	11.2	12.7	14.45	13.3	16

*All minus quantities are treated as 0's in determining average rises.

d. The data were rearranged to see whether successive stimulations of the hand or foot gave greater reaction than when a stimulation of one member was separated before its second trial by stimulation of the other member. The systolic/diastolic rises are as follows: hand following hand, 9.0/10.8; hand following foot, 7.8/11.3; foot following foot, 13.6/15.5; foot following hand, 17.6/16.2. Inspection of these figures shows that in three cases pressure rises were less when the same member was re-stimulated on the next trial, while in one case the pressure rise was greater.

e. The test-retest reliabilities of the cold pressor test evaluated in terms of the maximum blood pressure rises are shown in Table 2. These reliabilities are considerably higher than are obtained with many other types of circulatory measures but are not high enough to justify putting high reliance on this test for purposes of individual diagnosis. It should, of course, be recalled that these were derived from only 24 subjects selected from a homogeneous healthy population.

TABLE 2

TEST-RETEST RELIABILITIES OF COLD PRESSOR TESTS
(N = 24)

	Systolic	Diastolic
$hand_1$ vs. $hand_2$	.76	.57
$foot_1$ vs. $foot_2$	.43	.59
$hand_{1\&2}$ vs. $foot_{1\&2}$	.68	.56

2. Pulse rates during cold stimulation. The pulse rates were counted in 20-second intervals directly from the photokymographic records of each subject. The obtained frequencies were then plotted on graphs similar to those prepared for blood pressure readings. Group averages for the susceptibles and non-susceptibles were obtained by direct averaging of readings. This could be done because the measurements were made on identical time intervals. Figures 3 and 4 show the data obtained from these analyses, the first showing sequential readings during the experimental period, the second showing pulse rate changes during the two stimulations of the hand and during the two stimulations of the foot. The results appear to be as follows:

a. The resting pulse rates were higher for the non-susceptibles. This may be regarded as a chance finding in as much as it reverses the situation more commonly found with such groups of subjects.

b. Comparison of the shift from lowest to highest mean pulse rate during the four cold pressor cycles shows that in each case the change in

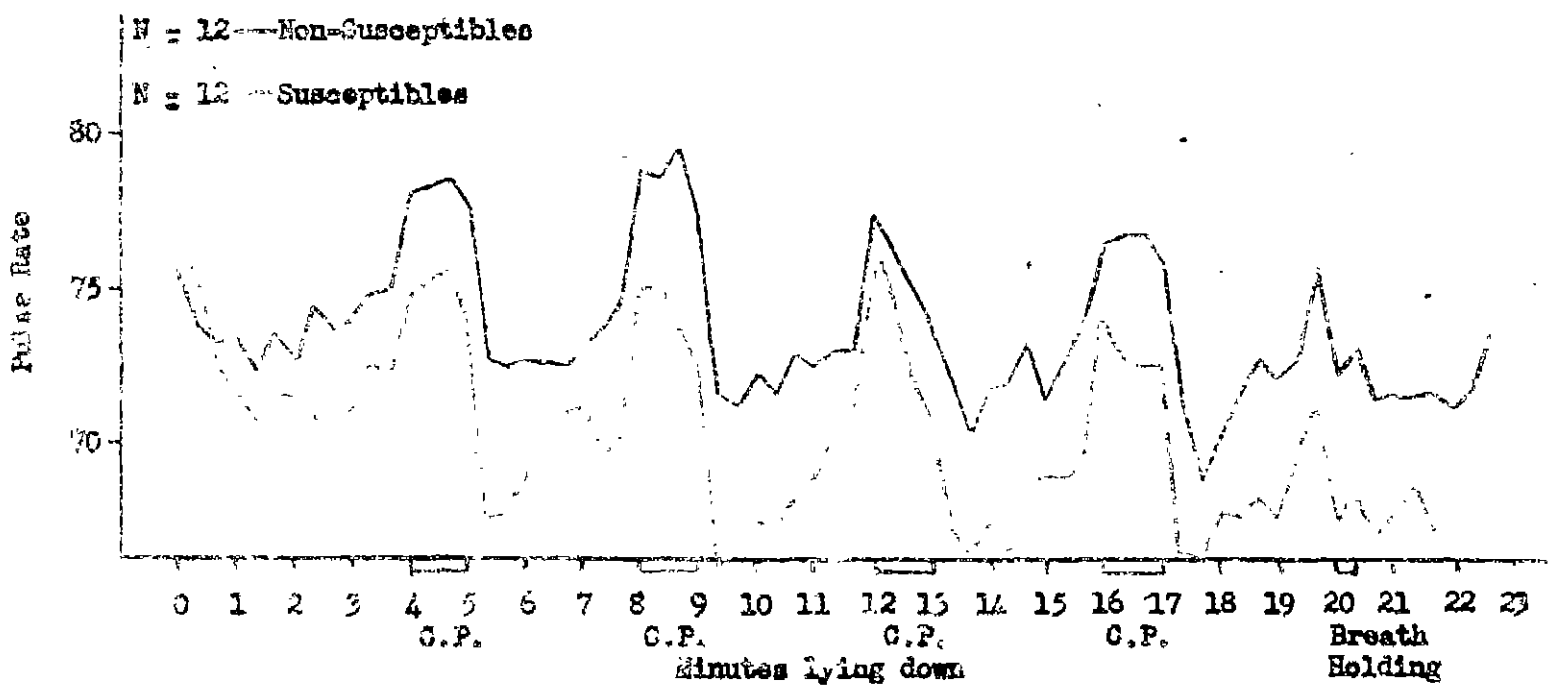

FIGURE 3

PULSE RATE CURVES (Cold Pressor Test)

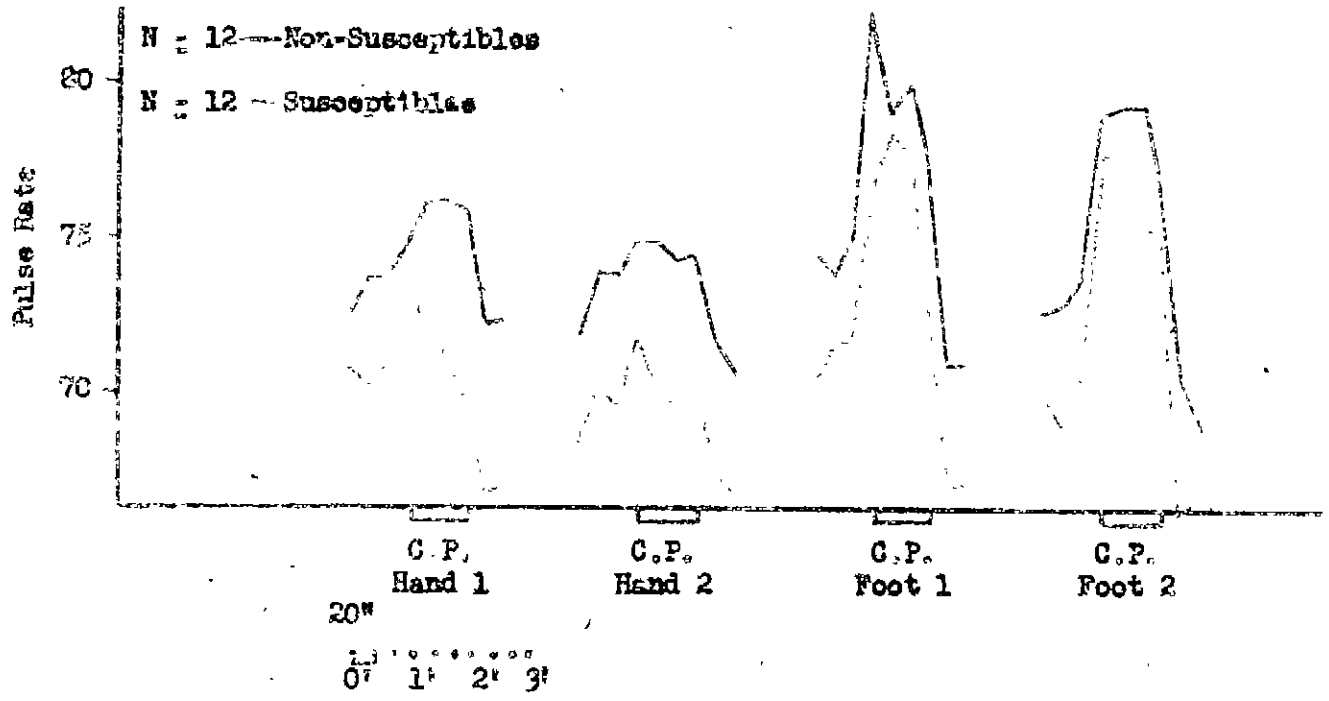

FIGURE 4

PULSE RATE CURVES (Cold Pressor Test)

the susceptible group was greater than in the non-susceptible group. However, in view of the rather large difference in base lines one cannot safely conclude that this represents a greater reactivity on the part of the susceptibles.

c. Inspection of the curves in Figure 4 shows a considerably greater increase in pulse rate after stimulation of the foot than stimulation of the hand. The pulse rate rise was approximately 2.5 beats per minute in the case of the hand and 7.5 in the case of the foot.

3. Breathing rates. Respiration rates were measured in 20-second intervals and the average curves for susceptibles and non-susceptibles plotted. Figures 5 and 6 show the obtained results according to the same methods used in the case of blood pressures and pulse rates. It may be noted by inspection that the susceptibles showed a faster mean breathing rate and that their average curve showed fewer variations correlated with the stimulation.[7] The response to immersion of the foot was somewhat greater than that to immersion of the hand.

4. Subjective ranking of relative pain. At the end of the experiment each subject was asked to rank the painfulness of the four stimuli from 1 to 4. Ten of the subjects gave such rankings from 1 to 4, while fourteen indicated that they could not distinguish between the two hand stimulations or the two foot stimulations or other pairs. Every subject, however, found at least two levels of painfulness. The mean rank order of the four stimulations was as follows: the second immersion of the foot had a mean rank of 1.6; the first of the foot, 1.9; the first of the hand, 3.1; and the second of the hand, 3.3. It may be seen that the stimulation of the foot was definitely more painful than the stimulation of the hand. This fact may be correlated with the greater changes in blood pressure, pulse rate, and breathing following stimulation of the foot. Further analysis of the data in order to discover whether the amount of pain resulting from a stimulus was correlated with the extent of blood pressure change was unsuccessful in revealing such a correlation. Pain rank and blood pressure were compared for the two hand stimulations as a pair and the two foot stimulations as a pair. This showed about as many cases of disagreement as agreement. Furthermore, although fourteen subjects reported inability to distinguish the pain between some of the stimulations there were nevertheless marked differences in blood pressure reactions.

B. Breath holding test. The results of the breath holding test will be but briefly presented because the data lack completeness. In the absence of a repeat measure showing reliability it is not possible to give an adequate interpretation of the obtained results. Furthermore, since the systolic blood pressure readings were taken only about ten seconds after breath holding began, the techniques were not the same as those established by the original investigators.

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[7] No measures of breathing amplitude were made. Also there was such irregularity in the breathing rate records that it did not seem worthwhile to subject them to an extensive analysis.

