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PASSENGER RIDE QUALITY DETERMINED FROM COMMERCIAL AIRLINE FLIGHTS

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SUMMARY

The University of Virginia ride-quality research program is reviewed. Data from two flight programs, involving seven types of aircraft, are considered in detail. An apparatus for measuring physical variations in the flight environment and recording the subjective reactions of test subjects is described. Models are presented for (1) predicting the comfort response of test subjects from the physical data, and (2) predicting the overall comfort reaction of test subjects from their moment by moment responses. The correspondence of mean passenger comfort judgments and test subject response is shown. Finally, the models of comfort response based on data from the 5-point and 7-point comfort scales are shown to correspond.

INTRODUCTION

The general goal of the research reported here is to determine the relation between passenger comfort and vehicle ride quality. This goal implies two problems: (1) characterize and measure vehicle ride quality--a physical problem involving analysis of the environment, and (2) characterize and assess passenger reactions to that environment--a psychological problem. Determining the relations between problems (1) and (2) is a psychophysical problem.

PROBLEM 1: ANALYSIS OF THE ENVIRONMENT

The University of Virginia ride quality program has been concerned mostly with aircraft. The flight environment for a passenger consists of (1) the seat in which he finds himself, (2) the surrounding space-both tactile and visual, and (3) the physical conditions acting on him, such as motion, noise, temperature, pressure, lighting, and so on.

An emphasis on ride quality implies primary interest in the motion variables and the seat. UVa has designed and built a portable ride quality measuring apparatus (see ref. 1). It permits continuous recording of a vehicle's motion characteristics in 6 degrees of freedom: 3 linear accelerations and 3 angular rates. Pressure, temperature, and noise are also recorded and separate channels permit voice entries and a numerically coded comfort response to be entered by a test subject. This instrument is carried aboard a vehicle, and after some processing, a trace like that in figure 1 results. Noise spectra are also processed--a typical output shown in figure 2.

Measurements and descriptions of the seat, surrounding space, overall noise level (dB(A)), and temperature are taken by hand. Thus, most of the problem of characterizing the environment has been solved.

PROBLEM 2. ANALYSIS OF PASSENGER REACTIONS

The problem of how to assess psychological reactions is more complex. First, one must decide which states or reactions are most relevant. Passenger comfort is clearly important; on the one hand, it seems to be the most direct psychological correlate of ride quality; and on the other, it would seem to be related to a passenger's satisfaction with a mode of travel, his willingness to use it again. If one is comfortable on this trip, all other things being equal, one will probably be willing to use this vehicle again. The point of ride quality research is to increase passenger acceptance of particular types of vehicles, so as to increase actual use of them.

Comfort is a state of feeling, an affective reaction. It is assumed to depend on inputs from the environment, especially motion and seat variables. The passenger receives various physical inputs continuously throughout a flight. In figure 3, aspects of the physical environment are assumed to map into sensations or perceptions. Conglomerate impressions may exist for motion and seat variables. These inputs all influence one's level of comfort.

A passenger's comfort level may also depend on his expectations, anxiety, state of health, and so on. Individual difference variables of interest include (1) attitudes, beliefs, fears, moods & anxiety-psychological factors, (2) age, sex, somatotype, tendency toward motion sickness & general health-physiological factors, and (3) previous flight experience, preflight experiences, socioeconomic status, demographic characteristics--situational factors.

Comfort level acts to determine satisfaction with a flight and is coded in memory for future decisions. Figure 3 outlines a theory of comfort--a set of hypothesized relations to be tested empirically. Consider further a passenger in an airplane; he has come into a situation for a purpose. The purpose is to travel, to get from one place to another, but the passenger might have any of several reasons for traveling. His being in this situation may be the result of a choice between competing modes of travel. Such a decision would be influenced by attitudes, beliefs, and expectations concerning, say, air travel, based on prior experience and communication. Finally, the passenger holds values--some specific to travel, others more general, and these values influence choice, decision, and evaluation concerning air travel.

All the considerations in this section influenced the development of two questionnaires. The questionnaires were designed for use on board regularly scheduled commercial flights involving fare-paying passengers. Both questionnaires asked for (1) demographic information, (2) attitudes about, purpose of, and frequency of flying, (3) the perceived importance of various physical factors in determining comfort, (4) a comfort rating, and (5) an evaluation in terms of willingness to fly again on this type of craft. A sample questionnaire is shown in Figure 4. Various other items will be discussed as the results are reported.

FLIGHT PROGRAMS

Two initial flight programs involving fare paying passengers were conducted. In the first, three planes were used: The Volpar Beech, Nord, and Twin Otter; in the second, three planes and one helicopter: Beech 99, Nord, Twin Otter, and the Sikorsky S-61 helicopter. All these aircraft are used for commuter service. One or two UVa test subjects were present on each flight. These subjects were specially trained and highly experienced. They operated the ride-quality apparatus on the various flights and provided ratings of their comfort levels throughout the flight. The goal was to obtain motion recordings and subject comfort ratings for about 10 two-minute intervals of a flight. In addition, a comfort rating for the total flight was also obtained from each test subject. A five-point rating scale was used in the first flight program, a 7-point one in the second.

All passengers on each flight were asked to complete a questionnaire. It was filled out near the end of the flight, about five minutes prior to landing. There were 758 passengers in the first flight program and 861 in the second. Figure 5 provides an overview of the data collected in the UVa ride quality program. Motion recordings, test subject ratings, and passenger questionnaire data were collected during the two flight programs. Test subjects were also used to gather data in simulators: in flight: TIFS (Total in Flight Simulator) and GPAS (General Purpose Airborne Simulator), and on ground: PRQA (Passenger Ride Quality Apparatus), VMS (Vision Motion Simulator), and RDS (Ride Dynamics Simulator). These simulators and the data from them will be discussed in detail by others at this conference: some simulator data will be reported briefly later in this paper.

