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16. Abstract

The incidence of motion sickness in a large (N = 3,618) college population was determined by means of a questionnaire. Significantly greater proportions of men than women had low susceptibility scores; significantly greater proportions of women had high susceptibility scores. Comparisons of MSQ scores were made with other self-assessments, age changes, motion experiences, familial susceptibility, use of motion sickness medication, muscular coordination, willingness to participate in motion experiments, flying experience, phobias, visual motion effects, and use of alcohol. MSQ scores were next used to select groups of highly susceptible and nonsusceptible subjects (12 men and 12 women in each group) to assess the relationships of motion sickness susceptibility to laboratory measures of vestibular function and duration of the spiral aftereffect. When subjective alertness levels were controlled, there was no enhancement of either elicited nystagmus or turning sensations in comparing susceptible with nonsusceptible individuals. MSQ scores were also used to select an additional 25 men and 25 women for each of the two categories of susceptibility. These subjects were tested on at least three but not more than six of the following eight tests: Floor Ataxia Test Battery, State-Trait Anxiety Inventory, Menstrual Distress Questionnaire, Cornell Medical Index, Cornell Word Form, Eysenck Personality Inventory, Rotter Internal-External Locus of Control Scale, and the 16 Personality Factors test. The consistent and significant patterns of results from those tests are discussed in terms of the personality characteristics that generally distinguish those highly susceptible from those nonsusceptible to motion sickness.

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MOTION SICKNESS SUSCEPTIBILITY AND RELATED BEHAVIORAL CHARACTERISTICS IN MEN AND WOMEN

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I. Introduction.

Of the multiple methods used to assess motion sickness susceptibility,[9] the questionnaire approach has been shown to yield reasonably valid results[2] and is clearly the easiest technique to employ. Several motion sickness history questionnaires[4 7 11] have been considered for military application, primarily to predict attrition from flight training programs. In particular, the Pensacola Motion Sickness Questionnaire[7] has been used in a multiple prediction formula to estimate a candidate's likelihood of success in naval flight training.

In other than military settings, where individuals form relatively select groups because of various types of preliminary screening, motion sickness questionnaires (MSQ) have received only meager use. The most noteable example of a nonmilitary MSQ is documented in a study by Reason,[12] who administered a short motion sickness questionnaire to 150 men and 150 women at the University of Leicester. From this sample, he concluded that women reported a greater incidence of past motion sickness than did men and that both sexes reported a lower incidence of motion sickness following the age of 12.

In general, MSQ's have not been subjected to reliability tests and have rarely been used to examine specific features associated with motion sickness susceptibility.

The current investigation consisted of two phases, the first of which determined how motion sickness susceptibility was distributed in a relatively large college population. This survey was similar to that reported by Reason,[12] although it encompassed a much larger sample and was used to provide a source of potential subjects for a laboratory study of vestibular function.[8] The second phase, which included a test-retest sample, was similar to our first survey but also incorporated sets of items designed to assess the degree to which certain behavioral and other characteristics might be associated with motion sickness susceptibility.

II. Procedure.

A. *MSQ–1.* MSQ–1 was completed by 2,432 students in undergraduate classes at three local universities. The students ranged in age from 16 to 62 (mean=22.0); only 7 percent were 30 years of age or older. Although test taking was not mandatory, almost all classes had 100-percent participation.

MSQ–1, a modified version of a questionnaire developed by Birren,[4] was scored on the basis of responses to 20 items concerned with the individual's lifetime tendency to develop motion sickness in a variety of situations, such as in automobiles, trains, roller coasters, etc. (see Table 2 for a list of all 20 situations). The possible answers for each item and the numerical weights used to score those answers were: never sick (0), rarely sick (1), occasionally sick (2), often sick (3), and almost always sick (4). An individual could also indicate no experience in a particular situation.

Following the 20 basic items, MSQ–1 had three additional questions: In general, how susceptible to motion sickness are you? Have you ever taken a medication like Dramamine for motion sickness? Would you be interested in being a paid volunteer in an experiment that involves very mild motion?

B. *MSQ-2.* MSQ-2, developed as a more comprehensive version of MSQ-1, consisted of three sections. The first section, similar to MSQ-1, assessed the frequency of motion sickness as well as the degree of experience in 20 motion situations. The second section assessed motion sickness tendencies in the individual's immediate family as well as the individual's general susceptibility to motion sickness and how it had changed since the age of 12, and it included other items on muscular coordination, phobias, visual motion, flying experiences, and willingness to participate in a motion experiment. The third section inquired about the individual's experience with alcohol.

Students, ranging in age from 16 to 56 (mean= 20.5), in undergraduate classes at a state university were subjects; less than 4 percent were 30 years of age or older. MSQ-2 was administered on a test-retest basis with an interval of 6 to 8 weeks between sessions. The students were instructed to complete all three MSQ sections on their original testing and only the first section of 20 items on the retest. The original test was completed by 1,072 students and 548 completed the second test (no attempt was made to retest all classes); a total of 434 completed both forms. Thus, responses were available from a total of 1,186 students for the first section of the MSQ-2 questionnaire and from 1,072 students for the second and third sections.

III. Statistical Analyses.

Responses to items were omitted inconsistently and only occasionally. Two types of statistics were applied to the data: correlation coefficients and X^2 tests of significance of differences. Differences were considered significant at probability levels of .05 or less.

IV. Results.

A. *Distribution of Scores.* Data from MSQ-1 and MSQ-2 were combined into a single distribution. Mean scores ranged from 0 to 3.65 and were arbitrarily partitioned into nine categories. There were significant differences ($p<.001$) in the distribution of scores for men and women with a greater percentage of men than women in the low (least susceptible) MSQ categories and, conversely, a smaller percentage of men in the high (most susceptible) MSQ categories. The distributions of scores for men, women, and both sexes combined appear in Table 1. For some later analyses, subjects were divided into three degree-of-susceptibility groups based on the nine response categories of MSQ scores. The nonsusceptible subjects were those individuals in MSQ category 1; the moderately susceptible group included individuals in categories 2, 3, 4, and 5; the very susceptible group comprised individuals in MSQ categories 6, 7, 8, and 9.

B. *Test-Retest Reliability.* MSQ-2 was conducted on a test-retest basis. Based on 434 subjects the derived reliability coefficient for mean scores on the 20-item section was 0.84. The questionnaire thus yields consistent information.

C. *Self-Assessments.* Mean MSQ scores from the 20 motion situations were compared with the subjects' own estimates of their motion sickness susceptibility (In general, how susceptible to motion sickness are you: extremely, very, moderately, minimally, not all?). The mean MSQ scores for all subjects and their estimates (scored 0-4) of susceptibility were significantly correlated (r=0.70). Many susceptible subjects were somewhat inclined to underestimate their degrees of susceptibility relative to their mean MSQ scores.

TABLE 1. Distribution of Subjects by MSQ Scores

Category (Score)	1 (0)		2 (.01-.24)		3 (.25-.49)		4 (.50-.74)		5 (.75-.99)		6 (1.00-1.24)		7 (1.25-1.49)		8 (1.50-1.74)		9 (1.75 +)		Total
	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N
Men	520	27	731	37	405	21	152	8	63	3	43	2	22	1	10	0	6	0	1,952
Women	266	16	488	29	361	22	237	14	132	8	95	6	44	3	15	1	28	2	1,666
All	786	22	1,219	34	766	21	389	11	195	5	138	4	66	2	25	1	34	1	3,618

D. *Susceptibility Index.* A motion sickness susceptibility index was developed to provide a comparison between the 20 items involving motion. The susceptibility index was derived for each MSQ item (ignoring "no experience" answers) by calculating the mean score of all subjects who answered the item by using the following weights: 0=never sick, 1=rarely sick, 2=occasionally sick, 3=often sick, 4=almost always sick. Susceptibility index scores based on all subjects tested are presented in Table 2. An item with a high susceptibility index score is more likely to induce motion sickness than is an item with a low susceptibility index score. For instance, from Table 3 one can conclude than an individual is most likely to report the strongest degree of motion sickness susceptibility to carnival devices because those items had the highest susceptibility index scores in both subject groups.

E. *Experience With Forms of Motion.* Experience in motion situations for each of the three degree-of-susceptibility groups is shown in Table 3. Inspection of the data reveals that a significant overall difference ($p<.001$) was almost entirely due to the divergent scores from the very susceptible subjects; they reported fewer experiences in these motion situations. Men and women did not differ significantly.

TABLE 2. A Motion Sickness Susceptibility Index. Very Susceptible Subjects Are Those Whose Mean MSQ Scores for All 20 Items Were 1.00 or Higher.