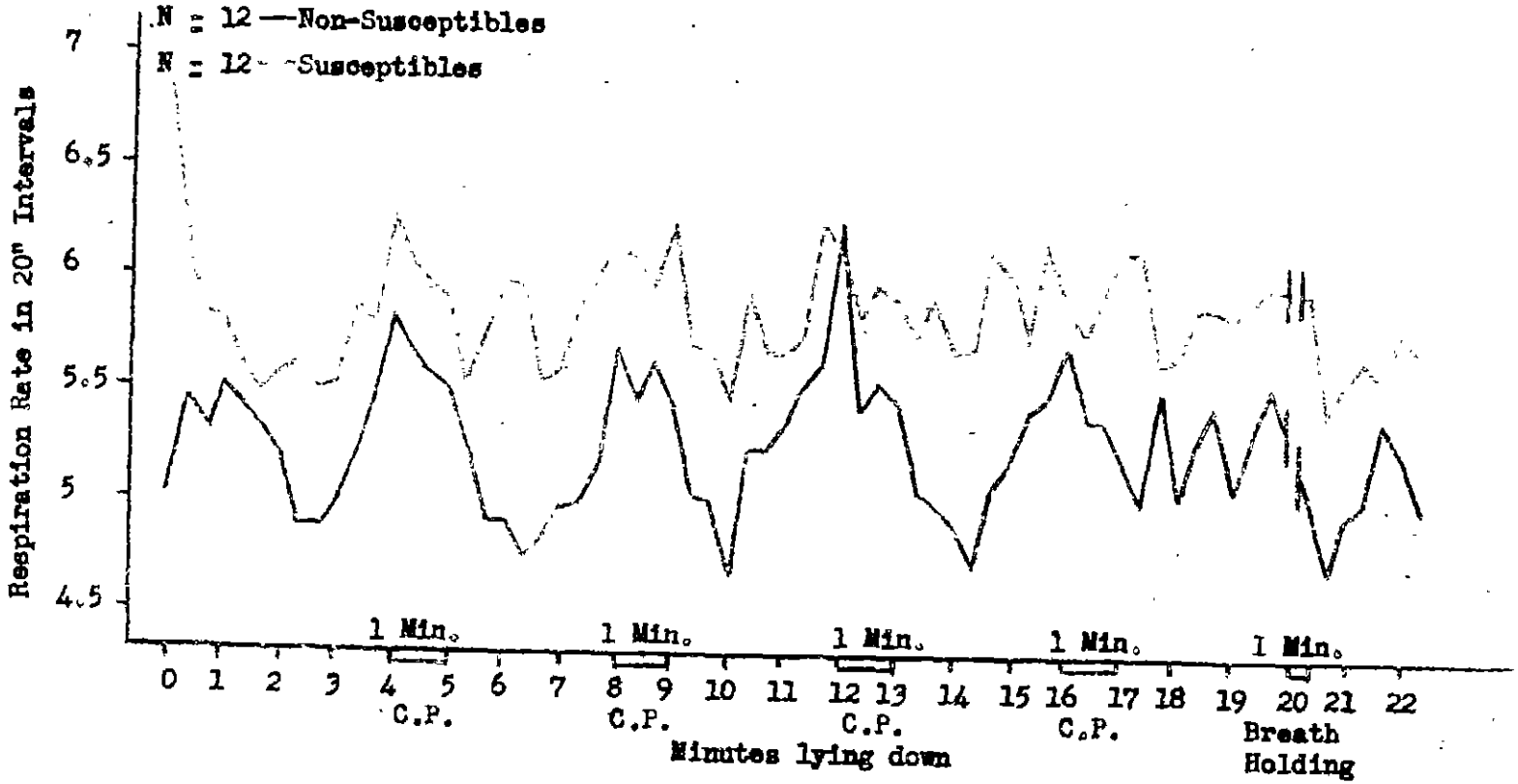

FIGURE 5

BREATHING RATE (Cold Pressor Test)

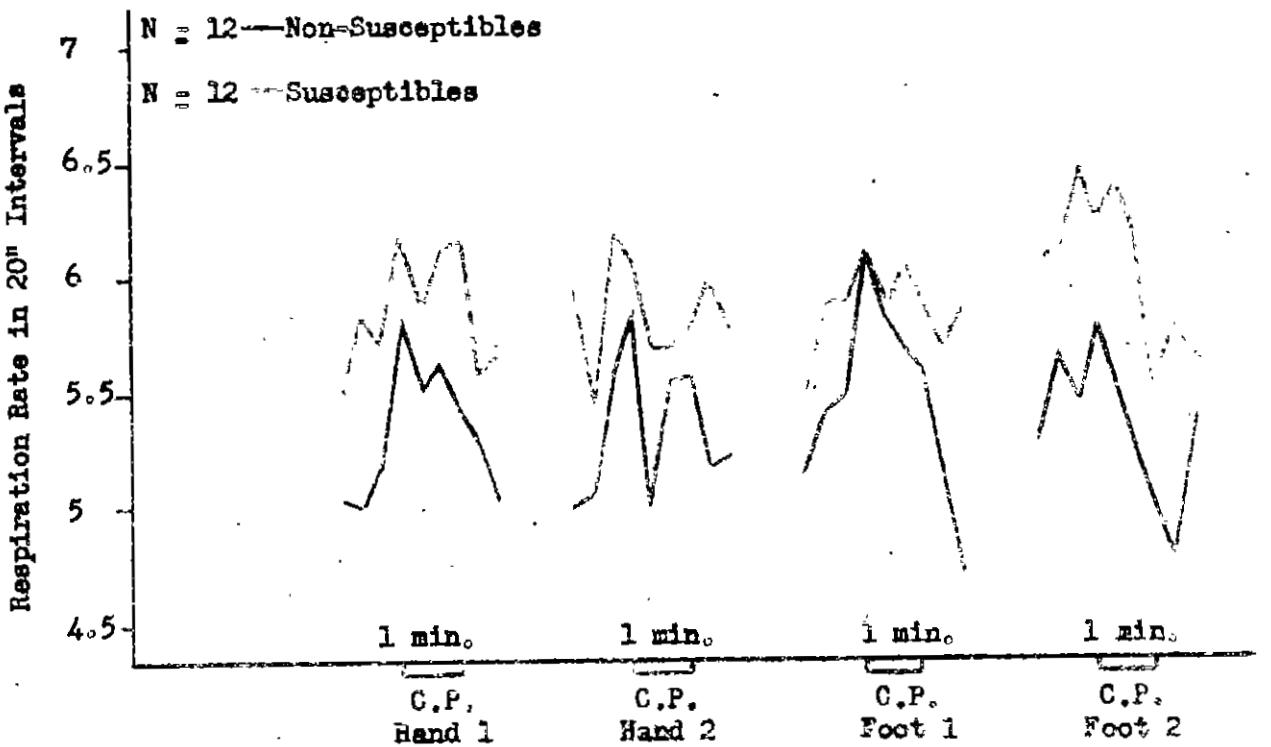

FIGURE 6

BREATHING RATE (Cold Pressor Test)

It was apparent that blood pressure and pulse rate changes in response to breath holding were small. The main rise in pulse rate associated with the breath holding test came before the test and must, therefore, be considered the result of expectation. There were no evident differences in the responsiveness of susceptibles and non-susceptibles as judged by inspection of blood pressures and pulse rate curves. The results with breathing rates were comparable to those with the cold pressor test.

Previous investigators have regarded the breath holding test as being wholly equivalent to the cold pressor test. This finding was not confirmed. The Pearson product-moment correlation coefficients of blood pressure changes during breath holding and cold stimulation (average of both responses to immersions of the hand) were r = .10 for systolic pressure rises and r = .19 for diastolic pressure rises. These results do not encourage one to regard these two tests as measuring the same thing. However, in the absence of a breath holding test reliability determination there is no sure way of judging whether this result was due to the method or due to the lack of a physiological relationship. The absence of large pulse rate changes in the subjects indicates, however, that the holding of the breath was without significant circulatory effect.

INTERPRETATION

The present subjects were selected from a group susceptible to motion sickness and from a group non-susceptible to motion sickness in order to test the hypothesis that motion sickness is a consequence of vasomotor instability. They were then compared according to their reaction to tests commonly accepted as being measures of such instability. The obtained results showed no reliable differences in their reactivity, the actual difference being slightly in a direction opposite to that predicted by the hypothesis. In order for the results of this investigation to be positive it would have been necessary to obtain an almost complete lack of overlap in the reactions of the two groups. It may therefore be concluded that, to the extent that these tests are valid measures of vasomotor instability, motion sickness susceptibility is not a result of vasomotor instability.

Subsidiary results on reliability of the cold pressor test and on the relationship of the breath holding test to the cold pressor test indicate a need for further experimentation in this field. In view of certain changes in technique made by the authors in the interests of experimental design, the interpretation of the differences between these studies and those of earlier investigations should await further experimental work.

STUDIES IN MOTION SICKNESS

Series C

II

EXPERIMENTAL COMPARISON OF VARIOUS AUTONOMIC RESPONSES IN INDIVIDUALS SUSCEPTIBLE AND NON-SUSCEPTIBLE TO MOTION SICKNESS

by

S. J. Alexander
J. S. Helmick
J. H. Taylor
C. R. Wendt

SUMMARY

This is one of a series of studies in which certain physiological reactions in individuals susceptible and non-susceptible to motion sickness were compared experimentally. In the present experiment five susceptibles and five non-susceptibles served as subjects on each of six days during which their reactions to epinephrine (adrenaline), to acetyl-beta-methylcholine (mecholyl), to hyperventilation, to breath holding, and to immersion of the foot in ice water were studied. The experiment constituted an indirect approach to the problems of whether susceptibility is a matter of blood chemistry, of abnormal sensitivity to one or another of the substances released at autonomic nerve endings, or of vasomotor instability.

All of the measures employed in this study have been used by the authors and other investigators in previous or subsequent studies. For this reason it seems wise to withhold conclusions about the present data and to refrain from presentation of reliabilities of differences, since the results of all studies taken together are negative for each of the measures employed. The data available from the present study for comparison of susceptibles and non-susceptibles are as follows: resting respiration, blood pressures, pulse rate, perspiration and salivation; response of the same variables to mecholyl and to adrenaline, and response of the circulatory and respiratory measures to immersion of the foot in ice water, to breath holding for twenty seconds, and to hyperventilation for three minutes. Various observational data such as dermographia, abdominal noises, etc., were recorded but none yielded data which were methodologically adequate for use.

EXPERIMENTAL COMPARISON OF VARIOUS AUTONOMIC RESPONSES IN INDIVIDUALS SUSCEPTIBLE AND NON-SUSCEPTIBLE TO MOTION SICKNESS

INTRODUCTION

This study is one of a number undertaken to explore the physiological correlates of motion-sickness susceptibility. Other researches in the area of motion sickness carried out in the Wesleyan laboratory under the auspices of the Committee on Selection and Training of Aircraft Pilots have been reported.[1]

In the present experiment susceptible and non-susceptible subjects were selected from the extremes of the population to see whether they tended to be distinct groups in respect to certain physiological conditions. An attempt was made to test a variety of hypotheses concerning the relationship of the autonomic nervous system to susceptibility, of blood chemistry to susceptibility, and of vasomotor instability to susceptibility. Adrenaline and mecholyl were used to test whether susceptibles tend to be abnormally sensitive to one or the other of these autonomic substances. Mecholyl, it may be recalled, is a drug very similar in its physiological effects to acetylcholine, which is the substance produced at certain autonomic nerve endings. Hyperventilation and breath holding vary the CO_2 content of the blood, and the possibility of this factor being related to motion-sickness susceptibility was investigated. The cold pressor test[2] was used in an attempt to determine vasomotor instability which has been considered also as a possible condition of susceptibility.

PROCEDURES

A. General description. Each subject went through six sessions at one-week intervals, each session being 45 minutes long. Continuous records of respiration and pulse were taken and intermittent measurements made of blood pressures, sweating, and salivation. At intervals during each session a test was made of response to immersion of the foot in ice water, to breath holding and to hyperventilation. During two sessions an injection of mecholyl was made and during four sessions an injection of adrenaline.

B. Records taken. Three kinds of records were taken, continuous photokymographic records, intermittent measurements and intermittent clinical

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[1] See: Wendt, G. R. Motion sickness in aviation. NRC Division of Anthropology and Psychology, Committee on Selection and Training of Aircraft Pilots, May 1944. Wendt, G. R. Studies in motion sickness. Series A. Washington, D. C.: CAA Division of Research, Report No. 40, December 1944. Wendt, G. R. Studies in motion sickness. Series B. Washington, D. C.: CAA Division of Research, Report No. 60, April 1946.

[2] This test was described in the first report of Series C.

observations.

1. Photokymographic records.

a. Respiration. A respiration record from the chest was made with a Byrd Company pneumograph (which offers relatively slight resistance to breathing), operating a pneumatic tambour with a mirror on the diaphragm.

b. Pulse rate and vasoconstriction. A metal tube was slipped over one finger and the pulse variation recorded from a mirror-bearing tambour. A small leak in the system filtered out volume changes, making this a measure of pulse amplitude and pulse rate.

c. Blood pressures. In order to synchronize the intermittent measurements with the photokymographic records a record of the pressure in the blood pressure cuff was taken. In order to get an indication of the time when the systolic blood pressure reading was taken a pulse record was made from a secondary cuff attached to the wrist below the pressure cuff.

d. Signal marker. This was used to indicate onset and cessation of stimuli and for synchronizing the experimenter's notes with the photokymographic record.