QUESTIONNAIRE RESULTS

Characteristics of the samples of passengers in the two flight programs are shown in table 1 along with information from General Travel Surveys. Age, income, education, occupation and purpose of trip information is comparable for all three groups. The ratio of men to women deviates from that reported in general travel surveys. In flight program II, the proportion of women varied with plane type; a greater proportion of the passengers were women on the Twin Otter (32%) and the Beech (26%) than on the S-61 (14%) or the Nord (10%). In general, the proportion of women flying commuter service is quite small.

Both flight samples had a predominance of frequent travelers; 75% of the passengers in the first sample had flown 10 or more times in the prior two years, while only 2.3% had not flown before; in the second flight sample, 70% of the passengers had flown 4 or more times, but 16% were flying commuter service for the first time.

Attitudes toward flying were generally favorable. In the first sample, 45% of the passengers reported that they "loved to fly," 34% had "no strong feelings," and 21% "flew because they had to" and 0.7% said they disliked flying. This item was ambiguous: more than one response might be appropriate for a given passenger. In the second questionnaire, one item assessed attitude toward flying, while another asked whether one had to fly. The contingency table relating these two items is shown in table 2. Of those who have to fly, about ½ have no strong feelings about flying; of those who don't have to fly, 67% indicate that they like to do so.

Factors in satisfaction with air travel were rated similarly by both samples. The first sample rated safety and reliability of greatest importance, followed, in order, by time savings, convenience, comfort, and cost. In the second sample, time saving and on time arrival and departure were rated very important, with convenience and ride comfort rated moderately important.

Passengers report that thinking and looking out the window are the most frequently performed activities, with reading and talking also done with some frequency. Writing is rarely done and is rated difficult to perform on these types of planes. Ability to work (read or write) was however rated one of the least important factors in trip satisfaction.

COMFORT RESPONSE

Passengers were asked to report their level of comfort on their flight. A rating scale with adverb-adjective descriptors was used: a five-point scale for the first flight program, and a seven-point scale for the second. The distributions of comfort judgments taken over all passengers, flights, and plane types are shown in figure 6. The distribution on the left is from the first questionnaire with a five-point rating scale. Using the seven-point scale distributed the judgments in the middle range, fewer passengers found it necessary to use the neutral category. The percent of passengers using the extreme categories was about the same for both samples.

Comfort should be related to satisfaction. In terms of questionnaire items, the rated comfort level should correlate with willingness to fly again. Figure 7 shows the percent of passengers with no doubts about taking another flight plotted against comfort rating for the first sample. As rated comfort decreases so does the percent of passengers willing to fly again. For the second sample, the curve in figure 8 results. The same decline in percent of passengers satisfied occurs as comfort decreases. The adjectival labels for the two comfort scales were identical at the two extremes ("very comfortable," "very uncomfortable") and in the middle of the scale ("neutral"). For these three scale positions, the percent of subjects with no doubts about flying again are nearly identical, see the heavy dots in figure 8. Thus, subjects in both flight programs relate the comfort scale to satisfaction in the same way. Further, the curve drops in the predicted manner through scale points 2, 3, 5, and 6. Thus, not only does the relation between comfort and willingness to fly replicate, but the meaningfulness of the scale labels is supported by this replication.

COMFORT RATING AS A FUNCTION OF PLANE

Tables 3 and 4 show the distribution of comfort ratings according to the type of plane. For each program, these distributions differ as a function of the plane. For flight program I, the mean comfort ratings were 2.71 for the Nord, 2.97 for the Volpar Beech, and 3.02 for the Twin Otter. For flight program II, the order of aircraft by mean comfort response is S-61 ($\overline{X}$ = 2.71), Nord ($\overline{X}$ = 3.52), Twin Otter ($\overline{X}$ = 3.55), and Beech ($\overline{X}$ = 3.60). The Nord is rated more comfortable than the other two planes in both samples. However, the S-61 helicopter is rated the most comfortable vehicle in flight program II. It should be noted that it has the shortest average flight time (7-10 minutes).

Although women are relatively more prevalent on the Twin Otter and Beech, the least comfortable planes, the distribution of their comfort responses (see table 5) overrepresents the best comfort categories. Thus, these two aircraft may have higher mean comfort ratings than they would have given samples whose proportions more closely approximated those of the S-61 and Nord.

PHYSICAL FACTORS RELATED TO COMFORT

In the first flight program, passengers were asked to rank the importance of various physical factors in determining their level of comfort. Table 6 shows the results: seat comfort was seen as most important, followed by noise and temperature, then the motion factors. Figure 9 shows the mean rankings of the physical factors in comfort separately for men and women. Women rated seat comfort less important, and gave greater importance to the motion variables than did the men.

In the second questionnaire, passengers' perceptions of these various factors were assessed directly. This questionnaire contained rating scales for rather detailed aspects of the physical situation: motion, temperature, pressure, lighting, noise, workspace, ventilation, smoke, and odors. A separate set of items dealt with seat variables: firmness, width, adjustment, leg room, and shape. Passengers were asked to rate their discomfort on these various physical factors. Thus, passengers indicated what they thought influenced their comfort. These ratings of physical factors could then be related to overall comfort ratings to provide direct assessment of the perceived aspects of the flight environment presumed to be related to comfort.

Seven of the physical factors showed no significant relation to plane type. These were lighting, noise, odors, tobacco smoke, temperature, ventilation, general vibration, and turning. For five of these physical factors, 75% of the respondents indicated that they were "not uncomfortable" due to that factor. However, most respondents cited that they were at least "somewhat uncomfortable" due to noise and general vibration. Between 60% and 72% of the passengers experienced discomfort due to noise, and between 54% a 66% did so due to general vibration.