Item	Susceptibility Index: All Subjects (N=3,618)	Susceptibility Index: Very Susceptible Subjects (N=251)
1. Large Ships	0.61	2.26
2. Small Boats	0.26	1.16
3. Merry-go-rounds	0.59	2.14
4. Roller Coasters	0.65	2.21
5. Ferris Wheels	0.47	2.01
6. Other Carnival Devices	0.98	2.56
7. Automobiles (as a passenger)	0.53	1.86
8. Buses	0.38	1.74
9. Trains	0.16	0.98
10. Subways	0.11	1.10
11. Streetcars	0.08	0.98
12. Airplanes (small or large)	0.46	1.91
13. Elevators	0.33	1.52
14. Swings	0.32	1.57
15. Hammocks	0.07	0.69
16. Ring and Bar Gymnastics	0.16	0.85
17. Somersaults	0.30	1.28
18. Rollerskating	0.05	0.44
19. Ice Skating	0.04	0.33
20. Dancing	0.06	0.34

TABLE 3. The Frequencies in Percentages With Which the Four Experience Categories Were Checked for the 20 Motion Items (MSQ-2)

Group	Number of Experiences: 0 (%)	1-3 (%)	4-9 (%)	10+ (%)	Total Experiences	Total N Subjects
Nonsusceptible	18	13	12	56	4,816	241
Moderately Susceptible	18	14	12	55	16,197	814
Very Susceptible	24	17	14	45	2,595	131
All Men	19	14	12	54	12,756	640
All Women	19	14	12	54	10,852	546

F. *Reported Changes in Susceptibility With Age.* Responses to items concerning how the individual's tendency to develop motion sickness may have changed since the age of 12 are presented in Table 4. Analysis of the data indicated a significant sex difference ($p<.001$) with women reporting more increases and fewer decreases in susceptibility since the age of 12 than did men. In comparing susceptibility groups, the majority of nonsusceptibles reported no change (although they denied any motion sickness experiences, 4 of 213 respondents indicated an increased tendency to develop motion sickness, and 25 others indicated a decreased tendency) whereas most of the moderately and very susceptible individuals reported a change in susceptibility ($p<.001$) with very susceptible subjects reporting the greatest percentage of increases (19 percent). More than 40 percent of the latter two groups indicated a decrease in susceptibility since the age of 12.

G. *Familial Susceptibility.* Estimates of motion sickness susceptibility in family members are presented in Table 5. This set of questions required the individual to estimate the motion sickness susceptibility of his or her parents and siblings. There were significant differences between susceptibility groups ($p<.001$ in each case) for reported susceptibility of sister(s), brother(s), mother, and father. In each instance, highly susceptible individuals more often reported having susceptible siblings and parents. In comparing differences between men and women, women more often reported having susceptible siblings (sister(s), $p<.05$; brothers(s), $p<.001$) than did men; however, this sex difference was not evident in responses to parents' susceptibility.

H. *Use of Motion Sickness Medication.* MSQ–1 inquired about the use of anti-motion-sickness drugs. Of the individuals tested, 16 percent of the men and 27 percent of the women reported they had taken a medication like Dramamine for motion sickness (Table 6). Women were more likely to take medication than were men ($p<.001$) and, as susceptibility increased, so did the frequency of taking anti-motion-sickness medication ($p<.001$).

I. *Muscular Coordination.* Subjects were asked to describe their muscular coordination on a five-category response scale (very poor to excellent). Men rated their coordination significantly better ($p<.001$) than did women. There were no statistically significant differences between susceptibility groups, but there was a tendency for very susceptible subjects to rate themselves lower than did moderately susceptible or nonsusceptible subjects (Table 7).

J. *Willingness to Participate in Motion Experiments.* Both MSQ–1 and MSQ–2 inquired about the subject's willingness to be a paid participant in mild motion experiments (Table 8). Results differed for the two administrations; specifically, for MSQ–1 there were no significant differences for sex or for susceptibility groups while MSQ–2 yielded significant differences for both sex and susceptibility. The difference in findings is probably attributable to the time of year that the two questionnaires were administered. Specifically, MSQ–1 was given near the beginning of a school semester and MSQ–2, in the latter half of that semester; the likelihood is strong that growing financial needs of the students dictated the change in willingness to be a paid volunteer. The increase from MSQ–1 to MSQ–2 in the proportion of subjects willing to be involved in a motion experiment was greatest for the nonsusceptible subjects and least for the very susceptible. It is worth noting that more than half the subjects in each susceptibility category, including the very susceptible, were willing, for pay, to participate in mild motion experiments.

K. *Phobias, Flying, and Visual Motion.* Table 9 presents data based on a series of four items from MSQ–2. Sex comparisons for the four items yielded the following results ($p<.001$ in each case); more men enjoyed movies with an emphasis on rapid motion, more men were pilots or had taken flying lessons, and more women were afraid of heights and of darkness. There were also significant differences between susceptibility groups on all four items ($p<.001$ by X^2 in each case): movies, flying lessons, heights, and darkness. However, nonsusceptible and moderately susceptible individuals did not differ on any of these items. Thus, very susceptible individuals can best be described as less likely to enjoy movies with an emphasis on rapid motion, less likely to have taken flying lessons, and more likely to fear heights and darkness. The same description would pertain to women as compared with men.

TABLE 4. The Percentages of Subjects by Group and Sex Describing How Their General Tendency to Develop Motion Sickness May Have Changed Since Age 12

Group	Increased (%)	No Change (%)	Decreased (%)	Don't Know (%)	Total N
Nonsusceptible	2	68	12	18	213
Moderately Susceptible	9	33	41	16	719
Very Susceptible	19	21	44	16	116
All Men	5	38	38	18	552
All Women	14	39	33	15	496

TABLE 5. Estimates by Group and Sex, in Percentages, of the Degree to Which Motion Sickness Was Evidenced in Family Members

Family Members	Group	Never or Rarely (%)	Sometimes (%)	Often or Almost Always (%)	Don't Know (%)	Number of Family Members Reported
Sister(s)	Nonsusceptible	61	16	1	22	231
	Moderately Susceptible	52	24	5	19	898
	Very Susceptible	23	34	9	33	160
	All Men	48	20	3	29	663
	All Women	52	28	6	14	626
Brother(s)	Nonsusceptible	73	7	0	19	267
	Moderately Susceptible	63	14	2	22	890
	Very Susceptible	28	26	6	41	156
	All Men	63	12	1	24	719
	All Women	58	16	3	23	594
Mother	Nonsusceptible	60	23	3	14	212
	Moderately Susceptible	48	31	6	15	717
	Very Susceptible	29	36	17	18	115
	All Men	47	30	6	16	546
	All Women	50	30	7	14	498
Father	Nonsusceptible	78	6	1	15	216
	Moderately Susceptible	71	12	1	15	711
	Very Susceptible	54	18	5	24	114
	All Men	72	10	1	16	547
	All Women	69	13	2	16	494

TABLE 6. The Percentages of Subjects by Group and Sex Who Indicated Whether They Had Ever Taken Medication Like Dramamine for Motion Sickness

Group	Yes (%)	No (%)	Total N
Nonsusceptible	4	96	543
Moderately Susceptible	24	76	1,744
Very Susceptible	52	48	132
All Men	16	84	1,306
All Women	27	73	1,113

TABLE 7. The Percentages of Subjects by Group and Sex as They Described Their Muscular Coordination

Group	Very Poor (%)	Below Average (%)	Average (%)	Above Average (%)	Excellent (%)	Total N
Nonsusceptible	0	4	36	39	20	216
Moderately Susceptible	0	5	43	36	16	720
Very Susceptible	1	9	45	34	10	116
All Men	0	2	33	41	23	554
All Women	1	8	51	31	9	498

TABLE 8. The Percentages of Subjects by Group and Sex Who Indicated Whether They Were Interested in Being Paid Volunteers in an Experiment That Involved Very Mild Motion

Group	MSQ-1 Yes (%)	MSQ-1 No (%)	MSQ-1 Total N	MSQ-2 Yes (%)	MSQ-2 No (%)	MSQ-2 Total N
Nonsusceptible	58	42	539	78	22	213
Moderately Susceptible	55	45	1,734	73	27	715
Very Susceptible	54	46	132	63	37	115
All Men	57	43	1,293	80	20	549
All Women	55	45	1,112	65	35	494

TABLE 9. The Percentages of Subjects by Group and Sex Who Indicated Whether They Liked Movies That Emphasize Rapid Motion, Are Pilots or Have Ever Taken Flying Lessons, and Are Afraid of Heights or of Darkness

Group	Like movies with rapid motion			A pilot or have taken flying lessons			Afraid of heights			Afraid of darkness		
	Yes (%)	No (%)	Total N	Yes (%)	No (%)	Total N	Yes (%)	No (%)	Total N	Yes (%)	No (%)	Total N
Nonsusceptibles	82	18	211	11	89	216	21	79	213	7	92	215
Moderately Susceptible	74	26	702	7	93	719	28	72	720	11	89	714
Very Susceptible	44	56	113	3	97	115	51	49	115	30	70	112
All Men	85	15	539	11	89	554	21	79	552	5	95	551
All Women	57	42	487	3	97	496	37	63	496	20	80	490

L. *Alcohol.* The last six items on the MSQ–2 questionnaire were concerned with the consumption of alcohol and specifically included a description of drinking habits (Table 10) and alcohol-induced hangovers (Table 11). From the results of Table 10, one can conclude that men drink more frequently and in larger quantities than do women ($p<.001$ in both cases). In general, the data indicate the degree of motion sickness susceptibility is not significantly related to alcohol consumption, although there is a tendency for the more susceptible both to drink less often and to drink less on each occasion.

In the descriptions of alcohol-induced hangovers, the frequency and severity of hangovers, as well as the general concern about having them, become significantly ($p<.001$ in each case) more prominent in individuals as susceptibility increases. In addition, men more frequently reported having hangovers than did women ($p<.01$), although women more frequently reported both that they worried about having a hangover ($p<.05$) and that they vomited or thought they were going to vomit following alcohol ingestion ($p<.001$).