2. Intermittent records.

a. Blood pressures. Systolic and diastolic pressures were determined by the auscultatory method. Before, during, and immediately after stimulation periods these were made at approximately 30-second intervals. During relatively quiet periods they were made at about one-minute intervals.

b. Sweating. Sweat production on the forehead and axilla were measured by placing a two-inch square gauze pad for four minutes on the forehead and at the axilla. These were weighed on a Jolly balance before and after application to determine the total weight of moisture retained. This procedure has an obvious defect. It is probably not proper to compare individuals on the basis of a particular population of sweat glands found on the region of the forehead or axilla tested.

c. Salivation. A rough indication of salivary production was obtained by placing a dental absorbent roll under the tongue and weighing it before and after it had been in place for 30 seconds. It is questionable whether this technique has sufficient reliability for present purposes in as much as it samples far too short a time period and probably does not measure faithfully the production during that period.

d. Various other measures and observations were made as follows: mouth temperature by the ordinary clinical thermometer, heart sounds, and abdominal noises by auscultation, skin color and shivering by observation, and skin flare after stroking by observation. Subjective reports were also recorded.

C. Order of procedure. When the subject arrived, he removed his clothes and lay supine on a mattress. He was partially covered by a sheet. Five minutes were spent in getting a report concerning his conduct during the day and the day before, and two minutes on making various observations of skin color, abdominal noises, etc.

When the subject had been lying quietly for at least seven minutes, the photokymographic records were started. At the same time blood pressure records were begun. The following table shows the sequence of stimuli thereafter:

Time	Order of Procedure
7'	- start records.
9'	- place foot in ice water up to ankle for one minute.
12'40"	- hold breath in expiration for 20".
15'-17'	- rest period without records or observations.
17'	- start records.
17'-21'	- gauze pad on forehead.
17'30"-21'30"	- gauze pad at axilla.
20'-21'30"	- gauze roll under tongue.
22'	- inject mecholyl or adrenaline.
28'-28'30"	- gauze roll under tongue.
30'-34'	- gauze pad on forehead.
30'30"-34'30"	- gauze pad at axilla.
31'-31'30"	- gauze roll under tongue.
35'-35'30"	- gauze roll under tongue.
39'-42'	- hyperventilate 30 times per minute.
45'	- end of session.

To make this procedure run smoothly required the continuous services of three experimenters.

D. Drug schedule. The following table shows the drug schedule used:

Week 1 - subcutaneous mecholyl, 1 mgm. per 25 lbs. body weight.
Week 2 - subcutaneous adrenaline, 0.1 cc. of 1:1000 solution for each 50 lbs. of body weight.
Week 3 - subcutaneous mecholyl, dosage as for week one.
Week 4 - intramuscular adrenaline, dosage as for week two. (The results of week two had shown that subcutaneous adrenaline took effect too slowly and irregularly to constitute a good experimental procedure. The same thing occurred with intramuscular adrenaline so that for the subsequent weeks intravenous injection was used.)
Week 5 - intravenous adrenaline, 0.1 cc. of 1:10,000 solution for each 50 lbs. of body weight.
Week 6 - adrenaline as during week 5.

E. Other experimental conditions. The experiments were done between 4 and 6:30 P.M. It should be noted that the subjects were presumably hungry at this time and some of the results may have been affected by this factor. The room was dark and quiet. It had no special temperature control, so

that the room temperatures varied from 73-81° F. Relative humidity was always below 60%. The experiment was conducted during April, May, and June of 1941.

F. Subjects. The subjects selected were five people with a history of susceptibility to motion sickness dating back to childhood and being still present, and five people with a history of complete freedom from motion sickness. The subjects had medical records which showed good health and underwent a general physical examination immediately before the beginning of the experiment.

Since physiological measures of the kind here used are considerably affected by nervousness about experimental procedures, considerable trouble to reduce this factor was taken. All of the subjects had served in at least three other experiments in the same program and most had served in at least four. Each had also been interviewed twice in the laboratory, had undergone physical examination at the hands of one of the experimenters, and had received a hypodermic injection of saline solution to reduce apprehension about this matter. The subjects received fifty cents for each session and a bonus of ten dollars if they completed the six sessions according to the rules set up.

The subjects were required to regulate their sleeping, eating, drinking, smoking, coffee intake, exercise and activity according to a set of rules prescribed by the experimenters. Their health was checked each week before the experiment began.

RESULTS

A considerable proportion of the data gathered on these subjects will not be presented for a variety of reasons. The data from the respiratory tracings and from pulse amplitude as recorded from the finger have not been measured. In view of the generally negative results of this series of experiments it does not seem worthwhile to undertake these tasks. Certain other data were not measured or were rejected because of inadequacies of method, obvious inconsistencies in the response of the subjects from week to week, or unavoidable incompleteness of the records. Among these data are the records of forehead sweating, mouth temperatures, flare tests, the subjective reports, most of the clinical observations, and most of the measures after use of adrenaline and during hyperventilation. Some of these will be commented on below. Certain other data from this study which have been tabulated by the experimenters are not presented.[3] Particular attention is drawn to individual curves of blood pressures and pulse rates for each subject during each session.

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[3] Detailed procedures and unpublished data from this study are on microfilm in the files of the Committee on Selection and Training of Aircraft Pilots.

A. Resting records. Table 1 below shows for each subject the resting blood pressures, pulse rate, salivary production, and recorded sweat production from the axilla. The blood pressures and pulse rates show the base line obtained from the seventeenth to the twenty-first minutes. Salivary production is in grams of saliva soaked up by the dental roll during the test made at the twentieth minute. Sweat production is the similar measure beginning during the seventeenth minute. It will be observed that the measures taken from susceptibles and non-susceptibles overlap considerably in all distributions. It may, therefore, be stated that these data do not give support to a conclusion that the two groups of subjects differ in these respects.

TABLE 1

MEAN RESTING MEASURES (SIX SESSIONS)

Subject	Systolic blood pressure	Diastolic blood pressure	Pulse rate	Salivation (grams)	Axillary sweat (grams)
Susceptibles					
1	115	74	65	1.42	.09
2	140	75	67	.73	.28
3	130	86	87	.93	1.32
4	115	77	64	.38	.78
5	115	76	69	.80	.13
Mean	123	77.6	70	.85	.51
Non-Susceptibles					
6	124	77	71	1.12	.29
7	110	73	53	1.81	.17
8	122	78	68	.45	.38
9	140	78	70	.47	.84
10	127	66	63	2.53	.80
Mean	124.6	74	65	1.28	.49

B. Response to mecholyl. The data from individual subjects showing various physiological responses to subcutaneous mecholyl are presented in Table 2, where changes in blood pressures, pulse rates, sweating, and salivation are shown for Week 1 and Week 3 when mecholyl was injected. The figures shown in the case of blood pressures represent the change from the base line during the seventeenth to twenty-first minutes to the lowest recorded blood pressure during the four minutes following the injection. Pulse rate changes were determined from the same base period to the highest recorded rate. It may be noted that these figures would be changed somewhat if average pressures and average rates after mecholyl were computed. The figures for axillary sweating show the change between the normal record taken beginning at seventeen minutes and the record after mecholyl taken beginning with the

thirtieth minute. Salivary changes represent the average increase during the first three tests following the injection as compared with the test before injection. The fourth test was omitted because of incompleteness of records.

The response to mecholyl in all subjects was lowered systolic and diastolic blood pressure and increased pulse rate. All subjects also showed sweating and salivation according to clinical observations and subjective reports, but the recorded measures in a few instances fail to reveal this. These inconsistencies are attributed to the defects of the recording methods.

TABLE 2

RESPONSE TO MECHOLYL

Susceptibles Subjects	Blood pressure drop (Week 1)	Blood pressure drop (Week 3)	Pulse rate increase (Week 1)	Pulse rate increase (Week 3)	Axillary sweat grams increase (Week 1)	Axillary sweat grams increase (Week 3)	Salivary output, grams increase (Week 1)	Salivary output, grams increase (Week 3)
1	- 7/-12	- 5/-12	+20	+28	0	+0.2	+1.23	+1.8
2	-15/-14	-20/-24	+ 3	+14	+1.1	+0.1	+0.17	+3.33
3	-12/-27	-12/-13	+24	+20	+1.3	+0.5	+0.20	+2.53
4	-16/-18	-15/-16	+24	+26	+1.0	+0.2	+0.12	+0.23
5	- 4/- 9	-16/-14	+13	+23	+0.1	+0.4	+0.43	+4.23
Mean	-10.8/-16	-13.6/-15.8	+16.8	+22	+0.70	+0.28	+0.18	+2.42
Non-Susceptibles								
6	- 7/-13	-14/-12	+39	+25	+1.75	+0.2	+2.23	+3.93
7	- 6/- 9	-18/- 8	+28	+48	+0.5	+1.2	+1.23	+8.73
8	- 5/-23	-15/-32	+50	+43	+0.4	+2.9	+2.37	+5.70
9	-20/-30	-18/-27	+30	+53	+0.6	+0.9	+2.63	+7.07
10	- 3/-16	-20/-25	+23	+27	+0.1	-0.2	+3.77	+5.73
Mean	- 8/-18	-17/-20.8	+34	+39	+0.67	+1.00	+2.45	+6.23

In the case of each measure except axillary sweating the recorded response in the third week was on the average greater than during the first week. This same result was later obtained in another investigation. It may presumably be attributed to a neutralization of the effects of mecholyl during the first week by apprehension on the part of the subject.

By inspection it is evident that the distributions of the decreases in blood pressure in susceptibles and non-susceptibles are overlapping. The mean changes are roughly similar. On the other hand, the mean pulse rate increases among the non-susceptibles were almost twice those recorded from

the susceptibles. If one takes the average pulse rate changes of both weeks, it is evident that the highest increase among the susceptibles was 25, which is the same as the least increase among the non-susceptibles. However, in view of the failure to confirm this result in a later experiment it should not be taken as an indication of difference between the groups.

Measures of sweating and salivation show larger response for the non-susceptibles, except for axillary sweating during week 1 in which the two groups are equal. In view of the defects of these records and failure to confirm the result in a later experiment this cannot be regarded as established.

C. Effects of adrenaline. Four sessions were run for each subject during which adrenaline was injected. The first two of these were rejected from the data because subcutaneous and intramuscular injection proved to be ineffective in eliciting large physiological changes. After intravenous injection there was a very large systolic blood pressure change which was, however, so extremely rapid that one can have no assurance that the serial auscultatory method recorded the actual highest point. The peak systolic pressure was ordinarily reached during the first minute with a total duration of pressure increase rarely running as long as three minutes. The most common response of the diastolic pressure was a transient increase in pressure followed by a fall. Table 3 shows the maximum recorded increases in systolic and diastolic pressures by comparison of the seventeen to twenty-one minute base line with the peak pressure in the first two minutes following the injection. The data are shown separately for Week 5 and Week 6. It is evident to inspection that the distributions of susceptibles and non-susceptibles are similar.

TABLE 3

RESPONSE TO ADRENALINE

Subjects	Blood pressure rises (Week 5)	Blood pressure rises (Week 6)
Susceptibles		
1	+54/+17	+55/+25
2	+46/+29	+74/+30
3	+24/+ 8	+42/ 0
4	+30/+10	+20/+10
5	+72/+ 7	+84/+20
Mean	+45/+14	+55/+17
Non-Susceptibles		
6	+45/+16	+42/+ 8
7	+50/+ 9	+45/ 0
8	+54/+12	+68/+10
9	+58/+ 7	+58/ 0
10	+70/+10	+70/+12
Mean	[illegible]	[illegible]

Pulse rates after intravenous adrenaline show rapid shifts under the initial action of the drug which are complicated by the reflex effects of increased blood pressure. The average curves showed a transient increase lasting about one minute, followed by a decrease lasting about three minutes. The mean initial increase for susceptibles and non-susceptibles respectively were 7 and 20 beats per minute during Week 5, and 14 and 21 beats per minute during Week 6. These mean increases are taken from the average summated curves of each group of subjects rather than from the individual maximal points.

D. Cold pressor test. The effects of immersion of the foot in ice water on the systolic and diastolic peak blood pressure rises are shown in Table 4 for each subject for each week, along with subject averages and weekly averages of all subjects. The increases shown are those from the base line in the four minutes preceding the test when compared with the peak points in the two minutes after the beginning of the test. The systolic pressure rises in the two groups, while showing some mean difference, overlap in their distributions. In the case of diastolic pressures there is also a difference of means with considerable overlap. In both systolic and diastolic pressures the mean rise was greater in the non-susceptibles.