Significant relationships between plane type and response are evident for pressure, workspace, sudden jolts, up and down motion, backward and forward motion, side to side motion, and sudden descents. The strongest relation to plane type was found for up and down motion: Forty-eight percent of the passengers found the Twin Otter and Beech uncomfortable on this factor, while only 21% so rated the S-61 and only 12% of the Nord. Discomfo due to side to side motion is also significantly related to plane type. Over a third of the passengers on the Twin Otter and Beech reported discomfort, but only 17% of the S-61 passengers did, and only 10% of the Nord passengers. Similar patterns of differences emerge for sudden jolts, backward and forward motion, and sudden descents. In each case, the Beech and Twin Otter are associated with greater proportions of uncomfortable passenge However, on the last two physical factors, less than 25% of the passengers are uncomfortable. Pressure is also significantly related to plane type. The Beech is uncomfortable to 60% of the passengers, while the proportions for the other three plane types range from 26 to 38 percent. Workspace is rated uncomfortable by 81% of the Nord passengers, but by only 43% of the S-61 passengers. The Twin Otter and Beech are also rated poorly.

SEAT VARIABLES

Passenger reactions to five aspects of the seat were obtained. Passengers could "agree," "disagree," or "strongly disagree" with the statements: "The seat has enough leg room," "The firmness of the seat is satisfactory," "The seat is wide enough," "The shape of the seat is satisfactory," and "The seat can be adjusted to your satisfaction." Characteristics of the seats for the four aircraft are summarized in table 7. Seat firmness is generally satisfactory; 75% of the respondents agreed with this statement for the Nord, and even greater agreement was found for the other planes. All seats had foam cushions. Seat shape was rated poorly for the Nord, but not for the other three planes. The S-61 helicopter had the greatest percentage of passengers satisfied with both seat shape and firmness. Seat adjustment was uniformly poor, the highest percent agreement was for the S-61 and that was only 43%. Since none of the seats could be adjusted, it is assumed that some passengers were responding to the actual position of the seat rather than its potential for adjustment. Those passengers who agreed with the item on adjustment probably felt that the seats were already adjusted to their satisfaction.

Sixty-one percent of the passengers were satisfied with the seat width on the S-61, 57% on the Beech, but both the Twin Otter and Nord were rated unsatisfactory by most of the passengers. Only the S-61 satisfied a substantial proportion of the passengers with respect to leg room. These two seat variables are quantitative. Measurements of width and leg room are given in table 7. When the percentage of passengers satisfied is plotted against these measurements, figures 10 and 11 result. Seat width is related linearly to percent of passengers satisfied; further, the difference in width between a seat that satisfies 61% of the passengers (S-61) and one that satisfies 34% (Nord) is only 11.4 centimeters. Leg room is related to percent of passengers satisfied in a nonlinear fashion. There is a large increase in percent satisfied when leg room is increased from 24 to 27 centimeters. The S-61, which rates best on leg room, also rated best on workspace in the previous item.

PERCEIVED RELATIONS BETWEEN ENVIRONMENTAL FACTORS

Do passengers tend to respond as though certain environmental factors go together? Goodman and Kruskal's (ref. 2) gamma coefficient (γ) was chosen to index the degree of association between responses to different items. When all the environmental factors (physical and seat) are related to each other over all plane types, the γ's in table 8 result. Two major clusters are immediately apparent: one involving the motion factors and the other, the seat factors. The γ's within each cluster are quite large, while the γ's relating factors in the motion cluster to those in the seat cluster are small. Thus motion factors appear to be independent of seat factors. Workspace goes into the seat cluster and is strongly related to leg room and seat width. The motion factors are all highly interrelated, with general vibration associated with the motion cluster and with noise. Judgments of discomfort due to temperature and ventilation also tend to covary. It should be kept in mind that these results concern the structure implicit in response variation from the passengers and not necessarily the actual physical covariation present in the environment.

RELATION OF RATED SOURCES OF DISCOMFORT TO OVERALL COMFORT JUDGMENTS

Gamma coefficients were computed relating the degree of discomfort attributed to each of the environmental factors to the overall comfort rating and to the rated willingness to fly again. These values are shown in table 9. Ratings of noise, vibration, motion, and seat variables are significantly associated with comfort and evaluation judgments. Passengers perceive these factors as determinants of their comfort level, and their judgments covary in an appropriate way. These ratings of discomfort due to environmental factors are rather crude, but they suggest that our modelling efforts are concerned with the right variables.

MOTION VARIABLES AND TEST SUBJECT RESPONSES

The output from the ride quality measuring apparatus was processed by the NASA Langley time series analysis program and sent to Univ. of Va. as rms values and power spectra for the motion variables and appropriate digital representations of the other physical variables. Thus, a series of numerical values corresponding to each two minute flight segment was obtained, together with a rating of that segment by one or two test subjects.

Various models were examined for the data from the first flight program which had used a five-point comfort scale. In trying to predict comfort ratings from rms motion values, a simple linear model proved best. More complex models were tried but the small increase in the percent of variance they accounted for did not justify the added complexity. For the commercial airline data obtained using the five-point comfort scale, the model is given by

$$C = 2.0 + 7.6\,\bar{a}_{\text{TRANSVERSE}} + 11.9\,\bar{a}_{\text{VERTICAL}}$$

In all the tests done to date, vertical and transverse accelerations dominate the comfort responses. The constants are all significant at the 0.001 level or better, the Pearson correlation is 0.72, and the rms residual error is 0.59. The N for this model is 2976. This model is valid over the range of accelerations which were encountered in commercial operations, given by

$$\bar{a}_V \geq 1.6\bar{a}_T$$

For the range of accelerations $\bar{a}_V < 1.6\,\bar{a}_T$, the data from the flight-similator (Jetstar GPAS-see ref. 3) experiments were used giving an equation of the form

$$C = 2 + \bar{a}_V + 25\,\bar{a}_T$$

Again the constants are all significant at the 0.001 level or better. A composite of these two models is shown in figure 12 with isocontours of constant C indicating the transition region from comfortable to uncomfortable motions.

For each flight, test subjects provided an overall comfort rating and the mean of the passenger comfort ratings was computed. These quantities are plotted against each other in figure 13. There is some curvilinearity to the relation, but one can predict mean passenger response quite well using the overall rating from the test subjects.