V. Discussion.

Although most previous efforts have been directed toward determining the incidence of motion sickness in specific occupational populations (such as among pilot candidates or seagoing personnel) it is noteworthy that motion sickness affects a considerable number of people in the general population in relatively common situations. For example, our definition of very susceptible individuals as those whose mean motion sickness history questionnaire scores exceed 1.00 (see scoring procedure) accounts for 8 percent of our surveyed population. More-

TABLE 10. The Percentages of Subjects by Group and Sex as They Described Their Drinking Habits

Item	Group	Total abstainer (%)	Only one or two drinks in life (%)	Drink Rarely (%)	Drink occasionally (%)	Drink Often (%)	Total N
Description of drinking habits	Nonsusceptible	6	4	15	53	22	216
	Moderately Susceptible	8	6	13	57	17	719
	Very Susceptible	4	12	19	48	16	115
	All Men	8	5	10	55	23	553
	All Women	6	7	18	55	13	497

Item	Group	Total abstainer (%)	One time or less per month (%)	Two or three times per month (%)	One or two times per week (%)	Three or more times per week (%)	Total N
Frequency of drinking	Nonsusceptible	8	20	24	34	13	216
	Moderately Susceptible	11	21	28	28	11	716
	Very Susceptible	11	30	26	24	8	115
	All Men	11	15	24	33	16	553
	All Women	10	30	30	24	6	494

Item	Group	Total abstainer (%)	One (%)	Two or three (%)	Four or five (%)	Six or more (%)	Total N
Average amount of drinks per occasion	Nonsusceptible	8	14	36	24	17	215
	Moderately Susceptible	10	14	40	26	9	716
	Very Susceptible	10	19	40	22	9	115
	All Men	10	8	34	30	17	552
	All Women	9	22	45	21	3	504

TABLE 11. The Percentages of Subjects by Group and Sex as They Described Aspects of Their Alcoholic Hangovers

Item	Group	Never (%)	Rarely (%)	About Half the Time (%)	Frequently (%)	Always (%)	Total N
Have hangover after drinking	Nonsusceptible	47	43	8	1	1	210
	Moderately Susceptible	40	48	10	1	0	684
	Very Susceptible	35	42	12	10	0	113
	All Men	36	49	12	2	0	531
	All Women	47	44	7	2	0	476
Worry about hangover when drinking	Nonsusceptible	78	20	2	0	0	210
	Moderately Susceptible	70	25	4	1	0	682
	Very Susceptible	51	32	9	4	4	113
	All Men	71	24	4	1	0	529
	All Women	68	25	4	2	1	476
Vomited or felt like it after drinking	Nonsusceptible	35	61	3	1	0	211
	Moderately Susceptible	27	64	6	2	0	689
	Very Susceptible	32	46	10	10	2	112
	All Men	23	69	5	2	0	534
	All Women	36	53	6	3	1	478

over, slightly more than 20 percent of our population had taken a medication like Dramamine for motion sickness. In an increasingly mobile world, the extent of the problem of motion sickness susceptibility can only become greater.

Motion sickness history questionnaires provide an adequate approach to susceptibility determinations and have the advantage of quick administration with no sophisticated apparatus. In the present application, the test-retest reliability of MSQ–2 was of a magnitude sufficient to suggest good testing stability. Until the differences between susceptible and nonsusceptible individuals can be better defined, a prudent approach to several types of human research (e.g., vestibular, motion, and performance) would be to delineate motion sickness susceptibility for all subjects tested. This approach would allow better interstudy comparisons of results and might also provide an explanation for deviant results.

Our findings confirm the report[12] that proportionately more women than men report motion sickness. However, an unresolved question is whether this reported sex difference in susceptibility is based on physiological differences, on psychological differences, or on a combination of those two, or whether it is merely reflective of a socialization process in which it is more acceptable for women to report illnesses (including motion sickness). Bawkin[3] and Abe, Amatomi, and Kajiyama[1] have suggested that susceptibility differences are genetically determined. The latter have reported that at age 3, girls suffered more frequently (12.1 percent) from motion sickness than did boys (6.5 percent). A potential hereditary factor in motion sickness susceptibility may be supported by our results, which indicate that, compared to nonsusceptibles, susceptible individuals more often report susceptible parents or siblings. However, susceptible people may be more inclined to attend to and be aware of such characteristics in their family members.

Very susceptible individuals reported significantly fewer experiences with the 20 itemized motion situations than did nonsusceptibles. This probably reflects the simple fact that susceptible individuals avoid situations in which they are likely to become sick. Moreover, a little more than 40 percent of those who reported motion sickness experiences believed that their susceptibility had decreased since age 12. This finding is in agreement with the results of a previous MSQ study[12] and with the results of at least one experimental report.[5] Such a decrease in susceptibility with increasing age could be attributable to (i) avoidance of motion situations, (ii) a decrease in the physiological sensitivity of the vestibular sensory apparatus, or (iii) an increase in vestibular experiences with age and thus a learning-induced moderation of affect. The first possibility, an avoidance of motion situations, cannot account for the age-related reduction of demonstrated susceptibility shown by Chinn *et al.* wherein groups of subjects of different ages were exposed to the same motion stimuli. The second suggestion, a decrease in physiological sensitivity, is inconsistent with other work[8] that indicates, at least with young subjects, no differences between nonsusceptible and very susceptible men or women in vestibular nystagmus or in turning sensations produced in the laboratory despite the continuing high level of susceptibility of the latter group. The third possibility, that experience acts as a moderator of vestibular responses, seems to be the best current explanation of the age-related reduction in motion sickness susceptibility.

Since motion sickness can be induced by purely visual means,[10] it was not surprising that a significantly greater percentage of susceptible individuals did not like movies with an emphasis on rapid motion. Moreover, extremely susceptible individuals had a greater fear of heights and of darkness than did their less susceptible counterparts. The relationship of phobias to psychosomatic disturbances suggests that additional psychological characteristics may be associated with motion sickness susceptibility. A possibly related datum is that very susceptible individuals reported they more frequently worried about having alcoholic hangovers. Although alcohol affects vestibular functioning[6] and can produce undesirable effects similar to those encountered during motion sickness, there was no significant difference between our susceptible and nonsusceptible groups in the amount of alcohol consumed. However, in assessing the latter finding, one must consider the young age of our subjects and that their drinking habits may not be representative of other geographic regions.

Our data also indicate a number of significant sex differences related to motion sickness susceptibility. These findings suggest that behavioral profiles will differ for men and for women in relation to their degrees of susceptibility. In seeking to delineate characteristics of those prone to motion sickness, one must take into account these sex differences.

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NYSTAGMUS, TURNING SENSATIONS, AND ILLUSORY MOVEMENT IN MOTION SICKNESS SUSCEPTIBILITY

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I. Introduction.

Some previous investigators[18 20 23] have reported that vestibular sensitivity, as manifested by nystagmic eye movements, is of greater magnitude in motion sickness-susceptible individuals than in nonsusceptible individuals. However, there also have been reports of no differences in nystagmic output between susceptible and nonsusceptible individuals,[21] and at least one contrasting report[2] indicated that nonsusceptibles had more intense nystagmus.

Investigations concerning rotation-induced sensations of turning have been equally inconclusive.[19] Several early reports[1 9 15 23 26] and at least one recent report[24] indicated that susceptibles had longer durations of turning sensations or steeper sensation cupulograms than did nonsusceptibles. However, other experiments have not substantiated these reports; for example, in one study Dobie[10] found that sensation cupulograms were significantly less steep for susceptible student pilots than for nonsusceptible student pilots, although in later, more extensive studies[11] he concluded that sensation cupulograms were not significantly different for susceptible and nonsusceptible individuals. The later finding was supported by Clark and Stewart,[5] who reported that thresholds for the perception of rotation were not correlated with motion sickness susceptibility.

Although it is logically appealing to speculate that motion sickness-susceptible individuals have more sensitive vestibular systems, the conflicting reports do not provide unequivocal support for this position. It should be pointed out that sensitivity differences are not necessary to explain differential susceptibility to motion sickness. For instance, Graybiel's model[13 14] of the structural elements of motion sickness does not necessarily suggest that susceptible and nonsusceptible individuals will differ in their nystagmic or subjective turning responses. The basic proposition of his theory is that two separate response systems are activated by vestibular stimulation. The first, or V I, response system is characterized by nystagmic eye movements, sensations of turning, oculogyral illusions, dizziness, and ataxia. The second, or V II, response system is manifested by the classic components of motion sickness: sweating, pallor, nausea, and vomiting. The factor that determines whether a V I response will activate the V II system is obtusely termed the "facultative linkage." Graybiel's theory implies that the individual who has a strong facultative linkage is more susceptible to motion sickness than is an individual who has a weak facultative linkage. Although the precise nature of this facultative linkage is not described, it may involve a neurophysiological mechanism or some other general nervous system phenomenon. The crux of the Graybiel theory is that primary vestibular responses (V I) are mediated by a system separate from that which mediates motion sickness (V II). Thus, individuals differing in their susceptibility to motion sickness would not necessarily be expected to differ in their primary vestibular responses.

Some of the conflicting reports of nystagmus differences between susceptibles and nonsusceptibles may have been the result of several experimental deficiences related to a restricted range of subject samples, inadequate control of subjective alertness, or factors associated with previous laboratory experience and habituation processes. In this study, susceptible and nonsusceptible subjects were chosen from a laboratory-naive general population (students) so that the subject samples were not biased by a self-exclusion process (such as might exist in a pilot-candidate population) and were not comparisons of individuals who were laboratory naive with those who were laboratory experienced.