TABLE 4

COLD PRESSOR TESTS
SYSTOLIC AND DIASTOLIC PRESSURE RISES
FOR EACH OF SIX SESSIONS

Susceptibles							
Subjects	1	2	3	4	5	6	Averages
1	15/31	14/20	13/18	20/23	10/15	0/6	12.0/18.8
2	5/ 8	4/ 4	5/ 0	4/ 3	4/ 8	4/5	4.3/ 4.6
3	20/28	30/33	22/31	19/38	25/21	15/27	21.8/29.6
4	6/10	7/15	5/ 3	0/ 5	6/ 6	4/2	4.7/ 6.8
5	20/ 8	12/10	2/ 8	5/ 5	9/15	0/4	6.5/ 8.3
Averages	13.2/17	13.4/16.4	9.4/12	9.6/14.8	9/13	4.6/8.8	9.9/13.6
Non-Susceptibles							
6	17/36	30/50	38/52	26/60	32/50	20/45	27.2/48.8
7	20/16	22/18	16/16	20/30	22/20	12/23	18.7/20.5
8	14/14	6/16	10/14	10/17	5/ 8	0/11	7.5/13.3
9	20/15	15/36	26/30	30/42	20/21	14/35	20.8/29.8
10	14/23	14/ 7	8/ 8	5/11	10/10	6/10	9.5/11.5
Averages	17/20.8	17.4/25.4	19.6/24	18.2/32	17.8/21.8	10.4/24.8	16.7/24.7
	15.1/18.9	15.4/20.9	14.5/18	13.9/23.4	13.4/17.4	7.5/16.8	13.3/19.2

There is a suggestion in the data that the recorded peak systolic pressure rise decreased slightly during the experiment. The verification of this finding would require a more objective method of blood pressure determination than the auscultatory one.

The pulse rate changes resulting from cold stimulation were a transient increase followed by a decrease. The mean initial increase for six sessions among the susceptibles was 3 beats per minute and among the non-susceptibles 10 beats per minute, as judged by the peak point of the summated curves of each group.

E. Breath holding. The physiological consequences of breath holding as recorded in the experiment were slight. There were mean increases in systolic and diastolic blood pressures of only two to three mm. Hg. There was an anticipatory increase in pulse rate followed by pulse retardation during and after breath holding. In view of the difficulties in interpretation of such effects detailed data are not presented.

F. Hyperventilation. The results during the three minutes of over-breathing are incomplete due to difficulties of recording. Blood pressure observations were interfered with and pulse rate determinations were intermittent. During 35 of the 60 sessions a pulse rate determination was possible. These incomplete data showed a pulse increase of 40 per minute in the susceptibles and 42 per minute in the non-susceptibles.

One susceptible developed Jacksonian seizures from hyperventilation during each session for six weeks and one non-susceptible developed such a seizure during the second week. The remaining subjects developed only small muscular twitchings, stiffness of the fingers and toes, and occasional shivering. It may be noted that these data are probably defective in that they were recorded at a late hour of the afternoon when the subjects were beginning to get hungry. Variations in hour of employing subjects or in amount of food taken may be presumed to have affected the results of over-breathing.

SUMMARY

In this study five subjects susceptible to motion sickness and five non-susceptible to motion sickness were selected from the extremes of the population to determine if they tended to be distinct groups in respect to certain physiological conditions. The reactions of the two groups to adrenaline, to mecholyl, to hyperventilation, to breath holding, and to immersion of the foot in ice water were studied. This was an attempt to determine indirectly if motion sickness susceptibility was a matter of blood chemistry, of abnormal sensitivity to one or another of the substances released at autonomic nerve endings, or of vasomotor instability. Real differences between the two groups in terms of the variables investigated were not evident.

STUDIES IN MOTION SICKNESS

Series C

III

A SECOND EXPERIMENTAL COMPARISON OF AUTONOMIC RESPONSES IN INDIVIDUALS SUSCEPTIBLE AND NON-SUSCEPTIBLE TO MOTION SICKNESS

by

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SUMMARY

This is one of a series of studies in which certain physiological reactions in individuals susceptible and non-susceptible to motion sickness were compared. It differed from previous studies in that experimental conditions were more carefully controlled, more objective recording of responses was employed, and certain new measures were investigated. Eleven susceptibles and twelve non-susceptibles served as subjects on each of two days during which the following were studied: dermographia, cold pressor test, breath holding test with positive and then with negative pressure, reaction to injection of mecholyl, and reaction to tilt on the tilt table. Data on respiration, pulse rate, variability of pulse duration, blood pressure, skin temperature, forehead sweating and salivation were recorded. The findings presented include means and standard deviations of response and changes in response from day 1 to day 2, test reliabilities, test intercorrelations, and differences between susceptibles and non-susceptibles. Reliabilities and intercorrelations are in many respects lower than would be expected from tests so commonly used clinically. None of the measures served to distinguish between susceptibles and non-susceptibles, either as single tests or as a whole, with the possible exception of pulse duration variability and day 1 to day 2 changes from habituation to the conditions of the experiment.

A SECOND EXPERIMENTAL COMPARISON OF AUTONOMIC RESPONSES IN INDIVIDUALS SUSCEPTIBLE AND NON-SUSCEPTIBLE TO MOTION SICKNESS[1]

INTRODUCTION

This is one of a series of investigations in which various "autonomic tests" were applied to individuals susceptible to motion sickness and to those not susceptible to motion sickness. The present study was designed to repeat under more adequate control those measures which had previously given promise of revealing differences between susceptibles and non-susceptibles.

PROCEDURES[2]

A. General description. Each of 11 susceptibles and 12 non-susceptibles went through two experimental sessions consisting of approximately a half hour of rest and indoctrination followed by 40 minutes of recording. Continuous graphic records of pulse and respiration and serial graphic records of systolic and diastolic blood pressures were made while the subject lay on his back on a tilt table. At intervals during each session a test was made of reaction to skin stimulation (dermographia), reaction to immersion of the hand in ice water (cold pressor test), reaction to breath holding with increased intrapleural pressure, reaction to breath holding with decreased intrapleural pressure, reaction to a subcutaneous injection of mecholyl, and reaction to tilting to the vertical posture. Intermittent measurements were made of skin temperatures, salivary output and sweat production from the forehead.

In the following description of recording methods, procedures, experimental conditions and subjects, the same outline will be followed as in the second report of Series C in order to facilitate comparison.

B. Records taken. Three types of records were taken.

1. Photokymographic records. Respiration was recorded from the chest by means of a Byrd Company pneumograph operating a mirror-bearing tambour. Pulse was recorded by means of an inflated cuff fastened about the ankle, connected with a mirror-bearing tambour. A signal-marker was used to indicate onset and cessation of stimuli and to synchronize with separately recorded blood pressure records. The paper speed of the photokymograph was 5 inches per minute.

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[1] An earlier investigation undertaken to explore the physiological correlates of motion sickness susceptibility in the area with which this report is concerned has been described in the second study of Series C.

[2] Other details of method employed in this study are on microfilm in the files of the Committee on Selection and Training of Aircraft Pilots.

Twice during each session a 30-second period of record at 1 inch per second was taken so that individual pulse durations could be measured.

2. Serial blood pressures. Blood pressure records were made by a device designed and constructed by F. A. Webster and loaned to the experimenters.[3] This yielded a graphic determination of systolic and diastolic pressures at 30-second intervals. A pressure cuff on the upper arm was automatically inflated and slowly deflated. The pulse sounds below the cuff affected a microphone strapped to the arm. The microphone actuated a frequency-tuned amplifier the output of which operated a recording pen mounted on the end of a metal arm which indicated cuff pressure. By manipulating the amplifier frequency and output controls a point could be found which yielded a maximally sharp cut-off of the pulse at diastolic pressure. Systolic pressures were read at the first pulse sound; diastolic pressures at the final sharp drop in amplitude of pulse sounds. Systolic and diastolic readings were 5 to 20 seconds apart, depending on the magnitude of the pulse pressure.

3. Intermittent records. Sweat production was measured by applying a 2" x 4" gauze pad to the forehead and covering it with a rubber dam bandage. The weight of the pad was determined on a Jolly balance before and after application. Salivary output rate was determined by having the subject expectorate into a suction tube. Skin temperature readings were made by means of a thermocouple and galvanometer readable to the nearest 0.05° C.[4] These were taken from the tip of the tongue, the forehead, the inner aspect of the left forearm and the palm of the left hand.

C. Stimulation procedures. Observations were made of the latency and duration of red dermographia resulting from skin stimulation on the chest, using the calibrated stimulator described by Patek and Weiss.[5] The cold pressor test was applied by immersing the right hand in ice water for one minute to the level of the wrist. Breath holding tests were applied using the same water manometer with an air leak described in the first report of Series C, by means of which intrapleural pressure could be controlled. A 20-second test was made at increased positive pressure, equivalent to 3 inches of water, and another at negative pressure equivalent to 3 inches of water. Mecholyl was injected subcutaneously, 1 mgm. per 25 pounds of body weight. Reaction to postural change was studied by tilting from horizontal toward vertical through 65° and maintaining that posture for 3 minutes.

The following order shows the sequence of stimuli. Before the onset of recording, the subject spent 30 minutes in the experimental room for

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[3] No published description of this device is available.

[4] This equipment was loaned by F. K. Heiser.

[5] Patek, A., and Weiss, S. Tests of tonus of the autonomic nervous system in arterial hypertension. New England J. Med. 1931, 205, 330.

adaptation, indoctrination, and instruction in the technique of each of the tests. This was designed to reduce variability and to minimize the effects of psychological factors.

Time	Order of Procedure
0'	- start recorders and apply dermographia stimulator.
1'	- take skin temperatures.
3'-6'	- collect total salivary output.
6'20"-6'50"	- fast record of pulse durations.
8'40"-9'40"	- hand in ice water.
13'20"-13'40"	- hold breath with positive pressure.
16'20"-16'40"	- hold breath with negative pressure.
18'	- take skin temperatures
19'45"-20'15"	- fast record of pulse durations.
22'30"	- inject mecholyl.
22'50"-34'	- collect total salivary output.
23'-34'30"	- pad on forehead for measurement of sweat.
35'	- take skin temperatures.
37'-40'	- move subject to vertical posture.
40'	- end of records.

D. Other experimental conditions. The experiments were done between 3:30 and 6:00 P.M. during the period April 22 to June 25, 1942. Each subject served for two sessions. The intervals between sessions differed somewhat as follows: 3 days for two subjects, 5 days for two, 6 days for six, 7 days for nine, and 9, 10, 20, and 30 days for one each. A sound-shielded room was used. Room temperature varied from 36° to 89° F; humidity varied from 31% to 71%; for only 3 sessions was the humidity above 60%. There were three experimenters in the room throughout each session.

E. Subjects. Subjects were selected by questionnaire and interview on the basis of history of motion sickness. The susceptibles were those with a history of long standing and recent motion sickness; the non-susceptibles had histories of complete freedom from motion sickness. The subjects were in good health and underwent a general physical examination before the experiment. Fourteen susceptibles were used, but only eleven of them completed both sessions. Thirteen non-susceptibles were used, of whom twelve completed both sessions. The subjects were required to regulate their sleeping, eating, drinking, smoking, coffee intake, and activity according to a set of rules prescribed by us. Their health was checked each week before the experiment began. The subjects were given a financial reward.

RESULTS

In this experiment a large number of variables was employed. However, an exhaustive treatment of the data has not been made. The purposes of what follows will be to present (a) a statement of procedures used in working up the data, including a presentation of means and standard deviations for the entire group of subjects (N = 23), (b) a presentation of the cor-

relations between two applications of the same measures (reliability of tests), (c) a display of certain interrelationships between the measures as revealed by correlation coefficients, (d) a presentation of differences in responses of susceptibles and non-susceptibles, and (e) an attempt to find patterns of response in the two groups of subjects.

A. Procedures in analysis of results. For purposes of the presentation of results the methods of selection and combination shown below were used. Means and standard deviations of the distribution of the 23 subjects are included.

Pulse rates

1. Normal resting rate. The mean of six successive 20-second periods was taken, 17'40" to 18'40" inclusive and 21' to 21'20" inclusive. (Beats per minute.) Mean, 70.8; standard deviation, 9.2.

2. Rise during cold pressor. The highest reading during the time of cold pressor stimulation was taken and the average of the two readings preceding the cold pressor subtracted from it. Mean, 4.7; standard deviation, 3.5.

3. Drop after cold pressor. The mean of the two readings preceding the cold pressor test was subtracted from the lowest reading following the peak reached during cold pressor stimulation. Mean, 7.2; standard deviation, 4.3.

4. Anticipation of injection. The normal reading was subtracted from the highest reading immediately preceding the injection of mecholyl or following it before a noticeable drop and continued rise (due to drug). Mean, 7.5; standard deviation, 5.0.