The moment by moment test subject responses were related to their overall responses with a variety of types of models. The best fitting information integration model was a simple weighted average with the weight for each data point increasing as the time into the flight increased. The largest weights were given to the segments near the end of the flight. The best weighting function is shown in figure 14.

Data from the second flight program (7-point scale) were also used to model test subject reactions to the motion variables. The data reported here are only for the Nord and Twin Otter. Again, a simple linear model involving vertical and transverse accelerations was best. The equation for predicting comfort was

$$C = 2.1 + 17.1\bar{a}_T + 17.2\bar{a}_V$$

This equation yielded a multiple R of 0.75, thus accounting for 56% of the variance in comfort judgments. While the transverse component is significant, it should be noted that the correlation of vertical rms alone and comfort is 0.74. Further vertical and transverse accelerations are highly correlated (r = 0.82). Table 10 gives the summary statistics for the physical measures and test subject comfort responses, table 11 shows their intercorrelations.

Isocontours of constant C are plotted in figure 15 for equations based on both the 5-point model and the 7-point model. There are some discrepancies, but in general the models agree. If values of the model equations are solved in terms of a_V, and various a_V, values are inserted into both equations, the relations between the two models can be derived. Figure 16 shows the results of that process. Figure 16 may be used to convert 5-point comfort ratings to 7-point or vice versa. The two models produce predicted comfort values that are linearly related to each other.

FURTHER REMARKS

These two flight programs are part of a larger research effort dealing with ride quality. They were preceded by a flight program used to test the instrumentation (ref 1) and ground-based surveys (refs. 4, 5) used to develop and refine the questionnaires. The data from the flight programs are reported in greater detail in a series of papers appearing in the British journal Ergonomics (refs. 5 to 7). Additional commercial flight programs are now in progress.

In-flight flight similators are also being used to investigate ride quality. With test subjects and experimental aircraft, motion characteristics not normally seen on commercial flights can be realized. For example, a preliminary investigation of the effect of bank angle on comfort ratings was carried out on the Jetstar. The results are plotted in figure 17. Mean comfort responses do change with bank angle, and a 25° bank is probably a maximum for comfortable passenger operation (ref. 8). Ground-based simulator studies are also being pursued.

Other directions in which our research is going include (1) the effects of noise on perceived comfort, (2) the role of anxiety and mood in determining reaction to a flight, and (3) the extension of our research effort to other modes of transportation.

REFERENCES

1. Kuhlthau, A. R. and Jacobson, I. D.: Analysis of Passenger Acceptance of Commercial Flights Having Characteristics Similar to STOL, Canadian Aer nautics and Space Journal, 1973, 19, 405-409.

2. Goodman, L. A. and Kruskal, W. H. : Measures of Association for Cross Classifications, Journal of the American Statistical Association, 1954, Vol. 49, pp. 732-64.

3. Jacobson, I. D. and Kuhlthau, A. R. ; Flight Research Experiments to Determine Ride Quality and Passenger Acceptance, 1974, University of Vi ginia, Department of Engineering Science and Systems, Memorandum Report No. 403903.

4. Jacobson, I. D. and Martinez, J.: The Comfort and Satisfaction of Air Travelers--Basis for a Descriptive Model, Human Factors, 1974, 16, 46-5

5. Richards, L. G. and Jacobson, I. D.: Ride Quality Evaluation 1. Questio Studies of Airline Passenger Comfort, Ergonomics, 1975, Vol. 18, No. 2, pp. 129-150.

6. Jacobson, I. D. and Richards, L. G.: Ride Quality Evaluation 2, Modellin of Airline Passenger Comfort, Ergonomics, in press. (Available as STO Memorandum report 403217, School of Engineering and Applied Science, University of Virginia, Dec. 1974.)

7. Richards, L. G. and Jacobson, I. D.: Ride Quality Evaluation 3: Questio naire Results from a Second Flight Program. Submitted to Ergonomics, Aug. 1975. (Available from School of Engineering and Applied Science, U. Va.)

8. Jacobson, I. D. and Rudrapatna, A. N.: Flight simulator experiments to Determine Human Reaction to Aircraft Motion Environments. STOL Program Memorandum Report 403902, July 1974, Department of Engineering Science and Systems, University of Virginia, Charlottesville.

Table 1. Characteristics of the flight samples

	General Travel Surveys	Previous In-flight Sample	Present In-flight Sample
N	3000+	758	861
Sex			
Male	75%	88%	80%
Female	25	12	20
Age			
20 & under	12	6	4
21-40	40	47	45
41-60	35	42	45
over 60	13	5	6
Education			
College	80	81	N.A.
Noncollege	20	19	N.A.
Occupation			
Executive Managerial Professional Technical	60	68	66
Other	40	32	34
Purpose of Trip			
Business	75	79	72
Other	25	21	28
Income			
Median	$22,000	$22,293	$24,069

Note: N.A. = not asked on this questionnaire.

Table 2. Feelings about flying versus "have to fly" responses for commuter flights

Have to fly	Feelings about flying			
	Positive	Neutral	Negative	N
Yes	40.4	48.8	10.8	498
No	66.8	30.0	3.2	280

Table 3. Distributions of passenger comfort ratings by type of aircraft*

	1	2	3	4	5	N
Nord	7.6	35.3	38.0	16.4	2.7	408
Volpar Beech	1.0	34.0	37.0	23.0	5.0	100
Twin Otter	5.1	24.8	38.9	25.2	6.0	234

* Table entries are percent of row total.

Table 4. Distributions of rated comfort by plane type*

	Comfort Rating							
	1	2	3	4	5	6	7	N
Beech	5.5	29.4	15.3	17.8	18.4	8.0	5.5	163
Nord	7.2	23.7	22.4	12.5	27.0	5.3	2.0	152
S-61	12.6	46.5	12.3	17.9	8.2	1.9	0.6	318
Twin Otter	6.2	28.7	16.9	14.9	22.1	7.7	3.6	195

* Table entries are percent of row totals.