Since it is well known that nystagmic responses can be enhanced by increasing the subject's alertness level and, conversely, can be greatly dimished by decreasing his alertness level,[6 22] one of the specific goals of the present study was to determine how alertness levels, as defined by mental arithmetic and reverie instructions, affect the expression of nystagmus in motion sickness-susceptible and nonsusceptible individuals; another goal was to carefully assess motion sensations. Of secondary interest was Reason's report[24] that individuals having long spiral aftereffect (SAE) durations (i.e., long durations of apparent motion of a stationary spiral subsequent to viewing it while it was turning) had high scores on a motion sickness questionnaire (MSQ) and, conversely, low SAE scores were associated with low MSQ scores. Although it is tempting to conclude that motion sickness susceptibles have longer SAE durations than do nonsusceptibles, this conclusion may be unjustified because Reason's subjects were selected on the basis of extreme SAE scores and not on the basis of MSQ scores. Since the present study was particularly concerned with delineating individuals in the extremes of motion sickness susceptibility, it was on this basis (MSQ scores) that subject groups were selected and SAE durations compared.

II. Method.

A. *Subjects.* Forty-eight college students ranging in age from 18 to 39 yr served as subjects. Only one subject was older than 30, and the mean age of the group was 22.0 yr. The subjects were separated into four groups (N=12 subjects per group) on the basis of sex and susceptibility to motion sickness (susceptible men, susceptible women, nonsusceptible men, nonsusceptible women). Susceptibility to motion sickness was determined by scores on a biographical motion sickness history questionnaire administered to a larger group of students.

Our motion sickness questionnaire was a modified version of one used by Birren[3] and was scored on the basis of responses to questions concerning the individual's tendency to develop motion sickness in a variety of situations (e.g., while riding in automobiles, trains, or roller coasters). The MSQ was administered to a large group of students, and only individuals who had extreme scores were considered for inclusion in the experimental groups. Twenty-two percent of the total population tested (N=2,426) indicated that they had never been motion sick on any of the 20 items included in the MSQ; all "nonsusceptible" subjects were drawn from this group. "Susceptible" subjects were drawn from the other extreme; viz, from among the 9 percent having the highest questionnaire scores in the total population tested.

Subjects reporting a history of inner-ear problems, deafness, oculomotor disturbances, or head injuries that resulted in prolonged unconsciousness were eliminated from the study. All subjects were paid volunteers who agreed to remain free of drugs for at least 48 h prior to the testing period (this did not include birth control medications used by some of the female subjects). Female subjects were tested between days 6 and 20 of their menstrual cycle to avoid possible confounding effects of menstrual and premenstrual symptoms.

B. *Rotation Trials.* All rotatory stimuli were delivered via an enclosed Stille-Werner RS-3 rotation device located in a lightproof room. Each subject sat above the center of rotation in a small simulated cockpit fitted with two head restraints. One restraint held the subject's head in a normal, relatively upright position, placing the lateral semicircular canals approximately in the plane of rotation. The other head restraint was designed so the subject looked down 90° (1.57 rad) and to his left 45° (0.78 rad), thereby placing a pair of vertical semicircular canals approximately in the plane of rotation. In addition, the subject held a microswitch for signaling the start of turning, each perceived 90° turn, and the cessation of turning sensations.

Each subject was tested during a single session that consisted of 12 rotation trials with intertrial rest intervals of 2 min each. All trials were conducted in total darkness and involved rotation in a clockwise direction. Each odd-numbered trial was an 18-s acceleation at $5°/s^2$ ($0.09 rad/s^2$) followed by rotation at a constant velocity of 90°/s (1.57 rad/s). During each of the acceleration trials, the subject estimated his turning velocity in a manner similar to that described by von Békésy[27] and by Groen and Jongkees.[15] Each even-numbered trial consisted of a deceleration at $5°/s^2$ and resulted in the cockpit's becoming stationary. During the deceleration trials, the subject, according to instructions, either performed a mental arithmetic problem or assumed a reverie state. In trials 1 through 8, the rotatory stimulation was applied to the lateral semicircular canals (the first four trials were used to familiarize the subjects with apparatus and procedures; these trials were not scored); in trials 9 through 12, the rotatory stimulation was applied to the vertical semicircular canals.

C. *Recording.* Electrodes were taped to the outer canthus of each eye to record horizontal eye movements. Vertical eye movements were recorded from a pair of electrodes positioned above the left eyebrow and below the eye on the malar surface. A ground electrode was placed near the center of the forehead. The corneoretinal potentials were amplified and recorded by an Offner type T electroencephalograph using a 3–s time constant.

Eye movements were calibrated by means of lights mounted on the front of the cockpit and subtending a visual angle of 15° (0.26 rad). Both horizontal and vertical eye calibrations were taken periodically during the testing sequence.

D. *Scoring.* Horizontal nystagmus was scored with respect to total duration, number of nystagmic beats, and slow-phase displacement (degrees of eye movement). The duration of nystagmus was the time in seconds from the start of the stimulus to the last nystagmic beat. The number of nystagmic beats was the total number of beats (fast phases) that occurred during a given trial. Slow-phase displacement was the total extent to which the eyes deflected in a given direction during primary nystagmus. Eye movement calibrations allowed slow-phase eye displacement to be quantified in degrees. In all instances, the scorer was not informed of the subject category or stimulus condition.

Vertical nystagmus during acceleration trials was scored in the same manner as was horizontal nystagmus. Vertical nystagmus during deceleration trials was often of poor quality[8 12 16 17] and, as a result, was scored by an output rating technique that yielded scores of 0 (no nystagmus) to 4 (vigorous nystagmus). The rating was conducted by an experienced nystagmus rater under a strict double-blind procedure wherein the rater was unware of subject category or stimulus condition.

Sensations of turning were measured with respect to duration and the number of reported 90° turns. Duration was the time in seconds from the initiation of physical turning to the signal representing the end of subjective turning. The number of 90° turns was the total number of subjective signals minus two (start and stop signals).

E. *Spiral Aftereffect.* The stimulus was a black, three-throw, arithmetic spiral imposed on a white disc 20.32 cm in diameter. The disc was positioned at a distance of 1.52 m from the seated subject and was operated at a speed of 100 r/min.

Each subject was instructed to maintain visual fixation on the center of the spiral disc and to estimate the persistence time of the SAE following randomized induction periods of 15, 30, 60, and 110 s. There were three practice trials, each having an induction period of 30 s. The test trials consisted of three repetitions of each induction period; the order of presentation was randomized for each subject.

III. Results.

A. *Nystagmus.*

1. Subjective turning condition. Table 1 presents the mean nystagmus measures obtained from stimulation of the horizontal and vertical semicircular canals during those trials in which subjects signaled their turning sensations. Based on the 0.05 level of significance, separate analyses of variance revealed no significant sex nor susceptibility main effects or interactions for any of the nystagmus measures (slow phase, number of beats, and duration).

2. Mental arithmetic and reverie conditions. Nystagmus measures obtained from stimulation of the horizontal semicircular canals during the reverie and the mental arithmetic conditions are presented in Table 2. There were no overall differences between susceptibles and nonsusceptibles for either condition. However, the mental arithmetic condition was associated with significantly greater magnitude of slow-phase nystagmus (F (1, 44) = 130.75, $p < .001$) and nystagmus duration (F (1,44) = 38.72, $p < .001$) when compared to the reverie condition. Thus, changing the subject's instruction set significantly changed both slow-phase nystagmus and nystagmus duration. In addition to the significant main effect, there were significant interactions of sex x sus-

TABLE 1. Mean Nystagmus Measures During Trials in Which Turning Sensations Were Recorded

		Motion Sickness Susceptibles			Motion Sickness Nonsusceptibles			Group Means by Sex		
		Nystagmus Slow Phase (Degrees)	Number of Nystagmic Beats	Nystagmus Duration (Seconds)	Nystagmus Slow Phase (Degrees)	Number of Nystagmic Beats	Nystagmus Duration (Seconds)	Nystagmus Slow Phase (Degrees)	Number of Nystagmic Beats	Nystagmus Duration (Seconds)
Horizontal Canal Stimulation	Men	774	79	49	794	95	52	784	87	50
	Women	1013	85	53	847	77	53	930	81	53
	Means	894	82	51	821	86	52			
Vertical Canal Stimulation	Men	345	35	28	393	29	24	369	32	26
	Women	442	33	28	437	37	27	440	35	27
	Means	393	34	28	415	33	25			

TABLE 2. Mean Nystagmus Measures for Horizontal Canal Stimulation During Reverie and Mental Arithmetic Conditions

		Reverie or Low-Alertness Condition			Mental Arithmetic or High-Alertness Condition		
	N	Nystagmus Slow Phase (Degrees)	Number of Nystagmic Beats	Nystagmus Duration (Seconds)	Nystagmus Slow Phase (Degrees)	Number of Nystagmic Beats	Nystagmus Duration (Seconds)
Susceptible Men	12	570	76	45	773	74	49
Susceptible Women	12	660	78	46	1054	79	55
Nonsusceptible Men	12	495	86	45	964	103	61
Nonsusceptible Women	12	666	85	47	996	78	54
All Men	24	532	81	45	868	89	55
All Women	24	663	81	46	1025	78	54
All Susceptibles	24	615	77	46	913	76	52
All Nonsusceptibles	24	580	86	46	980	90	57

ceptibility x instructions for slow-phase nystagmus (F (1, 44) = 7.31, $p < .05$) and nystagmus duration (F (1, 44) = 5.99, $p < .05$).