5. Mecholyl effect. The normal reading was subtracted from the mean of the 30 periods from 24' to 33'40" inclusive. Mean, 17.0; standard deviation, 6.9.

6. Tilt effect. The mean of the six periods, 34'40" to 36'20" inclusive, was subtracted from the maximum reading following the tilt. Mean, 15.2; standard deviation, 6.6.

Blood pressures

7. Normal. The means of the ten systolic and of the ten diastolic blood pressure readings preceding the cold pressor (3'30" to 8' inclusive). Blood pressure in mm. Hg., Mean, 111.7/74.3; standard deviation, 8.0/5.9.

8. Rise during cold pressor. The normal readings subtracted from the highest readings during or immediately after the cold pressor test. Mean, 13.1 syst./20.9 diast.; standard deviation 4.7 syst./8.7 diast.

9. Rise during breath holding, positive pressure. The highest readings during or immediately after breath holding minus the mean of four readings preceding (11' to 12'30" inclusive). Mean, 7.1 syst./9.1 diast.; standard deviation, 4.0 syst./5.9 diast.

10. Anticipation of injection. The mean of the six readings before 22' was subtracted from the highest reading immediately before the injection or within two minutes after, for both systolic and diastolic. Mean, 8.1 syst./9.3 diast.; standard deviation, 4.6 syst./4.7 diast.

11. Mecholyl effect. The mean of the six readings before 22' was subtracted from the average of the twenty readings from 24' to 33'30" inclusive. (The same period as used for pulse rate determination.) These means show an average loss in pressures, viz.: Mean, 2.9 syst./12.4 diast.; standard deviation, 3.4 syst./7.5 diast.

12. Drop in pulse pressure after tilt. The total of the five diastolic readings preceding the tilt were subtracted from the total of the five systolic readings for the same period. The same procedure was followed for the five readings after the injection, from 37' 30" to 39'30" inclusive. This latter total was subtracted from the former giving the total drop in pulse pressure. This procedure was followed for each day and the resulting totals combined into a total for both days. Mean, 19.1; standard deviation, 8.4.

13. Mean period difference in pulse duration. The average of the successive differences in pulse duration for each strip of fast record was divided by the average duration for that period. The four averages for each individual were totaled. Mean period difference in pulse duration in seconds, mean .061; standard deviation, .028.

Changes in response

14. Normal pulse rate drop, day 1 - day 2. The normal reading for day 1 was subtracted from the normal reading for day 2. Mean, 0.2; standard deviation, 3.2.

15. Mean period difference in pulse duration, record 1 - record 2. The total of the first records for both days combined was subtracted from the total of the second records. Mean, .002; standard deviation, .004.

16. Pulse rate anticipation of injection, drop day 1 - day 2. The value for the first day obtained as above was subtracted from the value for the second day. Mean, 0.7; standard deviation, 3.8.

17. Pulse rate mecholyl effect, increase day 1 - day 2. The value for the first day obtained as above was subtracted from the value for the second day. Mean, 1.9; standard deviation, 2.8.

18. Blood pressure anticipation of injection, drops day 1 - day 2. The value for the first day obtained as above was subtracted from the value for the second day for both systolic and diastolic. Mean, 0.04 syst./1.5 diast.; standard deviation, 4.5 syst./5.0 diast.

19. Blood pressure effect of mecholyl, drops day 1 - day 2. The value for the first day obtained as above was subtracted from the value for the second day for both systolic and diastolic. Mean, 0.7 syst./2.0 diast.; standard deviation, 3.6 syst./4.8 diast.

Respiration rates

20. Normal. The total number of cycles from 8' to 12', 14' to 15', from 17' to 18', and 35' to 39' was taken. This value was obtained for each day and the total of the two days taken as the final value. Cycles per minute, mean, 16.0; standard deviation, 3.0.

21. Drop in normal, day 1 - day 2. The value for the first day obtained as above was subtracted from the value for the second day. Mean, 0.2; standard deviation, 1.1.

Salivation

22. Normal. Total amount in ml produced in three minutes. Day 1 and day 2. Mean, 2.4; standard deviation, 2.2.

23. Mecholyl. Total amount in ml produced in 11'10". Day 1 and day 2. Mean 57.0; standard deviation, 27.7.

24. Increase in normal, day 1 and day 2. The value for the first day obtained as above was subtracted from the value for the second day. Mean, 0.23; standard deviation, 0.76.

25. Increase in mecholyl response, day 1 - day 2. The value for the first day obtained as above was subtracted from the value for the second day. Mean, 8.7; standard deviation, 14.5.

Skin temperatures

26. Palm. The first reading in degrees Centigrade was taken each day and the total for the two days combined. Mean, 33.44; standard deviation; 1.10.

27. Forehead minus palm. The value for the palm for each day obtained as above was subtracted from the average of the first two readings for the forehead. This was done for each day and the total for the two days combined was the value used. Mean, 0.62; standard deviation, 1.07.

Perspiration

28. Mecholyl. The amount of change in pad weight in scale units was taken each day. The final value was the total for the two days combined (grams x .378). Mean, 4.8; standard deviation, 5.1.

29. Change, day 1 - day 2. The value for the first day obtained as above was subtracted from the value for the second day. Mean, 0.7; standard deviation, 1.9.

B. Test-retest reliabilities. Table 1 shows Pearson product-moment correlation coefficients for the tests during session 1 vs. those during session 2 for a number of variables.

TABLE 1

TEST-RETEST CORRELATIONS
(N = 23)

Variables	r
Pulse rate, normal	.73
Pulse rate, rise during cold pressor	.15
Pulse rate, drop after cold pressor	.55
Pulse rate, increase in anticipation of injection	.31
Pulse rate, increase after injection	.73
Pulse rate, increase after tilt	.43
Systolic blood pressure, normal	.57
Diastolic blood pressure, normal	.01
Systolic blood pressure, rise during cold pressor	-.09
Diastolic blood pressure, rise during cold pressor	.41
Systolic blood pressure, change after positive pressure breath holding	.00
Diastolic blood pressure, change after positive pressure breath holding	.15
Systolic blood pressure, increase in anticipation of injection	.01
Diastolic blood pressure, increase in anticipation of injection	-.06
Systolic blood pressure, change from mecholyl	.04
Diastolic blood pressure, change from mecholyl	.42
Drop in pulse pressure after tilt	.20
Respiration rate, normal	.77
Salivation, normal	.80
Salivation after mecholyl	.77
Palm temperature, normal, 1 measure	.02
Difference between forehead and palm	.06
Tongue temperature, 2 measures	.44
Perspiration after mecholyl	.78

Table 2 shows some reliability figures and intercorrelations of the data on mean period differences in successive pulse durations. There was one very deviant subject so figures are shown with and without him.

TABLE 2

CORRELATIONS OF MEAN PERIOD DIFFERENCE IN PULSE DURATION

	N = 22	N = 22
MPD (absolute) first 13 cycles vs. next 13 cycles, day 1, record 1	.82	.91
MPD/D (absolute) first 13 cycles vs next 13 cycles, day 1, record 1	.60	.82
MPD (absolute) vs. pulse duration (D) using all records	.32	.67
MPD/D using all records, day 1 vs. all day 2	.71	
MPD (absolute) record 1, day 1 + record 1, day 2 vs. record 2, day 1 + record 2, day 2	.92	.92
MPD (absolute) vs. MPD/D using all cycles	.96	.98

The data in Tables 1 and 2 indicate that with these healthy subjects used under carefully controlled conditions, measures of autonomic activity are not very consistent when made about a week apart. This fact in its own right would argue strongly against the possibility of finding that such measures might consistently differentiate between individuals susceptible and those non-susceptible to motion sickness.

C. Intercorrelations of measures. Table 3 shows certain intercorrelations calculated from the combined data of the 23 subjects.

TABLE 3

INTERCORRELATIONS OF VARIABLES
(N = 23)

	r
Pulse rate, normal vs.	
Pulse rate rise in anticip. inject.	-.13
Systolic blood pressure, normal	.04
Diastolic blood pressure, normal	.36
Respiration rate, normal	-.08
Mean period difference of pulse duration	.67
Pulse rate rise during cold pressor test vs.	
Pulse rate drop during cold pressor test	-.08
Systolic blood pressure rise during cold pressor test	.07
Pulse rate rise during tilt	-.19
Pulse rate drop during and after cold pressor test vs.	
Systolic blood pressure rise during cold pressor test	.50
Pulse rate increase in anticip. inject.	-.02

	r
Pulse rate increase in anticip. inject. vs.	
Pulse rate increase mecholyl	-.27
Diastolic blood pressure, normal	.37
Pulse rate increase during tilt	.10
Systolic blood pressure increase anticip. inject.	.27
Diastolic blood pressure increase anticip. inject.	.28
Pulse rate change, day 1-day 2, anticip. inject.	-.72
Pulse rate increase after mecholyl vs.	
Pulse rate increase during tilt	-.49
Systolic blood pressure after mecholyl	.42
Diastolic blood pressure after mecholyl	-.29
Salivation after mecholyl	.40
Perspiration after mecholyl	.05
Pulse rate increase during tilt vs.	
Diastolic blood pressure increase during positive pres. breath holding	.52
Pulse pressure drop during tilt	-.17
Systolic blood pressure, normal vs.	
Diastolic blood pressure, normal	.84
Respiration rate, normal	.13
Systolic blood pressure rise during cold pressor test vs.	
Diastolic blood pressure rise cold pressor test	.76
Systolic blood pressure rise positive pressure breath holding	.07
Systolic blood pressure rise anticip. inject.	.27
Diastolic blood pressure rise cold pressor test vs.	
Diastolic blood pressure rise positive pressure breath holding	.25
Diastolic blood pressure rise anticip. inject.	.02
Systolic blood pressure rise positive pres. breath holding vs.	
Diastolic blood pressure rise positive pressure breath holding	.29
Systolic blood pressure rise anticip. inject. vs.	
Diastolic blood pressure rise anticip. inject.	.23
Systolic blood pressure change after mecholyl vs.	
Diastolic blood pressure change after mecholyl	.26
Salivation after mecholyl	-.13
Perspiration after mecholyl	-.24
Diastolic blood pressure change after mecholyl vs.	
Salivation after mecholyl	-.20
Perspiration after mecholyl	.05

	r
Mean period difference pulse duration vs.	
Change in mean period difference, record 1 - record 2	-.04
Pulse rate (normal), change day 1 - day 2 vs.	
Change pulse rate, day 1 - day 2 anticip. inject.	-.32
Pulse rate after mecholyl, change day 1 - day 2	
Change day 1 - day 2, systolic blood pressure after mecholyl	-.10
Systolic blood pressure anticip. inject., change day 1 - day 2 vs.	
Diastolic blood pressure anticip. inject., change day 1 - day 2	.19
Diastolic blood pressure after mecholyl, change day 1 - day 2 vs.	
Salivation after mecholyl, change day 1 - day 2	-.58
Respiration (normal) vs.	
Respiration, normal, change day 1 - day 2	.15
Salivation (normal) vs.	
Salivation, normal, change day 1 - day 2	.22
Salivation after mecholyl	.24
Salivation after mecholyl vs.	
Perspiration after mecholyl	.35
Palm temperature vs.	
Palm minus forehead temperatures	-.89
Perspiration after mecholyl vs.	
Perspiration after mecholyl, change day 1 - day 2	.25

Inspection of the above table shows many expected interrelations and suggests a number of interesting hypotheses concerning the interplay of chemical, mechanical, and psychological factors in production of the results. On the other hand, it shows that in some respects the data indicate an absence of close relationship where such had been expected.

D. Response of susceptibles and non-susceptibles. In this section are displayed the mean figures for susceptibles and for non-susceptibles for each of a number of variables. The probabilities of the reliability of the obtained differences have in most cases not been computed and are in no case presented. Reference to the standard deviations in Section A in most cases yields a convincing demonstration that the small obtained differences do not indicate that we are dealing with two populations of sub-

jects. The hypothesis of this investigation, set up to compare subjects from the extremes of the total population with respect to susceptibility, requires a clear separation of the group on the experimental measures in order to yield a useful result.

Skin temperatures are shown in Table 4. Respiration rates appear in Table 5. These are based on different time periods than the rates in Section A, selected to show the data in greater detail. Table 6 shows salivation, perspiration, and latency of dermographia. Salivation is the total of two days, rather than the mean, as is perspiration. The latter is shown in scale units on the Jolly balance, where 1 unit equals 0.378 grams. Duration of red dermographia is not shown because the records were incomplete. Table 7 shows various aspects of the blood pressure levels and responses. As in the case of the pulse rates, time periods were selected to show the data in greater detail and for periods yielding maximum discrimination between stimuli. Table 7 contains no data on responses during breath holding because of their low level. The summated curves of all 23 subjects show systolic/diastolic changes of +6/+7 and +4/+2 for positive and negative pressure stimuli. Table 8 shows pulse rates, also for selected time periods. Day-to-day changes are here shown for the combined group.