Table 5. Distribution of comfort responses by sex *

	1	2	3	4	5	6	7	N
Male	7.1	32.8	16.9	17.8	17.1	5.7	2.6	662
Female	15.6	42.5	11.3	10.0	15.6	2.5	2.5	160

*Table entries are percent of row totals.

Table 6. Rank ordering of physical factors in comfort (first flight program)

	Total In-flight Sample	Sex		Ground-based Sample
		Male	Female	
Seat comfort	1	1	4	1
Noise	2	2	2	3
Temperature	3	3	3	2
Up & down motion	4	5	1	4
Pressure changes	5	4	6	7
Side-to-side motion	6	6	5	5
Work space	7	7	9	9
Lighting	8	8	7	6
Smoke	9	9	8	8

Table 7. Approximate seat dimensions and features

Aircraft	Width	Depth	Arm Rests	Leg Room*	Adjustment	Cushion Type
Twin Otter	41.3 cm	45.7 cm	No	24.1 cm	None	Foam
Nord 262	37.5 cm	44.5 cm	Yes	20.3 cm	None	Foam
Beech 99	44.5 cm	44.5 cm	No	20.3 cm	None	Foam
S-61	48.3 cm	45.7 cm	Yes	21.6-26.7cm	None	Foam

* Between seats (front of passengers seat to point of contact with the seat in front--in upright position).

Table 8 . Association (gammas) between ratings on environmental factors. Decimal points are omitted.

Factors rated

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1. Lighting																			
2. Pressure	50																		
3. Noise	42	67																	
4. Odors	57	35	57																
5. Tobacco Smoke	13	31	41	60															
6. Temperature	52	31	38	49	42														
7. Ventilation	46	33	42	53	56	90													
8. Workspace	46	27	47	30	26	47	46												
9. General Vibration	52	48	74	53	27	48	44	48											
10. Sudden Jolts	37	45	41	38	22	40	36	38	78										
11. Up & Down Motion	34	46	37	35	30	43	33	35	73	94									
12. Backward & Forward Motion	52	48	42	53	46	54	47	40	76	90	96								
13. Side to Side Motion	39	43	37	46	32	43	40	42	72	89	93	96							
14. Sudden Descents	43	50	42	42	26	50	51	34	71	89	89	87	87						
15. Turning	57	55	65	63	33	62	67	34	76	84	84	90	90	95					
16. Leg Room	24	27	31	02	28	26	29	66	23	26	32	26	29	23	07				
17. Seat Firmness	41	40	38	31	30	36	45	61	39	27	30	53	36	42	55	70			
18 Seat Width	25	13	33	14	22	22	29	61	37	29	34	29	34	30	15	66	74		
19. Seat Shape	22	26	34	23	26	26	23	48	32	20	24	31	29	38	45	63	87	75	
20. Seat Adjustment	26	14	35	25	26	19	30	54	31	29	29	27	33	32	19	66	68	70	74

Table 9 . Association (gammas - γ's) between rated sources of discomfort and overall comfort judgments and evaluations

Factor	Comfort Judgment	Willingness to Fly Again
Lighting	.27	.25
Pressure	.26	.28
Noise	.41	.38
Odors	.15	.29
Tobacco Smoke	.23	.15
Temperature	.27	.25
Ventilation	.31	.26
Workspace	.49	.46
General Vibration	.44	.39
Sudden jolts	.43	.47
Up and Down Motion	.46	.41
Backward and Forward Motion	.40	.49
Side to Side Motion	.48	.50
Sudden Descents	.35	.45
Turning	.28	.41
Leg Room	.54	.43
Seat Firmness	.54	.52
Seat Width	.52	.41
Seat Shape	.51	.48
Seat Adjustment	.47	.34

Table 10

Summary Statistics on Physical Measures and Comfort (rated by Test Subjects)

	Mean	Median	Mode	Std. Dev.	Maximum	Minimum	Skewness
Comfort	3.140	3.046	3.000	.935	6.000	2.000	.574
Yaw	.263	.119	.009	.372	3.646	.009	3.575
Roll	.961	.721	.455	.735	3.642	.112	.980
Pitch	.300	.211	.109	.252	2.227	.046	2.340
Longitudinal	.014	.013	.011	.009	.076	.001	1.826
Transverse	.014	.010	.001	.012	.080	.001	1.622
Vertical	.044	.034	.014	.031	.188	.008	1.529

Table 11

Intercorrelations of Physical Measures and Comfort (as rated by Test Subjects)

	Comfort	Yaw	Roll	Pitch	Longitudinal	Transverse
Yaw	.30					
Roll	.71	.50				
Pitch	.56	.66	.81			
Longitudinal	.30	.25	.41	.54		
Transverse	.68	.57	.86	.78	.40	
Vertical	.74	.40	.91	.78	.39	.82

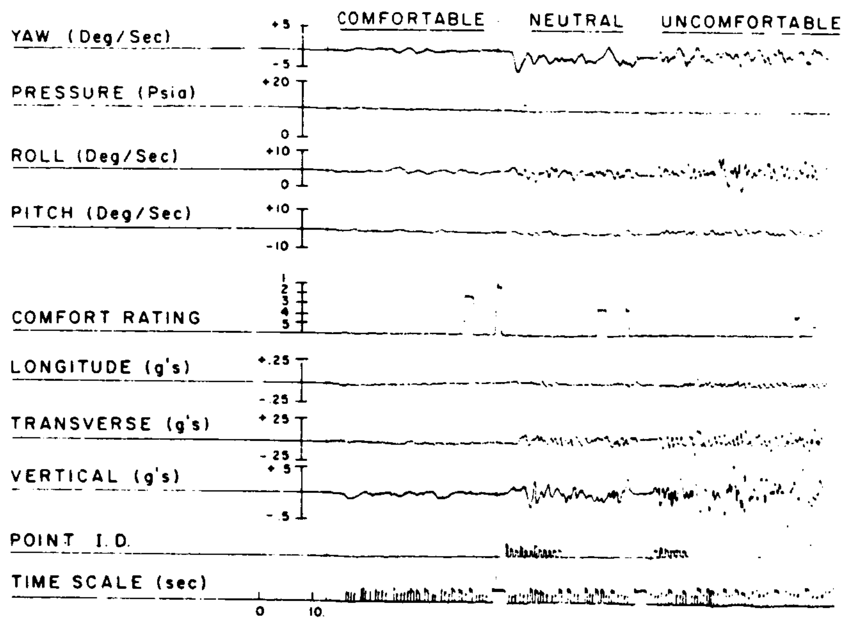

Figure 1.- Typical motion time histories.