It should be noted that a simple effects comparison indicated that in the mental arithmetic condition, susceptible men had significantly less slow-phase nystagmus than did nonsusceptible men. This particular finding might be interpreted as suggesting the existence of a sex-linked trait expressed only in an alert or activated state. But this possibility seems minimal because differences were not obtained between the same two groups in the subjective turning trials (Table 1), which also involved heightened alertness.

The significant three-way interactions for slow-phase nystagmus and nystagmus duration were largely the result of the unusually low scores of two individuals in the susceptible male group. Data from the female groups indicated that motion sickness susceptibility was not consistently associated with either slow-phase or duration scores.

During vertical semicircular-canal stimulation, the reverie and mental arithmetic conditions produced nystagmus scores (ratings, in this case; Table 3) that yielded no statistical difference based on susceptibility to motion sickness but did yield a significant main effect for instructional conditions (F (1, 43) = 4.89, $p < .05$). Again, there was more nystagmus in the mental arithmetic condition than in the reverie condition. There was also a significant main effect of sex (F (1, 43) = 5.81, $p < .05$) in that women had a higher vertical nystagmus rating. Although women consistently had more slow-phase nystagmus in all conditions (Tables 1, 2, and 3), the only measures that evidenced a statistically significant difference between men and women were these vertical nystagmus ratings.

There was a significant sex x instructions interaction for the vertical nystagmus rating; a simple effects test indicated that the nystagmus rating for women was significantly lower in the reverie condition than in the mental arithmetic condition (F (1, 43) = 9.28, $p < .01$), whereas the ratings for men did not significantly differ between the instructional conditions. The difference in nystagmus ratings between men and women was not significant for the reverie condition but was significant for the mental arithmetic condition (F (1, 43) = 10.06, $p < .01$). It should be pointed out that the nystagmus rating for men decreased slightly from the reverie condition to the mental arithmetic condition. The decrease may be attributed (i) to two nonsusceptibible men who had large rating differences across the reverie to the mental arithmetic condition (Table 3) and (ii) possibly to the coarseness of the rating categories and the difficulty inherent in rating vertical nystagmus. The differences obtained here between the durations of vertical canal and of horizontal canal responses are consistent with differences in the time constant for those two sets of canals as reported in a number of other studies.

TABLE 3. Mean Nystagmus Ratings for Vertical Canal Stimulation During Reverie and Mental Arithmetic Conditions

	N	Reverie or Low-Alertness Condition	Mental Arithmetic or High-Alertness Condition
Susceptible Men	12	1.04	1.25
Susceptible Women	11*	1.50	2.18
Nonsusceptible Men	12	1.58	1.36
Nonsusceptible Women	12	1.73	2.13
All Men	24	1.31	1.30
All Women	23*	1.80	2.15
All Susceptibles	23*	1.26	1.70
All Nonsusceptibles	24	1.66	1.74

*One record was not scoreable.

TABLE 4. Mean Subjective Turning Measures

	N	Duration of Turning Sensations (Seconds)		The Number of Reported 90° Turns	
		Horizontal Canal Stimulation	Vertical Canal Stimulation	Horizontal Canal Stimulation	Vertical Canal Stimulation
Susceptible Men	12	32	24	19	14
Susceptible Women	12	35	26	21	15
Nonsusceptible Men	12	36	27	23	16
Nonsusceptible Women	12	29	24	17	12
All Men	24	34	26	21	15
All Women	24	32	25	19	14
All Susceptibles	24	33	25	20	15
All Nonsusceptibles	24	33	26	20	14

B. *Sensations of Turning.* The mean scores for the total duration of turning and the number of reported 90° turns are presented in Table 4. Based on the 0.05 level of significance, separate analyses of variance revealed no significant sex or susceptibility effects for both measures. However, horizontal semicircular-canal stimulation elicited much stronger sensations than did vertical semicircular-canal stimulation for both the duration of sensation (F (1, 44) = 126.56, $p<.001$) and the number of 90° turns reported (F (1, 44) = 101.56, $p<.001$). These results are probably attributable to differences in the response characteristics of the two sets of canals,[7, 12] but the fact that horizontal canal stimulation always preceded that of the vertical canals must be considered. In addition, there was a significant sex *x* susceptibility interaction (F (1, 44) = 7.42, $p<.01$) for the duration measures.

C. *Spiral Aftereffect.* The average durations of the sprial aftereffect illusion for the four induction periods are presented in Table 5. Nonsusceptible individuals had significantly shorter SAE durations than did susceptibles (F (1, 44) = 5.62, $p<.01$). There was a significant main effect across induction periods (F (3, 132) = 63.69, $p<.001$) in that longer induction periods produced longer SAE durations. In addition, there was a significant susceptibility *x* induction-period interaction (F (3, 132) = 4.82, $p<.01$). The significant interaction indicates that the motion sickness-susceptible individuals had a greater absolute increase in reported SAE durations as a function of increasing SAE induction periods than did nonsusceptibles. This result suggests that longer induction periods would have greater reliability if SAE durations were used to predict motion sickness susceptibility.

TABLE 5. Mean Spiral Aftereffect (SAE) Duration (Seconds)

	N	SAE Induction Period (Seconds)				
		15	30	60	110	Total
Susceptible Men	12	12.9	16.9	21.5	25.5	76.8
Susceptible Women	12	10.5	14.4	17.5	22.9	65.3
Nonsusceptible Men	12	6.0	8.6	10.3	11.9	36.8
Nonsusceptible Women	12	7.4	9.4	12.5	15.6	44.9
All Men	24	9.5	12.8	15.9	18.7	56.9
All Women	24	9.0	11.9	15.0	19.2	55.1
All Susceptibles	24	11.7	15.7	19.5	24.2	71.1
All Nonsusceptibles	24	6.7	9.0	11.4	13.8	40.9

IV. Discussion.

The primary emphasis of this study was to investigate the relationship of motion sickness susceptibility to both nystagmic eye movements and turning sensations elicited by vestibular stimulation. Contrary to data reported by other investigators,[18 20 23] the results of the present study indicate that motion sickness susceptibility is not consistently reflected in the magnitude of elicited nystagmus and, clearly, there is no enhancement of nystagmus in susceptible individuals.

It is apparent from the present results, as well as from other reports,[4 6] that an increased alertness level of the subject has an enhancing influence on elicited nystagmus. Uncontrolled alertness levels could account for some of the reports indicating that individuals susceptible to motion sickness have more nystagmus than do nonsusceptibles. For example, it is possible that nonsusceptible individuals being tested over several trials in a dark environment could have become bored and drowsy and thus experienced a consequent loss of alertness; such a condition would tend to produce nystagmus of relatively low intensity. Conversely, susceptible individuals in the same situation may have maintained alertness because of the unpleasant and perhaps threatening vestibular stimuli. The current data indicate that instructional procedures to control alertness fluctuations are particularly important when a decrease in alertness level across trials may be mistaken for decreased vestibular sensitivity or response habituation.

Motion sickness susceptibility was not reflected in the intensity or duration of turning sensations among subjects tested in this study. That some of the previous reports concerning turning sensations were in conflict may have been due to characteristics of the cupulometric technique employed. In comparison to most of the older studies, the current procedure used an acceleration of lower magnitude and longer duration, thereby allowing more time for central nervous system (CNS) processes to influence after-responses. The procedure should have been advantageous for discriminating among people with differentially developed adaptive or suppressive mechanisms.

The secondary emphasis of this study was to investigate the relationship between motion sickness susceptibility and persistence of the spiral aftereffect. The results indicated that motion sickness susceptibiles had longer SAE durations than did their counterpart nonsusceptibles; however, there was a large overlap in the range of scores. When considering individual SAE scores, susceptibility was best differentiated in the group of women. Thus, while there appears to be a relationship between motion sickness susceptibility and spiral aftereffect duration, the magnitude of this relationship is not such that highly reliable predictions of motion sickness susceptibility can be made on the basis of SAE values. In differentiating motion-sickness-susceptible and nonsusceptible individuals, the current SAE results are in agreement with those reported by Reason.[24] However, the current results tend not to support the Reason and Benson report[25] of a significant correlation between visual and labyrinthine aftersensations. If susceptibility can be differentiated by aftereffect characteristics in several sensory modalities as suggested by Reason and Benson,[25] then both motion sickness susceptibility and the aftereffect phenomenon are probably associated with a general CNS mechanism (i.e., inhibition), which could be important from a theoretical basis. Future studies should be directed toward further clarification of the relationship between susceptibility to motion sickness and characteristics of responses to the SAE and other aftereffect illusions.

There were no significant overall sex differences for nystagmus, sensations of turning, or SAE durations; however, there was a tendency for women to have more slow-phase nystagmus. This tendency, quite consistent but subtle in nature, suggests that further exploration of potential sex differences in nystagmic responses may be warranted.