TABLE 4

MEAN SKIN TEMPERATURES

	Susceptibles	Non-Susceptibles
Mean normal tongue temperature, readings 1 + 2 for days 1 + 2	36.18°C.	36.31°C.
Mean normal forehead temperature, readings 1 + 2 for days 1 + 2	34.61	34.61
Mean normal forearm temperature, readings 1 + 2 for days 1 + 2	34.03	33.77
Mean normal palm temperature, readings 1 + 2 for days 1 + 2	33.04	33.59
Mean tongue temperature after mecholyl, days 1 + 2	36.21	36.16
Mean forehead temperature after mecholyl, days 1 + 2	34.44	34.26
Mean forearm temperature after mecholyl, days 1 + 2	34.47	34.12
Mean palm temperature after mecholyl, days 1 + 2	33.95	33.92
Mean change in tongue temperature, day 1 to day 2, readings 1 + 2	-.30°C.	
Mean change in forehead temperature, day 1 to day 2, readings 1 + 2	-.26	
Mean change in forearm temperature, day 1 to day 2, readings 1 + 2	-.14	
Mean change in palm temperature, day 1 to day 2 readings 1 + 2	+.60	

(TABLE 5)

MEAN RESPIRATION RATES
(Cycles per Minute)

	Susceptibles	Non-Susceptibles
Resting rates, minutes 10-12, days 1 + 2	15.9	16.6
Resting rates, minutes 35-36, days 1 + 2	16.1	17.1
Rates after tilt, minutes 37-39, days 1 + 2	14.5	14.4
Rates during cold, minute 9, days 1 + 2	16.3	18.0

TABLE 6

SALIVATION, PERSPIRATION, DERMOGRAPHIA LATENCY

	Susceptibles	Non-Susceptibles
Total salivation per subject, minutes 3-6 in ml, days 1 + 2	2.37	2.43
Total salivation per subject after mecholyl, days 1 + 2	62.34	51.82
Total perspiration per subject after mecholyl, days 1 + 2	4.99	4.71
Mean latency of dermographia (seconds), days 1 + 2	19.4	20.5

Mean period differences in successive pulse durations for the two groups were calculated from the first 26 cycles of each of the four records. The means were 0.038 seconds and 0.046 seconds, respectively, for susceptibles and non-susceptibles, but one susceptible with a value of 0.18 played a large part in determining this. Ten out of 12 non-susceptibles were at or below the median of the susceptibles, closely grouped together at the low end of the scale (0.02-0.05).

The variables shown in Section A were tabulated to show the mean response of susceptibles and of non-susceptibles. The variables on which the susceptibles were higher and lower than the non-susceptibles (see Section A) were as follows: higher = 3, 4, 5, 7 (systolic), 8, 9, (systolic), 11, 13, 15, 17, 18 (systolic), 19, 20, 22, 23, 25, 27, 28, 29; lower = 1, 2, 6, 7 (diastolic), 9 (diastolic), 10, 12, 14, 16, 18 (diastolic), 21, 24, 26.

E. Response patterns. The data indicate that few of the tests show promise individually of distinguishing between susceptibles and non-susceptibles. An analysis was made to determine whether all of the tests taken together (Section A) would succeed any better. There are two possible approaches to this. First, it is possible to assign to each subject a total "score" indicating the consistency of his position in the suscepti-

TABLE 7

MEAN BLOOD PRESSURE
(mm. Hg. Systolic/Diastolic)

	Susceptibles	Non-Susceptibles
Mean resting levels, 17'-22', day 1	117/74	111/71
Mean resting levels, 17'-22', day 2	111/76	109/74
Mean level after mecholyl, 25'-29', day 1	105/57	108/62
Mean level after mecholyl, 25'-29', day 2	103/54	102/59
Mean resting levels, 17'-22', days 1 + 2	114/75	110/72.5
Mean levels after mecholyl, 25'-29', days 1 + 2	104/55.5	105/60.5
Mean levels before tilt, 35'-36'40", days 1 + 2	113/71	110/70
Mean levels after tilt, 38'40"-40', days 1 + 2	110/86	107/87
Mean cold pressor rise, days 1 + 2	+13/+20	+11/+20

TABLE 8

MEAN PULSE RATES
(Beats per Minute)

	Susceptibles	Non-Susceptibles
Mean resting rate, 17'-22', days 1 + 2	69.0	71.9
Mean rate after mecholyl, 26'-33', days 1 + 2	88.3	88.8
Mean rate before tilt, 35'-36'40", days 1 + 2	79.3	82.0
Mean rate after tilt, 38'40"-40', days 1 + 2	88.8	92.3

Mean resting rate 17'-22', day 1	70.8
Mean resting rate 17'-22', day 2	70.0
Mean rate after mecholyl, 26'-33', day 1	86.7
Mean rate after mecholyl, 26'-33', day 2	90.8

ble or non-susceptible portion of the distributions of test scores. As a short-cut method of doing this we counted for each subject the number of tests on which he lay on that side of the mean which according to our original hypotheses was the susceptible side. The result was that the mean "score" for the eleven susceptibles was 17.2 tests out of 36 on the susceptible side of the mean, while the mean score for the non-susceptibles was 16.4 tests on the susceptible side of the mean. This should be evaluated in terms of the fact that out of 36 predictions we were right in 22 cases, wrong in 14, as to whether the susceptible or non-susceptible mean would be the larger. A somewhat better separation of susceptibles and non-susceptibles resulted from tallying them on the basis of whether they fell on the susceptible or non-susceptible side of

the mean (or median) basing the division on obtained results rather than on hypothesis. Such an analysis is obviously contaminated and the results are, therefore, not presented.

The other approach is by means of the test intercorrelations, and would consist ideally of a factor analysis. The experimenters employed a very rough short-cut procedure of tallying for 180 pairs of tests (out of 1260 possible pairs) the frequencies of cases (out of 23 subjects) where both tests of the selected pair classified individuals on the same side of the distribution (susceptible or non-susceptible side). This was done on the basis of both hypothetical and obtained results and on the basis of both means and medians. The pairs selected were all the pairs involving normal pulse rate and pulse rate rise during cold pressor stimulation, all interrelations among blood pressures, all interrelations among day 1 to day 2 changes and other scattering measures. The average number of subjects (out of 23) who were classified on the same side of the mean (when the susceptible and non-susceptible sides of the mean were chosen according to our original hypotheses) for the 180 selected pairs of tests was 11.1.

SUMMARY

This study is another in a series of investigations in which certain physiological reactions in individuals susceptible and non-susceptible to motion sickness were compared. Reaction to the cold pressor test, to the breath holding test, to the injection of mecholyl, and to tilt on the tilt table were examined under controlled conditions. On analysis none of the variables investigated showed changes which appeared to suggest consistent physiological differences between the susceptible and non-susceptible groups.

STUDIES IN MOTION SICKNESS

Series C

IV

STUDIES OF SOMATIC, PHYSIOLOGICAL, AND PSYCHOLOGICAL CORRELATES OF HISTORY OF MOTION SICKNESS

by

G. R. Wendt

SUMMARY

This paper consists of brief reports of methods and results of early attempts to discover somatic, physiological, and psychological correlates of history of motion sickness. Results on more than 200 variables are presented, showing their frequency of occurrence as related to history of motion sickness. Some of the variables were obtained from personnel records, some from laboratory investigations, and some from questionnaires. In general, the purpose of this paper has been to give indications of what may be expected from further research.

STUDIES OF SOMATIC, PHYSIOLOGICAL, AND PSYCHOLOGICAL CORRELATES OF HISTORY OF MOTION SICKNESS

INTRODUCTION

This paper consists of reports of early attempts to discover somatic, physiological, and psychological correlates of history of motion sickness. The general technique was to administer a questionnaire on history of motion sickness to groups of college students and, after selecting the extreme cases of susceptibility and non-susceptibility, to compare them on other measures. These other measures were selected to test the very numerous hypotheses which various workers have offered concerning the nature of susceptibility, viz.: that it is endocrinological and associated with certain somatotypes, that it results from poor motor coordination, from poor coordination of visual, kinesthetic and vestibular control, from vasomotor instability, from inadequate vasomotor reflexes, from nervousness, low threshold of startle or fear responses, etc.

The purposes of this paper are to present the author's methods of approach to the problem of the nature of susceptibility to motion sickness and enough samples of data to give an indication of what may be expected from future research. A complete summary statement of findings presented in semi-popular form was prepared in 1942.[1] This report did not include details of method nor quantitative statements of results.

REPORT OF MAY 29, 1941[2]

A. Procedures. The total 1940 student body of Wesleyan University (N = 624) took a motion-sickness history questionnaire[3] and then the highest fifty and lowest fifty with respect to susceptibility took it again. From these 20 susceptibles and 20 non-susceptibles were selected who gave the most extreme consistent reports. Each came to the laboratory individually for measurements and tests lasting about 45 minutes. The measurements and tests used and the sequence of administering them were as follows:

1. The subject, while seated, was instructed in the procedures.

2. The subject, still seated, supplied data on age, on state of health and on sleep, meals, number of cigarettes smoked, etc.

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[1] Wendt, G. R. Motion sickness in aviation. NRC Division of Anthropology and Psychology, Committee on Selection and Training of Aircraft Pilots, May 1944.

[2] This study was conducted with the assistance of D. D. Bellis, Jr.

[3] Wendt, G. R. Studies in motion sickness. Series B. Washington, D. C.: CAA Division of Research, Report No. 60, April 1946, p. 31.

3. Systolic and diastolic blood pressures were determined by the usual auscultatory method (subject still seated).

4. Subject removed clothes (except underwear), was weighed and measured for standing height and sitting height.

5. Subject took pursuitmeter test. Used Koerth pursuitmeter[4] with 3/4" target 3½" off-center operating clockwise at 1 r.p.s. Total contact time summated by 1/100 second electric stop-clock. Subject standing; elbow at side. Six 30-second trials with 45-second rests. Preferred and non-preferred hands alternated as follows: PNPPNN.

6. Subject tested on Miles' ataxiameter.[5] Took a one-minute trial while blindfolded, a two-minute rest, then a one-minute trial with eyes open.

7. Blood pressures were again taken (seated).

8. Response to revolver shot,[6] .22 calibre, extra loud blank. Subject was blindfolded, knees slightly flexed, arms semi-flexed so as to hold between the hands a Byrd Company pneumograph to record arm movements. Photokymographic recordings were obtained of thoracic and abdominal breathing, pulse from the throat, pulse amplitude from the finger by means of a finger plethysmograph with a slow leak, amount of body crouch by recording any lowering of the position of the head, and movement of the hands holding the pneumograph. Record started 30 seconds before shot and stopped 30 seconds after.

9. Measure repeated on startle response after one-minute rest.

10. Tilt table test.[7] Subject was placed in vertical position while one-minute record was taken, tilted to horizontal for a five-minute record, tilted to vertical for a three-minute record. Photokymographic records were obtained of pulse from throat, pulse amplitude from the finger (as above) with the arm held in a sling at heart level, thoracic and abdominal breathing.

Some of the recorded data are not reported in this study for various reasons: (1) the ataxiameter data because of a slight but unknown amount of slippage of the recording dials, (2) the body-crouch and hand steadiness data because of inconsistencies in the direction of response among

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[4]Koerth, W. A pursuit apparatus: eye-hand coordination. Psychol. Monogr. 1922, No. 140, 288-292.

[5]Miles, W. R. Static equilibrium as a useful test of motor control. J. Industr. Hyg. 1922, 3, 316-331.

[6]Landis, C., and Hunt, W. A. The startle pattern. New York: Farrar and Rinehart, 1939, p. 168.

[7]McFarland, R. A., Graybiel, A., Liljencrants, E., and Tuttle, A. D. An analysis of the physiological and psychological characteristics of two hundred civil airline pilots. J. Aviat. Med. 1939, 10, 160-210.

the subjects, (3) the pulse amplitude data because extreme constriction during the startle observations made the records illegible, and (4) the tilt observations because the task of measurement was prohibitively large.