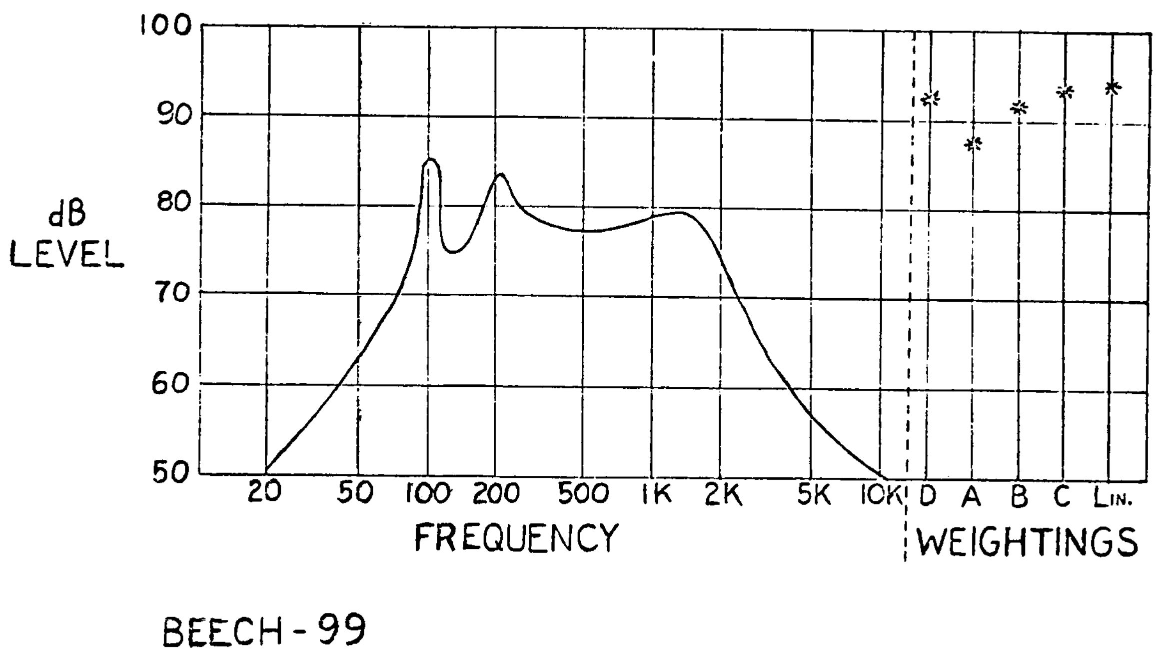

Figure 2.- Typical noise spectrum.

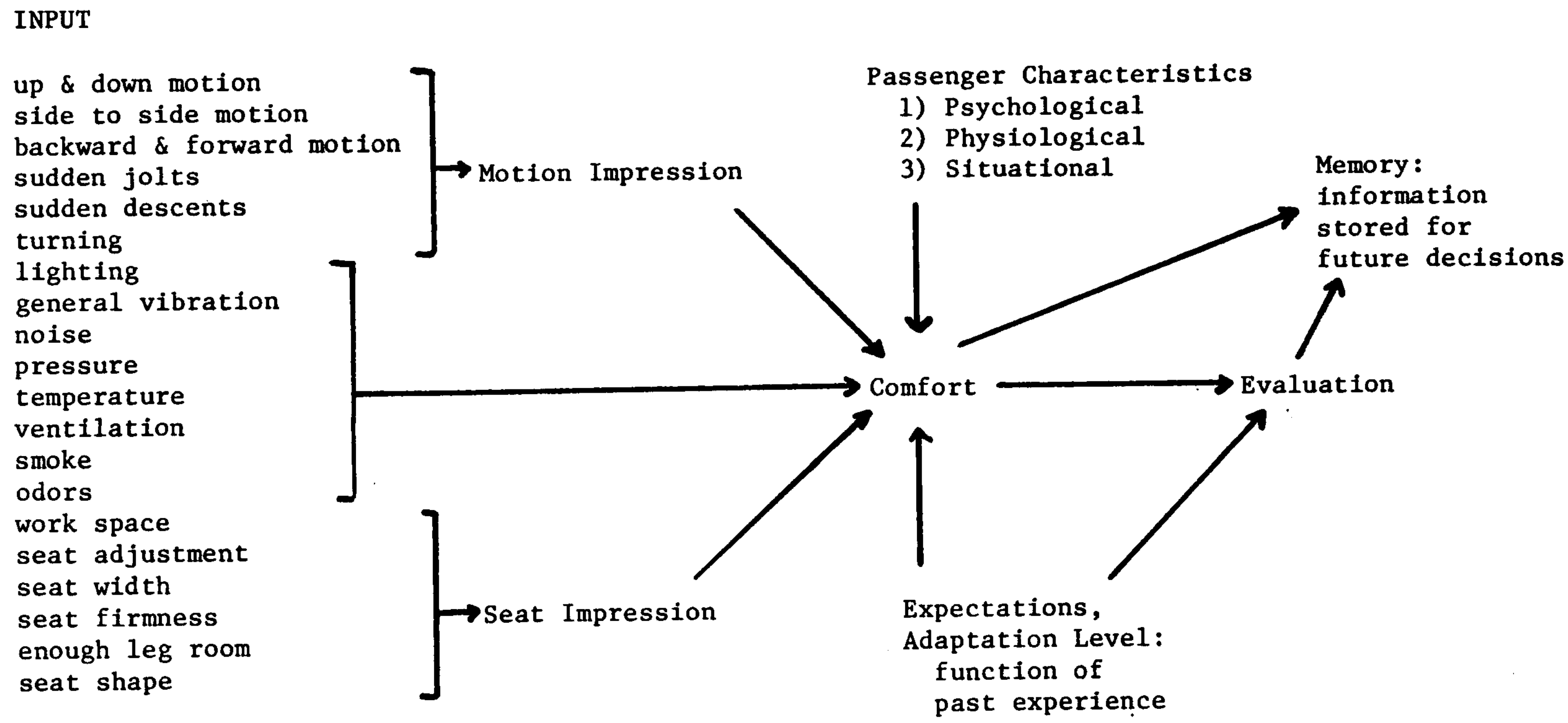

Figure 3.- Components of a theory of comfort.