From a theoretical approach, the lack of overall differences between motion sickness-susceptible and nonsusceptible individuals in nystagmus and sensations of turning clearly refutes the classical theory that these responses are enhanced in susceptible individuals. Moreover, since indivdiual differences in motion sickness susceptibility are not correlated with nystagmic responses or sensations of turning, it is suggested that approaches that use these responses to assess the effectiveness of anti-motion-sickness drugs will have limited validity.

The spiral aftereffect results suggest that motion sickness susceptibility may be related to some general CNS phenomenon that may be synonymous with the facultative linkage mechanism proposed by Graybiel.[13 14] The results are consistent with the implication from the Graybiel model that nystagmus and sensations of turning (V I responses) are not necessarily directly related to the classic symptoms of motion sickness (V II responses). It is speculated that a general nervous system process, such as inhibition, may be differentially developed in individuals and may be overtly expressed in spiral aftereffect durations, motion sickness susceptibility, and, perhaps, a variety of other measures but not in the primary measures of vestibular responses—nystagmus and turning sensations.

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SOME PSYCHOLOGICAL CORRELATES OF MOTION SICKNESS SUSCEPTIBILITY

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I. Introduction.

In earlier conceptions of what is currently known as motion sickness, individuals were considered to be of weak constitution and generally lacking in "moral fibre" if they manifested motion sickness symptoms. This viewpoint persisted in the literature through the late 1940's despite chronic motion sickness in individuals renowned for their courage, such as Julius Caesar, Lord Nelson, and Lawrence of Arabia.[19] During and following World War II, airsickness, one form of motion sickness, became a particular concern of the military and was often attributed primarily to psychic factors, such as tension, fear, anxiety, or nervousness.[5 9 10 16 21 24 26 29 33] In addition to airsickness, some chronic seasickness among Navy personnel was reported to be strongly associated with neurotic traits and a tendency toward fainting as revealed during psychiatric examinations.[27]

In the years immediately following World War II, the only noteworthy attempt to associate psychological characteristics with susceptibility was made by Birren,[1] who reported a significant positive correlation ($r=0.43$) between scores on the Cornell Selectee Index (a neuropsychiatric inventory) and those on a motion sickness history questionnaire. Although Birren and his predecessors had noted that some psychological factors appeared to be related to motion sickness, studies conducted by Wendt[31] were influential in causing this line of research to be almost abandoned for a decade. Wendt indicated that the primary cause of motion sickness was stimulation of the vestibular sensory apparatus and that "factors such as physiological state, posture, and wave-character are of far greater potency than psychological factors in their effects on motion sickness rates."

Zwerling[35] took exception to Wendt's suggestion. In 1947, Zwerling[34] had shown that the incidence of motion sickness in experimental subjects was significantly increased when they were exposed to electric shock during rotation trials; he concluded that fear or anxiety heightened susceptibility. He also noted a relationship (statistically nonsignificant) between motion sickness susceptibility and neurotic tendencies indicated as defined by the Minnesota Multiphasic Personality Inventory (MMPI). In reply to Wendt, Zwerling indicated that sensory stimulation, psychosomatic factors, general physical fitness, type of motion, and secondary factors (e.g., temperature, ventilation) were all operative in the etiology of motion sickness and there was no basis for the selection of any one as the single cause of motion sickness.

Naval cadets have been the subjects of many of the more recent studies of motion sickness susceptibility and personality characteristics. Harris[12] reported that conventional analyses of Rorschach Test scores and MMPI profiles provided no replicable differences between airsick and nonairsick cadets; however, he concluded that there remained at least suggestive evidence of a greater disturbance in personality functioning among the airsick group. In a study of nine cadets, McMichael and Graybiel[18] reported significant relationships between demonstrated motion sickness susceptibility and the Rorschach-derived composite dimensions of "rigidity" and "lability."

Using large samples (157–229) of naval flight students, Guedry and Ambler[11] reported that neuroticism on anxiety scores (from the Eysenck Personality Inventory and the Omnibus Personality Inventory) "tended to correlate significantly" with motion sickness symptoms (produced by a laboratory motion device) as rated in the Brief Vestibular Disorientation Test (BVDT); they also noted a significant (unspecified) correlation between BVDT symptoms and the masculinity-femininity scale of the Omnibus Personality Inventory (the masculinity end of the scale related to low motion sickness sensitivity). Similarly, Reason and Graybiel[23] have reported significant but small (about 0.20) correlations between the motion sickness history of 70 naval cadets and both the introversion and the neuroticism scales of the Eysenck Personality Inventory. A similar study by Wilding and Meddis[32] found that among a group of 60 students, motion sickness history was significantly correlated with Eysenck's neuroticism ($r=0.46$) but not with introversion ($r=0.04$). These results were, however, contrary to those obtained by Kottenhoff and Lindahl,[13] who had tested 50 volunteer subjects in the laboratory and reported a significant correlation (0.35) between introversion as measured by the Maudsley Personality Inventory (MPI) and demonstrated motion sickness symptoms. The MPI measure of neuroticism did not correlate significantly with the demonstrated symptoms, nor did either measure correlate significantly with a travel sickness questionnaire. Moreover, anxiety, as defined by the Taylor Manifest Anxiety Scale, showed no correlation with either the questionnaire or demonstrated symptoms.

The many studies on the relationship of personality factors to motion sickness susceptibility have varied considerably in their investigative approaches and perhaps even more divergently in their conclusions. A reason for the divergent findings may pertain to the subject populations used. In the vast majority of studies, subjects have been prescreened military trainees; in a few other studies, they have been relatively small groups of people unscreened for susceptibility characteristics. The need for a comparison of highly susceptible with nonsusceptible people was noted as early as 1949 by Tyler and Bard,[30] whose comments in this regard were more recently cited by Reason and Brand.[22] The intent of the present study was to conduct a comprehensive investigation of the relationship between motion sickness susceptibility and selected personality factors by comparing subjects who report high susceptibility to motion sickness with subjects who report nonsusceptibiilty to any form of motion sickness.

II. Method.

A. *Subjects.* Four groups of 37 subjects each (susceptible men, susceptible women, nonsusceptible men, nonsusceptible women) were obtained from a college student population ranging in age from 18 to 39 years. Susceptibility to motion sickness was determined by scores on a modified version of the motion sickness questionnaire (MSQ) used by Birren.[1] The MSQ was administered to a large group of university students (N=2,432), and only individuals with extreme scores were considered for inclusion in the experimental groups.[15] Twenty-two percent of the total population tested indicated that they had never been motion sick on any of the 20 items included in the MSQ (e.g., automobiles, trains, roller coasters, ships); all nonsusceptible subjects were drawn from this extreme. Susceptible subjects were drawn from the other extreme; viz, from among the 9 percent with the highest questionnaire scores in the total population tested. Within the susceptible and nonsusceptible categories, the experimental subjects were chosen at random.

B. *Procedure.* Each subject was tested on at least three but not more than six of the eight tests in Table 1 (the total number for each test is indicated in the table). The tests were administered in accordance with directions in respective test manuals or in published references with one exception: subtests in the Floor Ataxia Test Battery were presented in a modified order.

1. The Floor Ataxia Test Battery[7] is reported to be an indicator of the loss or impairment of vestibular function. The battery consists of five subtests that measure equilibrium while standing or walking without the aid of vision. The tests and their order of presentation were: Stand on One Leg—Eyes Closed (SOLEC: both left and right legs), Sharpened Romberg (SR: standing heel to toe), Walk on Floor—Eyes Closed (WOFEC), and Walk a Line—Eyes Closed (WALEC).

2. The State-Trait Anxiety Inventory (STAI) developed by Spielberger and his associates[28] assesses anxiety characteristics. The first portion of the STAI measures the individual's "state" anxiety, an expression of the individual's ongoing or current anxiety level, which can fluctuate considerably with changes in environmental situations. The second portion of the

TABLE 1. Number and Category of Subjects Administered Each of the Eight Tests

Tests	Susceptibles		Nonsusceptibles		
	Men	Women	Men	Women	Total
Floor Ataxia Test Battery	37	37	37	37	148
Cornell Medical Index	37	37	37	37	148
Cornell Word Form	25	25	25	25	100
Eysenck Personality Inventory	25	25	25	25	100
Rotter Internal-External Control Scale	25	25	25	25	100
16 PF (Form A)	25	25	25	25	100
State-Trait Anxiety Inventory	12	12	12	12	48
Menstrual Distress Questionnaire	--	12	--	12	24

STAI measures the individual's predisposition ("trait") towards anxiety. Trait anxeity is considered a relatively stable behavioral characteristic or pattern indicative of the individual's general response to anxiety-producing events. The STAI comprises 40 statements that people use to describe themselves. The first 20 statements describe the individual as he feels right now, and the last 20 statements, as he generally feels. For instance, to the statement "I feel calm" the individual has the choice of the following replies: not at all, somewhat, moderately so, or very much so. All subjects who completed the STAI were also used as subjects in another experiment involving whole-body rotation.[14] Following the rotation experiment, the subjects again completed the "state" portion of the STAI, and, therefore, both prerotation and postrotation state anxiety scores were obtained.

3. The Menstrual Distress Questionnaire (Form A) was constructed to determine the extent to which women experienced common menstrual symptoms.[20] The questionnaire asks a respondent to rate her degree of menstrual-related distress for 47 symptoms during three phases of her most recent menstrual cycle (menstrual flow, 1 week before menstrual flow, remainder of cycle). The distress rating is a 6-point scale ranging from no experience of the symptom to an acute or partially disabling experience.