B. Results. The major results of this investigation are displayed in Table 1 in terms of the group averages of susceptibles and non-susceptibles. As a general observation it may be noted that there are small differences between susceptibles and non-susceptibles on blood pressure and pulse measures consistent with those obtained in other studies in this series, and small differences in the other variables. The amounts of these differences are in some cases so small as to fall within the margin of error of the measurement, are in some too small to be of physiological consequence, and in some (respiration) inconsistent with the results of later studies. The over-all result is that differences of a clinically significant magnitude did not appear.

The differences in cigarette smoking are consistent with questionnaire studies. The difference in improvement in pursuitmeter scores is suggestive for further studies but should be confirmed by further investigations.

TABLE 1

AVERAGE RESULTS FROM SUSCEPTIBLES AND NON-SUSCEPTIBLES

		Susceptibles	Non-Susceptibles
1.	Number of subjects	20	20
2.	Median age (range 17 to 22 years)	19.8 years	19.7 years
3.	Mean standing height	177 cm.	178 cm.
4.	Mean sitting height	90.0 cm.	88.8 cm.
5.	Mean weight	161.5 lbs.	155 lbs.
6.	Mean ratio Ht. in cm/Wt. in lbs	1.10	1.15
7.	No. of cups of coffee before experiment (total)	10 cups	14 cups
8.	No. of cigarettes during day of experiment (total)	51 cigarettes	104 cigarettes
9.	Pursuitmeter, mean total contact time and standard deviation	23.9 secs. ± 21.1	28.1 secs. ± 20.9
10.	Pursuitmeter, mean improvement from 1st to best trial	648%	467%
11.	Mean systolic blood pressure, first determination (mm. Hg.) and standard deviation	129.3 mm. ± 1.8	124.7 mm. ± 3.0
12.	Mean systolic blood pressure, second determination (mm. Hg.) and standard deviation	125.1 mm. ± 2.8	122.7 mm. ± 2.3
13.	Mean diastolic blood pressure, first determination (mm. Hg.) and standard deviation	79.1 mm. ± 1.9	80.7 mm. ± 2.4
14.	Mean diastolic blood pressure, second determination (mm. Hg.) and standard deviation	78.5 mm. ± 2.2	76.8 mm. ± 2.5

TABLE 1 (Continued)

AVERAGE RESULTS FROM SUSCEPTIBLES AND NON-SUSCEPTIBLES

	Susceptibles	Non-Susceptibles
15. Mean pulse rate before first startle	97 c.p. min.	95.2 c.p. min.
16. Mean pulse rate after first startle	91.7 c.p. min.	89 c.p. min.
17. Mean pulse rate before second startle	92.8 c.p. min.	91.6 c.p. min.
18. Mean pulse rate after second startle	90.5 c.p. min.	87.1 c.p. min.
19. Mean pulse rate during last min. at horizontal	65.9 c.p. min.	64.6 c.p. min.
20. Mean pulse rate during last min. at vertical	93.5 c.p. min.	97.4 c.p. min.
21. Mean respiration rate before startle, 1st measure	20.9 c.p. min.	19.6 c.p. min.
22. Mean respiration rate after startle, 1st measure	19.5 c.p. min.	19.3 c.p. min.
23. Mean respiration rate before startle, 2nd measure	19.9 c.p. min.	19.0 c.p. min.
24. Mean respiration rate after startle, 2nd measure	19.8 c.p. min.	18.7 c.p. min.
25. Mean respiration rate in horizontal position (5 min.)	18.5 c.p. min.	16.9 c.p. min.
26. Mean respiration rate in vertical position (3 min.)	15.8 c.p. min.	14.6 c.p. min.

REPORT OF MAY 29, 1940[8]

A. Procedures. Most of the 1939-40 student body of Wesleyan University (N = 594) took a motion sickness history questionnaire (Sea, Train, Car, Airsickness Questionnaire, February, 1940) and the papers were scored to indicate freedom from history of sickness. They were then ranked in order of susceptibility and various comparisons made between the extremes of the distribution, susceptibles and non-susceptibles. Data were taken from college records: the personnel office, testing bureau, dean's office, college physician, and department of physical education. No check was made of the accuracy of these records. In addition, measures of standing height and sitting height were made in the laboratory.

B. Results. Some results of this study are shown in the following tabulations. The group size differs for the various comparisons, from comparison of 40 susceptible with 40 non-susceptibles to comparisons of 60 of each.

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[8]This study was carried out by D. D. Bellis, Jr.

1. Somatotype. The 50 most susceptible were compared with the 50 least susceptible in height and in height-weight ratio. The results are shown in Table 2.

TABLE 2

HEIGHT AND HEIGHT-WEIGHT RATIOS FOR SUSCEPTIBLES AND NON-SUSCEPTIBLES

	50 Susceptibles	50 Non-Susceptibles
Median height	69.7 inches	71.8 inches
Median ratio: Ht. (inches)/Wt. (lbs.)	.446	.445

A scatter diagram of Ht./Wt. ratios on susceptibility score for all 594 cases shows no evidence of correlation between the two variables. The median ratios in going from the most susceptible to the least show no trend whatever, viz.: .442, .450, .445, .435, .475, .440, .435, .440, .445, .450, .444, .445, .454, .445, .456, .450, .450, .455. A scatter diagram of height against sickness score gives a similar result.

Forty of each of the above groups of 50 were measured for standing height and sitting height. The median sitting Ht./standing Ht. ratios were: susceptibles, .527, non-susceptibles, .526.

2. Medical records. The same 50 susceptibles and 50 non-susceptibles were compared on the basis of medical records. The results are shown in Table 3. The small differences in blood pressure are consistent with other investigations. No other difference is a matter of consequence except smoking habits. The latter probably reflect personality factors.

TABLE 3

MEDICAL RECORDS

	50 Susceptibles	50 Non-Susceptibles
Mean systolic blood pressure, mm. Hg.	118.5	116.8
Mean diastolic blood pressure, mm. Hg.	73.9	71.4
Mean specific gravity of urine	1.0180	1.0186
Wears glasses (no. of cases)	24	24
General appearance good (no. of cases)	48	48
Serious illness in last 12 months (no. of cases)	4	1
Total no. of days spent in college infirmary, 1939-40	29	26
Total visits to college infirmary, 1939-40	140	138
Total no. of recorded diseases during life	181	200
Recorded that student smokes (no. of cases)	14	28

3. Sports history. The same students were compared on the basis of their records in required physical education courses and college sports. Wesleyan students were allowed to choose from 41 different sports and made five choices during each of the first two years. Only one of these students chose more than six sports; the mean number of choices by the susceptibles was 3.8 sports, by the non-susceptibles was 3.6 sports (medians: 4.3 and 4.0). Table 4 shows sports elections classification by type of sport.

TABLE 4

ATHLETIC PREFERENCES*

Sport	No. of elections by susceptibles	No. of elections by non-susceptibles
Handball	16	6
Touch football	20	8
Cross-country	5	2
Volley ball	3	0
Soft ball	5	3
Intramural basketball	12	8
Self-directed activity	6	5
Badminton	3	3
Soccer	6	6
Baseball	8	8
Wrestling	8	8
All basketball	14	16
Squash	23	26
Tennis	32	33
Swimming	18	19
Football	11	15
Fencing	2	4
Track	9	13
Golf	7	10
Intercollegiate basketball	3	8
Boxing	0	3

*In this table a sport is given a value of one election whether the individual has elected it once or more than once.

4. Intelligence and college grades. The same groups of 50 susceptibles and 50 non-susceptibles were compared on the basis of their recorded Ohio State Intelligence Test[9] performance at time of college entrance. The records were in terms of standard scores where 50 was the college mean over a period of years, 10 was the standard deviation. The median

[9]Published at the Ohio State University, Columbus, Ohio.

standard score of the susceptibles was 56, of the non-susceptibles, 50.

For comparison of college grades it seemed desirable to control the factor of college class. Table 5 shows the median grades during the preceding semester of the 20 most susceptible and 20 least susceptible in each of 3 classes. (Group 5 contains grades from 73.3 to 78.3%, group 4, from 78.3 to 83.3%.)

TABLE 5

MEDIAN COLLEGE GRADES

	Susceptibles	Non-Susceptibles
20 sophomores	4.3	4.3
20 juniors	4.2	5.4
20 seniors	4.8	5.7
60 men	4.4	5.4

5. Course elections. The susceptible juniors and seniors in the above group (N = 40) were compared with the non-susceptible juniors and seniors (N = 40) on basis of college course elections (total semester hours in each department). The results are displayed in Table 6.

TABLE 6

COURSE ELECTIONS
(Total Semester Hours)

Department	Susceptibles	Non-Susceptibles
Art	51	18
Astronomy	87	48
Biology	237	241
Chemistry	297	382
Classics	63	21
Econ. & Social Science	486	507
English	637	726
Ethics and Religion	111	63
Geology	116	89
German	229	252
Government	225	258
History	384	444
Mathematics	249	216
Music	78	42
Philosophy	108	72
Physics	64	66
Psychology	171	129
Romance Languages	387	258

6. Personality test scores. The 50 most susceptible and 50 least susceptible were compared on the basis of recorded scores on the Allport-Vernon Scale of Values[10] and on the Bernreuter Personality Inventory.[11]

The recorded values scores were standard scores with a standard deviation of 10. The medians of the two groups are shown in Table 7.

TABLE 7

ALLPORT-VERNON SCALE OF VALUES
(Median Standard Scores)

Value	Susceptibles	Non-Susceptibles
Theoretical	45	46
Economic	43.3	47.5
Aesthetic	39	34
Social	43.5	41.2
Political	48.8	53
Religious	47.5	40

Comparison on the Bernreuter for the same groups was in terms of standard scores based on national percentile norms. Medians of the two groups are shown in Table 8.

TABLE 8

BERNREUTER PERSONALITY INVENTORY
(Median Standard Scores)

Scale	Susceptibles	Non-Susceptibles
Neurotic tendency (B1-N)	65	56
Self-sufficiency (B2-S)	40	36
Introversion-extroversion (B3-I)	67.5	64
Dominance-submission (B4-D)	31.25	31.2
Confidence (F1-C)	56.3	48
Sociability (F2-S)	37.5	34.7

These same two tests were then subjected to rough item analysis by tallying for these 100 subjects the response frequency for each item. The items which showed the highest differential between responses of susceptibles and

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[10] Published by Houghton Mifflin Co.

[11] Published by the Stanford University Press, Stanford, California.

non-susceptibles were later included in an experimental questionnaire.[12] A report has recently been prepared showing the ability of certain of these items to predict airsickness in naval flight training among 971 cadets.[13]

STUDIES OF 1940-41

During 1940-41 extensive studies of somatic, physiological, and psychological correlates of motion-sickness susceptibility were made. The results have been reported elsewhere in summary form.[14] The following data represent only small parts of the available information, selected because they add to previous studies or illustrate points of special interest.

The procedures were those of the preceding studies, consisting in the administration of motion sickness history questionnaires followed by compilation of biographical and other data.

A. Relation of intellectual abilities to motion-sickness history. The class which entered Wesleyan University in September of 1940 took a motion-sickness history questionnaire (Experimental Questionnaire Form, June 1940),[15] and various tests. Table 9 shows median test scores for each of several degrees of susceptibility. The tests here reported were from the College Entrance Examination Board Tests[16] of verbal and mathematical ability, Cooperative Test Service achievement tests,[17] and the Iowa Reading Test.[18] The degree of susceptibility was determined by

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[12] Wendt, G. R. Op. cit., p. 35. (Footnote 3 of Report IV in this series.)

[13] Cotsin, M., Hill, C. J., and Wendt, G. R. Studies of motion sickness: IX. The prediction of laboratory motion sickness by means of a personal history questionnaire. (To be submitted for publication.)

[14] Wendt, G. R. The vestibular factor in flying: airsickness. August 1941. Progress report in the files of the Committee on Selection and Training of Aircraft Pilots. Also: Wendt, G. R. Op. cit. (Footnote 1 of Report IV in this series.)

[15] A copy of this questionnaire is found in: Wendt, G. R. Ibid., p. 35.

[16] Published by College Entrance Examination Board, Princeton, N. J.

[17] Published by Cooperative Test Service, New York City.

[18] Published by Bureau of Educational Research and Service, University of Iowa, Iowa City, Iowa.