ALLEGHENY COMMUTER

Operated by Atlantic City Airlines, Inc.

UNIVERSITY OF VIRGINIA

This questionnaire is part of an effort by Atlantic City Airlines, the National Aeronautics and Space Administration, and the University of Virginia to obtain from you, the flying public, information to be used in the improvement of transportation systems. The goal of the program is to identify the needs and desires of airline passengers, so that future systems may increase passenger satisfaction.

Your cooperation in completing this form will be most appreciated and can only be of benefit to you, the air traveler. Thank you, and enjoy your flight.

Maurice C. Young

Maurice C. Young
President, Atlantic City Airlines, Inc.

Please indicate only your first impression on each question. You need not answer any question that offends you.

1. Age ______ 2. Sex: ☐ M ☐ F

3. Education:
   - ☐ High School not completed
   - ☐ High School completed
   - ☐ College

4. Occupation:
   - ☐ Housewife
   - ☐ Craftsman, Mechanic
   - ☐ Professional, technical
   - ☐ Professional, nontechnical
   - ☐ Student
   - ☐ Armed Forces
   - ☐ Secretary, Clerk
   - ☐ Salesman
   - ☐ Manager, Official, Executive
   - ☐ Other ______________

5. Industry of Employment ______________

6. Approximate Household Income (before taxes):
   - ☐ Under $5,000
   - ☐ $ 5,000-$ 9,999
   - ☐ $10,000-$14,999
   - ☐ $15,000-$19,999
   - ☐ $20,000-$24,999
   - ☐ $25,000-$29,999
   - ☐ $30,000-$34,999
   - ☐ $35,000 or more

7. What is the primary purpose of this trip?
   ☐ Business ☐ Personal ☐ Other

8. How do you feel about flying?
   - ☐ I love flying
   - ☐ I have no strong feelings about flying
   - ☐ I dislike flying
   - ☐ I fly because I have to

9. Approximately how many times have you flown in the past two years?
   - ☐ None, this is my first flight
   - ☐ 1-3
   - ☐ 4-6
   - ☐ 7-9
   - ☐ 10 or more

10. How important is each of the following items in determining your feelings of comfort? Rank them using the numbers from 1 to 9, with 1 representing the **most important**, and 9 the least important. Please use each number only once.
    - ______Pressure changes (ears pop)
    - ______Noise
    - ______Temperature
    - ______Lighting
    - ______Seat comfort
    - ______Up and down motion (bouncing)
    - ______Side to side motion (rolling)
    - ______Work space and facilities
    - ______Presence of smoke
    - Other ______________

11. Place a check in the box which describes the importance of each of the following in determining your satisfaction with an airplane ride.

	Unimportant	Very Little Importance	Somewhat Important	Very Important	Greatest Importance
Comfort	☐	☐	☐	☐	☐
Convenience	☐	☐	☐	☐	☐
Cost	☐	☐	☐	☐	☐
Reliability	☐	☐	☐	☐	☐
Safety	☐	☐	☐	☐	☐
Time Savings	☐	☐	☐	☐	☐
Ability to Read	☐	☐	☐	☐	☐
Ability to Write	☐	☐	☐	☐	☐
Services on Board	☐	☐	☐	☐	☐
Surroundings	☐	☐	☐	☐	☐

12. Consider the motion you are experiencing. Indicate your reaction to this motion by checking the appropriate box:
    - ☐ Very Comfortable
    - ☐ Comfortable
    - ☐ Neutral
    - ☐ Uncomfortable
    - ☐ Very Uncomfortable

(Please see last page)

13. How difficult does the motion of this flight make the following activities?

	Not at all Difficult	Slightly Difficult	Difficult	Extremely Difficult	Impossible
Concentration	☐	☐	☐	☐	☐
Reading	☐	☐	☐	☐	☐
Writing	☐	☐	☐	☐	☐
Sleeping	☐	☐	☐	☐	☐

14. After experiencing the motion of this flight, I would: (Check only one)
    - ☐ be eager to take another flight
    - ☐ take another flight (without any doubts)
    - ☐ take another flight (but with some doubts)
    - ☐ prefer not to take another flight
    - ☐ not take another flight

15. Suppose a high-frequency shuttle service (8 or more round trips per day) were available at your local airport, scheduled to connect with flights of over 300 miles from a larger airport some distance away. Would you use the shuttle instead of ground transportation to the larger airport, if the cost were competitive?
    ☐ Yes ☐ No

16. Suppose a 25-passenger prop jet flew from an airport 15 minutes from your home or office to cities within 300 miles. Would you use this service rather than travel to a major airport an hour away?
    ☐ Yes ☐ No

THANK YOU FOR YOUR ASSISTANCE

Figure 4.- Sample of an in-flight questionnaire.