4. The Cornell Medical Index (CMI) is a health questionnaire designed to collect general medical and psychiatric data to facilitate patient examination.[2] The CMI is composed of 195 questions concerning a wide variety of medical and emotional problems that may have occurred in an individual's past; a "yes" or "no" answer is required to each item.

5. The Cornell Word Form (CWF–2) was designed to screen for potentially serious neuropsychiatric and psychosomatic disturbances. It consists of 80 single-word items to which the respondent associates one of two alternate descriptions.

6. The Eysenck Personality Inventory (EPI) measures personality in terms of two dimensions, extraversion-introversion and neuroticism-stability;[6] a Lie Scale is included. The EPI was developed from the earlier Maudsley Personality Inventory (MPI) and correlates highly with it. The test presents 57 questions relating to how the respondent may behave, feel, and act; each question requires a "yes" or "no" answer.

TABLE 2. Mean Scores for the Floor Ataxia Test Battery, the State-Trait Anxiety Inventory, the Cornell Medical Index (CMI), the Cornell Word Form (CWF), the Eysenck Personality Inventory (Extraversion, Neuroticism, and Lie Scales), and the Rotter Internal-External (I-E) Control Scale

	Floor Ataxia Test Battery					State-Trait Anxiety Inventory			Cornell Tests		Eysenck			Rotter
	SOLEC-R	SOLEC-L	SR	WOFEC	WALEC	Trait	State (Before Rotation)	State (After Rotation)	CMI	CWF	E	N	L	I-E Scale
Susceptible Men	89.6	86.4	208.8	26.1	35.9	37.5	35.8	37.2	22.5	3.7	12.1	8.9	2.8	9.6
Susceptible Women	75.1	68.3	196.8	25.2	44.9	35.7	31.9	37.5	28.0	4.0	13.4	10.4	2.4	10.7
Nonsusceptible Men	79.1	89.6	212.7	28.0	28.0	30.1	31.3	28.5	10.7	1.8	15.4	6.6	2.3	9.2
Nonsusceptible Women	57.0	61.2	180.2	23.5	49.1	30.6	32.9	32.3	17.0	1.8	13.2	7.3	2.6	11.1
All Men	84.4	88.0	210.7	27.1	31.9	33.8	33.6	32.8	16.6	2.8	13.8	7.8	2.6	9.4
All Women	66.0	64.7	188.5	24.3	47.0	33.1	32.4	34.9	22.5	2.9	13.3	8.8	2.5	10.9
All Susceptibles	82.4	77.3	202.8	25.6	40.4	36.6	33.9	37.3	25.3	3.9	12.7	9.6	2.6	10.1
All Nonsusceptibles	68.0	75.4	196.4	25.8	38.6	30.3	32.1	30.4	13.9	1.8	14.3	7.0	2.5	10.2

7. The Rotter Internal-External Locus of Control Scale[25] was developed to assess the extent to which individuals believed that they could control or influence events that affect them. For each of 29 items the subject must select one of a pair of statements about how he/she is affected by societal events.

8. The 16 Personality Factors (16 PF) test (Form A) is a multidimensional personality factor questionnaire established on the basis of Cattell's concept of the total human personality.[3] The test consists of 187 items to which one of three alternative responses must be selected (e.g., Money cannot bring happiness: (a) true (b) in between (c) false.). Scores can be determined for 16 primary factors, 8 secondary factors, and 4 criteria factors. The factors are described in detail elsewhere[2] but may be summarized, in order, as follows:

a. Primary factors: (A) reserved—outgoing; (B) dull—bright; (C) affected by feelings—emotionally stable; (E) humble—assertive; (F) sober—happy-go-lucky; (G) expedient—conscientious; (H) shy—venturesome; (I) tough minded—tenderminded; (L) trusting—suspicious; (M) practical—imaginative; (N) forthright—astute; (O) self-assured—apprehensive; (Q_1) conservative—experimenting; (Q_2) group dependent—self-sufficient; (Q_3) undisciplined self-conflict—controlled; (Q_4) relaxed—tense.

b. Secondary factors: (1) extraversion—introversion; (2) low anxiety—high anxiety; (3) sensitivity—tough poise; (4) dependence—independence; (5) discreetness; (6) prodigal subjectivity; (7) fluid intelligence; (8) superego.

c. Criterion factors: (1) neuroticism; (2) leadership; (3) creativity; (4) school achievement.

III. Results.

Group means for all tests except the Menstrual Distress Questionnaire and the 16 PF are presented in Table 2. With the same exceptions, all data were evaluated by using a two-way analysis of variance; the respective F-values are presented in Table 3 with $p<.05$ the accepted level for significance.

TABLE 3. Results of Analyses of Variance of Test Scores (F Ratios)

Test	Sex	Susceptibility	Sex x Susceptibility	dF
Ataxia Battery				
SOLEC-R	6.22 *	3.82	0.27	1,144
SOLEC-L	9.37 **	0.06	0.46	1,144
SR	4.76 *	0.39	1.02	1,144
WOFEC	8.00 **	0.03	3.52	1,144
WALEC	9.21 **	0.13	1.48	1,144
STAI				
Trait	0.14	8.14 **	0.24	1,44
State (Before Rotation)	0.44	0.99	2.44	1,44
State (After Rotation)	0.83	9.18 **	0.59	1,44
Cornell				
CMI	4.88 *	18.14 ***	0.02	1,144
CWF	0.06	12.89 ***	0.15	1,96
Eysenck				
EPI-E	0.50	4.99 *	6.05 *	1,96
EPI-N	1.97	12.11 ***	0.33	1,96
EPI-L	0.04	0.22	1.58	1,96
Rotter	3.23	0.00	0.17	1,96

* $p < .05$ ** $p < .01$ *** $p < .001$

A. *Floor Ataxia Test Battery.* The results from each of the five equilibrium subtests indicated that men had significantly better balance scores than did women ($p<.05$—$p<.01$). This significant effect was attributable to the differences between nonsusceptible men and women; no differences between susceptible men and women were significant. There were no significant differences between susceptible and nonsusceptible groups nor were there significant sex x susceptibility interactions.

B. *State-Trait Anxiety Inventory.* Susceptible individuals had significantly higher trait-anxiety scores than did nonsusceptibles ($p<.01$). This relationship indicates that two relatively permanent personality characteristics, trait anxiety and motion sickness susceptibility, are associated either directly or indirectly. The "state" portion of this inventory was administered both before and after rotatory vestibular stimulation.[14] Prior to rotation, there were no significant state anxiety differences between groups; following rotation, however, susceptible individuals had significantly higher state anxiety scores ($p<.01$). A three-way analysis of variance indicated that the state-anxiety level of susceptible individuals increased significantly ($p<.001$) from the prerotation to postrotation sessions, whereas nonsusceptibles evidenced a slight but nonsignificant decrease in state anxiety.

C. *Menstrual Distress Questionnaire.* Of the 47 symptoms possibly related to menstrual distress, fatigue was the only symptom differentially expressed; susceptible women reported more fatigue than did nonsusceptibles ($p<.05$ by t test). When the 47 symptoms were collated to the suggested eight general factors, there were no significant differences between susceptible and nonsusceptible women.

D. *Cornell Medical Index.* Susceptible individuals had significantly more "yes" answers on the Cornell Medical Index than did nonsusceptibles ($p<.001$). In addition, women had more "yes" answers than did men ($p<.05$).

E. *Cornell Word Form.* Evaluation of Cornell Word Form scores indicated that motion-sickness susceptible individuals had significantly higher scores than did nonsusceptibles ($p<.001$). There were no significant sex differences nor sex x susceptibility interactions.

F. *Eysenck Personality Inventory.* Nonsusceptible individuals had significantly higher scores on the Extraversion Scale of the Eysenck Personality Inventory than did motion sickness susceptibles ($p<.05$). In addition, there was a significant sex x susceptibility interaction ($p<.05$). On the Neuroticism Scale, susceptibles had significantly higher scores than did nonsusceptibles ($p<.001$). There were no significant differences on the Lie Scale.

G. *Rotter Internal-External Control Scale.* The Rotter Internal-External Control Scale did not significantly differentiate any of the groups in this study.

H. *16 PF.* All primary, secondary, and criterion scores for groups represented in Figure 1 fall within one standard deviation of the mean established for a college student population. However, within this relatively normal range of scores, there were numerous significant group differences. An analysis of Figure 1 for significant susceptibility differences plus a departure from mean scores yielded a description of our subject groups as indicated in Table 4.