TABLE 9

MEDIAN TEST SCORES
(Standard Score Units)

Group	Motion-Sickness Susceptibility 1 N=11	2 N=10	3 N=14	4 N=16	5 N=38	6 N=35	7 N=56	8 N=19	Total N
Verbal aptitude	53	54	48	48	45	47	46	47	184
Foreign Literature	56	56	47	46	47	48	48	48	195
English Mechanics	57	62	53	56	52	54	52	53	195
English Expression	55	49	47	47	48	50	47	48	195
Iowa Reading	46	53	51	46	50	52	48	48	195
Foreign Languages	48	48	51	56	51	51	48	46	195
Mathematical aptitude	47	48	52	47	47	50	50	50	180
Mathematical achievement	43	43	43	43	45	47	46	45	195
Social studies	54	48	52	46	46	54	47	54	195
Fine arts	49	48	43	41	45	47	46	48	195

scores on the history questionnaire.[19] Group 1 contained the most susceptible students, Group 8 the least susceptible. The numbers of cases shown for each group are maxima; slightly different numbers of students took each test. The total class had 199 students, but not every student took every test. The last column shows the actual total N for each test. All test scores are in standard deviation units where 50 is the mean and 10 the standard deviation.

The slight superiority of this group in verbal aptitude and English achievement may be a parallel of the slightly higher Ohio State Intelligence Test scores of the preceding study.

B. Height and weight. Height and weight data were collected by questionnaire. There were 187 complete reports. Table 10 shows the median figures for each of five susceptibility groups. It may be remarked that the median age of each of these groups did not differ by more than 1½ months from the median of all.

C. Correlation of motion-sickness history with biographical data. The Experimental Questionnaire Form of June, 1940,[20] consisted of 34 questions dealing with history of motion sickness followed by 107 questions on various biographical, medical, and psychological matters which previous studies had indicated as being related to motion sickness (see Report of May

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[19] For other data on these subjects see: Wendt, G. R. On. cit., p. 3. (Footnote 3 of Report IV in this series.)

[20] Wendt, G. R. Ibid., p. 35.

TABLE 10

MEDIAN HEIGHT, MEDIAN WEIGHT, AND HT./WT.
(Ht. in inches, Wt. in lbs.)

	Motion-Sickness Susceptibility				
	1 N=30	2 N=52	3 N=34	4 N=54	5 N=17
Median Ht. (inches)	69.5	70.6	69.4	69.2	68.7
Median Wt. (lbs.)	157	150	150	153	156
Ht./Wts.	.440	.453	.450	.441	.466

29, 1940, in this section). An item analysis of questions 35-141 was made on a group of subjects (Wesleyan freshmen, N = 199, Non-Wesleyan students, N = 243, student airplane pilots, N = 197) by dividing them into seven degrees of susceptibility as measured by response to questions 1 to 35.[21] Graphs were constructed to show for each item the frequency of response in relation to degree of susceptibility. On the basis of inspection of the graphs those items were selected which appeared to show the greatest differences between susceptibles and non-susceptibles and the most regular relationship to degree of susceptibility. A scoring system was devised, based on these judgments, in which each item associated with susceptibility was given a plus weight of 1, 2, or 3, the magnitude depending on the apparent discriminative capacity of the item, and in which each item associated with non-susceptibility was given a minus weight of 1, 2, or 3. The scores assigned to each item are shown in Table 11. Questions and items which do not appear in Table 11 were not used in scoring.

To the extent that the method of inspection is a proper, reliable, and valid method of judging the slope of a graph, the scores shown are confirmation of the earlier exploratory studies reported in the preceding section of this paper. In general, the items then selected as probably associated with history of motion sickness were found to be so associated in this study.

The questionnaires of four groups of subjects were then scored by the method shown in Table 11. Three of these groups were the ones composing the criterion group used in derivation of the scoring key, the other was a new group. Coefficients of correlation were then computed between the score on the items dealing with history of motion sickness and the score on the items shown in Table 11. Table 12 shows the obtained r's. The first four values, derived from the criterion groups used in key construction, are contaminated values. (However, see preceding paragraph.)

D. Athletic history of Wesleyan susceptibles and non-susceptibles. It is commonly stated that motion sickness is the result of fear and nervous-

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[21] Fuller descriptions of these groups of subjects are contained in: Wendt, G. R. Op. cit. Pp. 3-6. (Footnote 3 of Report IV in this series.)

TABLE 11

SCORING WEIGHTS ASSIGNED TO ITEMS ON EXPERIMENTAL QUESTIONNAIRE FORM, JUNE, 1940*

Question Number	Item Weights	Question Number	Item Weights
35	a-2, d+2	73	a+3, d-2
36	a+3, b+1, c-2	74	b+2
41	a+1	75	a+1
42	a+1	77	e+1
43	a+2, c+2	78	a+1, c+1
44	a+2, b-1, c+2	79	a+1
45	a+3, b-3	80	a+1, b-1
46	a-2, c+2, d+3	82	a+2, b-1
48	a+3, b+2, c-2	83	a+1
50	a+2	84	a+1
52	a+2, b+1, c-1	97	a-1, b+1
53	a+1, b+1	98	a+2, b-2, c+2
54	a-1, b+1, c+2	100	a-1, b+1
56	a-1, d+2, e+2	102	a-1, b+1
57	a+3, b+3, c-1	104	a+1, b-1
58	a+3, b+3, c-2	105	a+1, b-1
59	a+3, b+2	106	a+2, b-2
60	b+1, c-1	113	b+1
61	a+3, b+1, c-1	118	b+1
62	a+1, c-1	124	a+1
63	a+2	129	b+1
64	b-1	135	a+2, b-2
65	a+3, b-2	136III	b+1
66	a+3, b+2, c-1	136IV	b+1
67	a+3, b+2, c-1	136V	a+1
68	a+3, b+1, d-1	137I	a+2
		137VI	a+1

*For questions see: Wendt, G. R. Studies in motion sickness. Series B. Washington, D. C.: CAA Division of Research, Report No. 60, April 1946, p. 35.

ness. This belief is sometimes extended to include the belief that susceptibles are unsuitable for military duty. As one approach to the validity of this hypothesis we investigated the frequency of participation by susceptibles and non-susceptibles among five classes of Wesleyan students in sports regarded by us as "punishing" sports; e.g., football, wrestling, boxing, and cross country. For each class we determined the median susceptibility score, based on the motion-sickness history questionnaires, and then counted the sports-participants who were above and below the median. There were 77 participants who were less susceptible than the class medians and 75 who were more susceptible.

E. Motion-sickness history of migraine cases. Neurologists familiar with migraine cases claim to have observed that these individuals are susceptible to motion sickness. Through the cooperation of Dr. James C. Fox, Jr.,

TABLE 12

RELATION OF MOTION-SICKNESS HISTORY TO QUESTIONNAIRE SCORES

Group	Number of Cases	r
Wesleyan freshmen, Sept., 1940	199	.49
Non-Wesleyan students	243	.58
Student pilots	197	.32
Combined groups	639	.55
Wesleyan freshmen, Sept., 1941	210	.40

of the New Haven Hospital, the names and histories of 25 cases were obtained where the diagnosis of migraine seemed most certain. By correspondence and interview it was possible to get motion-sickness histories from 18 of them, and assign scores on the basis of these histories. These scores were then compared to the distribution of scores obtained from the 639 college students mentioned in the preceding section by finding the percentage of college students who exceeded each migraine case in susceptibility score. The results were as follows: three migraine cases were exceeded in susceptibility by 90% of the students, one by 85% of the students, two by 66%, one by 59%, one by 50%, two by 5%, two by 4%, and five by 2%. Since half of these fell below the fifth percentile in susceptibility, the result is suggestive. It cannot, however, be considered definitive.

STUDIES OF REACTION TO BODILY ROTATION

A number of studies of reactions to bodily rotation of susceptible and of non-susceptible subjects was undertaken. Three sets of data are presented here. The rotation method was similar in each study, but the recorded data differed.

The rotating chair was the one originally built by Raymond Dodge.[22] The subject sat upright with the head fixed in the normal upright position. The chair was motor-driven at 30 r.p.m. Acceleration covered a period of approximately 2 seconds and was constant during this period. It was automatically controlled. Deceleration covered a period of approximately 1/3 second. It was manually controlled.[23]

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[22]For a description of the chair see: Wendt, G. R. The form of the vestibular eye-movement response in man. Psychol. Monogr. 1936, No. 212, 311-328.

[23]For further details of methodology see microfilm records of procedures in the files of the Committee on Selection and Training of Aircraft Pilots.

A. Duration of sensations of rotation in susceptibles and non-susceptibles.[24] Ten susceptible and nine non-susceptible college students took part in the following experiment. With eyes blindfolded each was accelerated to 30 r.p.m., kept at that speed for 5 minutes, stopped and kept still for 10 minutes, then again rotated for 5 minutes and again kept still for 10 minutes. By means of a manual switch the subject signalled the onset and cessation of periods of apparent rotation, both during actual rotation and during quiet periods. (Pulse amplitude and pulse rate were recorded but are not reported here.)[25]

Under such stimulation the most typical response sequence is (1) an initial sensation when acceleration or deceleration begins opposite to the direction of rotation and lasting from 20 to 50 seconds, (2) a period of no apparent movement, (3) a period of apparent rotation opposite to the initial sensation lasting for varying periods up to 5 minutes. Each subject gave four such sequences, two following the acceleration periods, and two following the deceleration periods. The data here reported are the mean total times following each stimulus during which a sensation of rotation was reported by each subject.

The mean durations of the reported sensations of rotation for the nine subjects without history of motion sickness were 34, 63, 67, 82, 84, 97, 98, 109, and 174 seconds, yielding a group mean of 89 seconds. For the ten subjects with history of motion sickness the mean times were 74, 89, 95, 98, 99, 111, 129, 137, 140, and 187 seconds, yielding a group mean of 116 seconds.

The author is inclined to attribute the group differences to differences in attitude on the part of the subjects. When sensations of rotation become very faint, differences in attitude toward the instructions may introduce differences in report.

B. Duration of eye-movements in susceptibles and non-susceptibles.[26] Five susceptible and five non-susceptible college students went through the stimulation procedure described above while eye-movement records were made by means of the Dodge mirror recorder for photographing horizontal eye-movements through closed lids.[27] Magnification of records was such that one angular degree of eye-movement produced about 3 mm. of movement on the records. The subjects also signalled periods of apparent rotation.

Under these conditions the records showed a nystagmus beginning at acceleration (and at deceleration) and lasting for 28 seconds to 50 seconds.

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[24] Carried out with the assistance of J. S. Helmick.

[25] These findings have been reported in summary form in the progress report cited in Footnote 13 of this section.

[26] Carried out with the assistance of J. S. Helmick.

[27] For a description of this method see: Wendt, G. R. Methods of recording action. Arch. Psychol., N. Y., 1938, No. 228.

At termination of the initial nystagmus an inverse nystagmus began lasting for variable periods, but ordinarily continuing during the entire period of observation. Since these subjects were kept alert by being required to report sensations of rotation, there was little or no evidence of habituation in the original phase of nystagmus, although the inverse phases were obviously affected.[28] Only the duration of the original nystagmus is here reported. This can be determined with a high degree of precision by use of the Dodge mirror recorder. For each subject there were four determinations. The mean of the four response durations for each of the five subjects was as follows: susceptibles 32, 32, 37, 40, and 42 seconds; non-susceptibles 31, 33, 37, 37, and 46 seconds. The group means are in each case 37 seconds.

C. Duration of vestibular nystagmus with a visual fixation field.[29] Each of 29 subjects was rotated in the apparatus described above. The left eye was bandaged while the right eye observed a cylindrical white cardboard shield attached to the chair about 14 inches from the eyes. It covered about 125° of visual arc vertically and 160° horizontally. A horizontal black line at eye-level prescribed the fixation height while 3 vertical black lines spaced 20° of visual arc apart served as inhibitors of nystagmus. The field was illuminated by a 15 watt Mazda lamp placed over the head. The room was dark. Each subject was rotated at 30 r.p.m. for 3 minutes and then stopped while nystagmus was observed and timed by a stop watch. After a 5-minute rest a second rotation began and the observation was repeated.

The subjects were students of Middletown High School, selected by questionnaire. Sixteen had never been motion sick; thirteen reported history of sickness and recent sickness.

For each subject the mean nystagmus duration of the two stimulations was determined. These were combined into means and standard deviations for the susceptible and non-susceptible groups. For the susceptibles the mean was 19.6 seconds with a standard deviation of 6.8; for the non-susceptibles the mean was 14.9 seconds with a standard deviation of 5.0. The critical ratio of the difference was 2.04.

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[28] For details of habituation see: Wendt, G. R. An interpretation of inhibition of conditioned reflexes as competition between reaction systems. Psychol. Rev., 1936, 43, 258-281.

[29] Carried out with the assistance of Hugh Staples.