In general, nonsusceptibles tended to score as less neurotic, better adjusted, and more venturesome than susceptibles, and susceptibles in gen-

TABLE 4. Descriptions of Groups Based on 16 PF Scores by Sex and Susceptibility Categories

Group	Major Descriptors Based on 16 PF Scores
Male Nonsusceptibles	emotionally stable; assertive; happy-go-lucky; venturesome; extraverted; thinking (vs. emotionally) oriented; independent; less neurotic; good leader
Male Susceptibles	tenderminded; shrewd; discreet
Female Nonsusceptibles	shrewd; self-assured; relaxed; adjusted (less anxious); discreet; less neurotic; good leader
Female Susceptibles	tenderminded
All Nonsusceptibles	emotionally stable; venturesome; self-assured; relaxed; adjusted (less anxious); thinking (vs. emotionally) oriented; less neurotic; good leader
All Susceptibles	tenderminded; subjective
All Men	assertive; tough minded; experimenting; strong self-concept; thinking (vs. emotionally) oriented; independent; less neurotic; good leader; academic achievers
All Women	tenderminded; shrewd; discreet; subjective

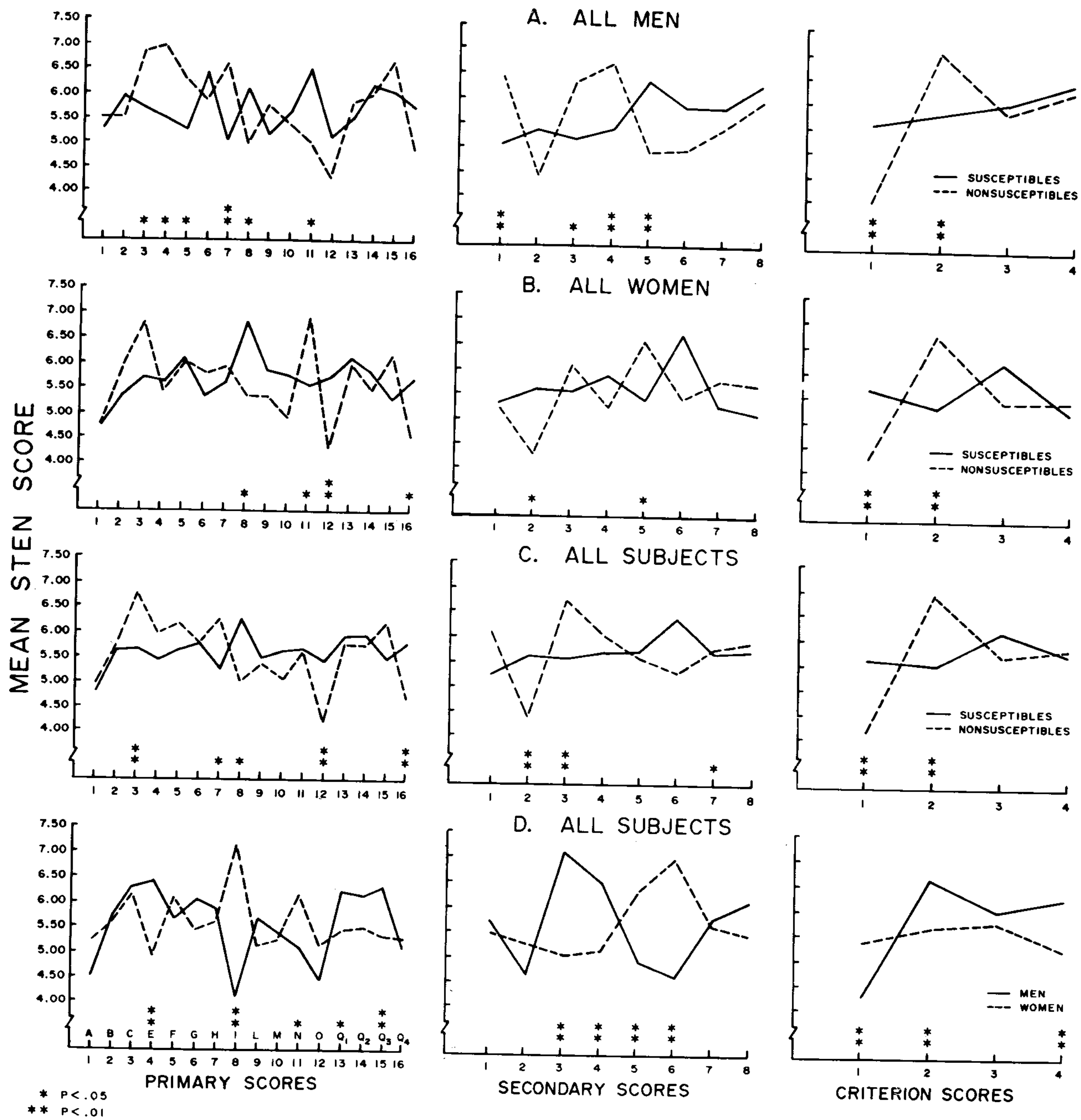

FIGURE 1. Mean sten values for primary, secondary, and criterion scores on the 16 PF test.

eral had factors in common with women (tender-minded, subjective). The 16 PF raw scores were converted by using established regression weights[3] to predict raw scores on the masculinity scale of the Guilford-Zimmerman Temperament Survey. Nonsusceptible individuals had significantly higher scores (more mascline) than did susceptible individuals in both the male ($p<.01$) and female ($p<.05$) groups.

IV. Discussion.

In this study, the Floor Ataxia Test Battery was the only test related in a classical or direct sense to vestibular functioning. Individuals who evidence dramatic differences in the manifestation of motion sickness might be expected to differ in their responses to the subtests in this battery because both motion sickness and the ataxia tests are directly dependent on vestibular functioning. Moreover, other investigators[8 17] have suggested that susceptible and nonsusceptible individuals may perform differently on equilibrium tests. Our data do not support this contention, although they do agree with previous reports indicating that men perform better than women on these tests. It should be noted that other direct manifestations of vestibular function, such as duration and magnitude of both nystagmus and turning sensations to angular stimulation, have also shown no relationship to motion sickness susceptibility.[14]

Some significant relationships between motion sickness susceptibility and personality or psychological factors were obtained. The State-Trait Anxiety Inventory (STAI) measured both trait anxiety, a persistent personality characteristic, and state anxiety, a temporary characteristic prone to frequent fluctuations. Susceptible individuals had significantly higher trait-anxiety scores; they also had significantly higher state-anxiety scores following a period of exposure to rotation than did nonsusceptibles. Although the rotational stimuli used was a type that usually does not induce motion sickness, the fact that most susceptible subjects were disturbed by it emphasized the high degree of susceptibility of this particular group. Since prerotational state-anxiety scores did not differ, it is proposed that the vestibular stimulation produced by the rotatory device triggered the dormant anxiety predisposition (trait anxiety) in susceptible subjects as was evidenced by elevated postrotational state-anxiety scores and some feelings of malaise.

Although alertness and axiety may be separate neuropsychophysiological entities, they may work in a highly correlated fashion in individuals susceptible to motion sickness. For instance, the high trait-anxiety predisposition of susceptible individuals might be quickly expressed in stressful motion environments. The elevated anxiety level could, in turn, heighten subjective alertness, which has been shown to accentuate some vestibular responses.[4] This interrelated system could become self-perpetuating in motion environments because of the tendency of increased vestibular activity to accentuate the development of anxiety.

The results from the Cornell Medical Index (CMI) indicated that susceptible individuals reported significantly more physical and emotional difficulties than did nonsusceptibles. According to the CMI test manual, many individuals in the susceptible group would be suspected of having a medically significant disturbance. Moreover, a significant difference between susceptible and nonsusceptible individuals was also evidenced by scores on the Cornell Word Form. In this instance, nonsusceptible individuals had significantly fewer indications of potential neuropsychiatric or psychosomatic disturbances. Care should be exercised in interpreting this significant difference, however, because the susceptible subjects did not have abnormally high scores.

The results from the Eysenck Personality Inventory (EPI) indicated that nonsusceptible individuals were significantly more extraverted and less neurotic than susceptibles. Again, the scores did not suggest that susceptibles were abnormal in either respect. Although the EPI indicated that nonsusceptibles were more extraverted, this tendency was not expressed in scores on Rotter's Internal-External Locus of Control Scale.

In summarizing scores on the 16 PF test, it can be generally concluded that nonsusceptible individuals tended to be scored as tough and aggresive. In some ways, these descriptors are suggestive of stereotypical male behavior; the results of other tests, on which nonsusceptibles scored significantly higher than susceptibles in masculinity ratings, support this general description.

Moreover, a basic conclusion that may be drawn from the 16 PF test as well as from most of the other tests in this study is that nonsusceptible individuals may be better prepared to cope in a nonemotional manner with stressful situations, whereas susceptible individuals may be more likely to manifest emotional responses in the same situations. In short, it appears that susceptibles are more likely to have an autonomic nervous system response to stress, be it a mental or a physical (e.g., vestibular) stressor.

Results across the battery of psychological tests used in this study seem quite consistent. That they show such consistency in significantly distinguishing susceptible from nonsusceptible people probably reflects the selection factors used in defining the two groups. The vast majority of previous studies used aviation or naval cadets as subjects and defined susceptibility in operational terms; i.e., by those who became motion sick during training or in laboratory devices. Such groups, however, were likely to exclude highly susceptible people, were virtually all men, and would have already been screened in medical examinations for psychological and physical abnormalities. Moreover, a precipitating cause of sickness in these military studies could well have been situation-specific anxiety and the fear of failure in meeting occupational requirements;[5] that is, fundamental factors that might underlie pervasive susceptibility to motion sickness might not be consistently manifested by those who demonstrate relatively situation-specific sickness or who suffer motion sickness only occasionally. One would expect that tests on less extreme groups than those used in this study would result in weaker and less consistent relationships between personality factors and motion sickness characteristics.

As a final point, the personality characteristics that distinguish our highly susceptible and nonsusceptible subjects are not, of course, universally generalizable. Thus, not all anxious, introverted individuals are highly susceptible to motion sickness, and not all masculine, extraverted, calm individuals are nonsusceptible.

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