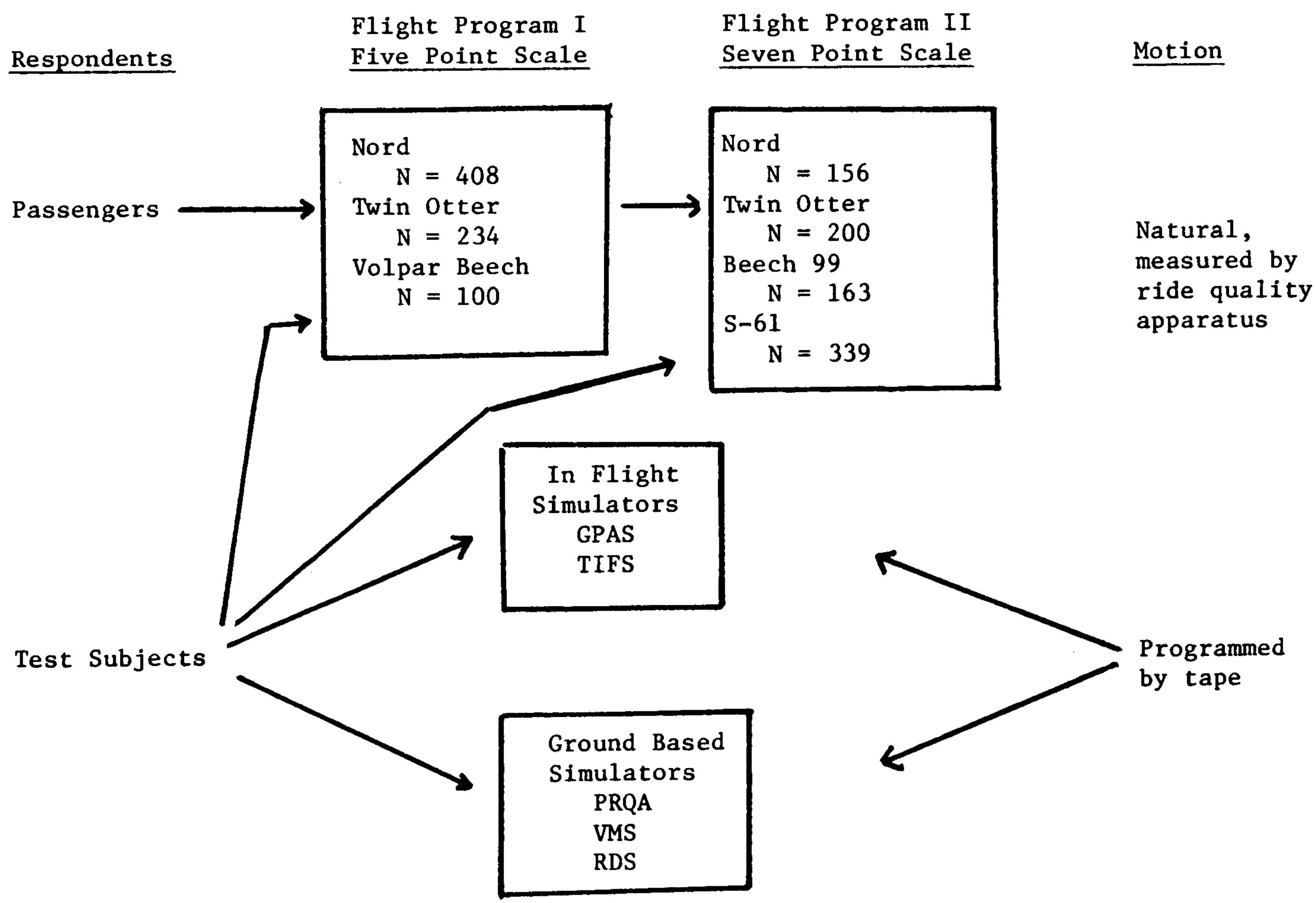

Figure 5.- Overview of the Univ. of Va. data base.

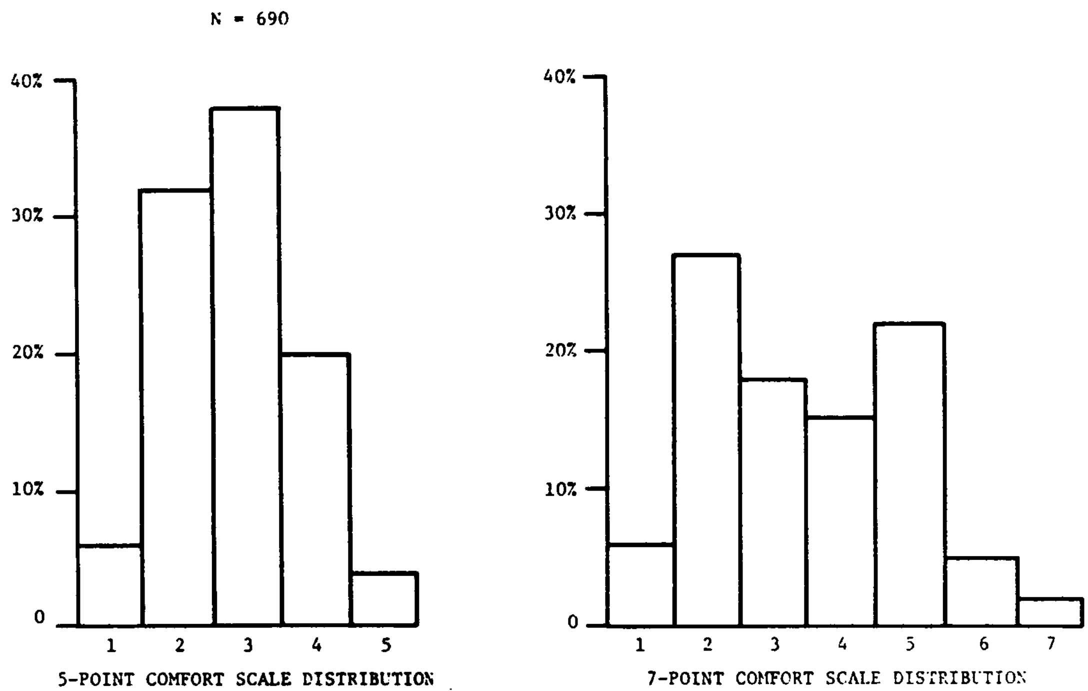

Figure 6.- Distribution of comfort responses.

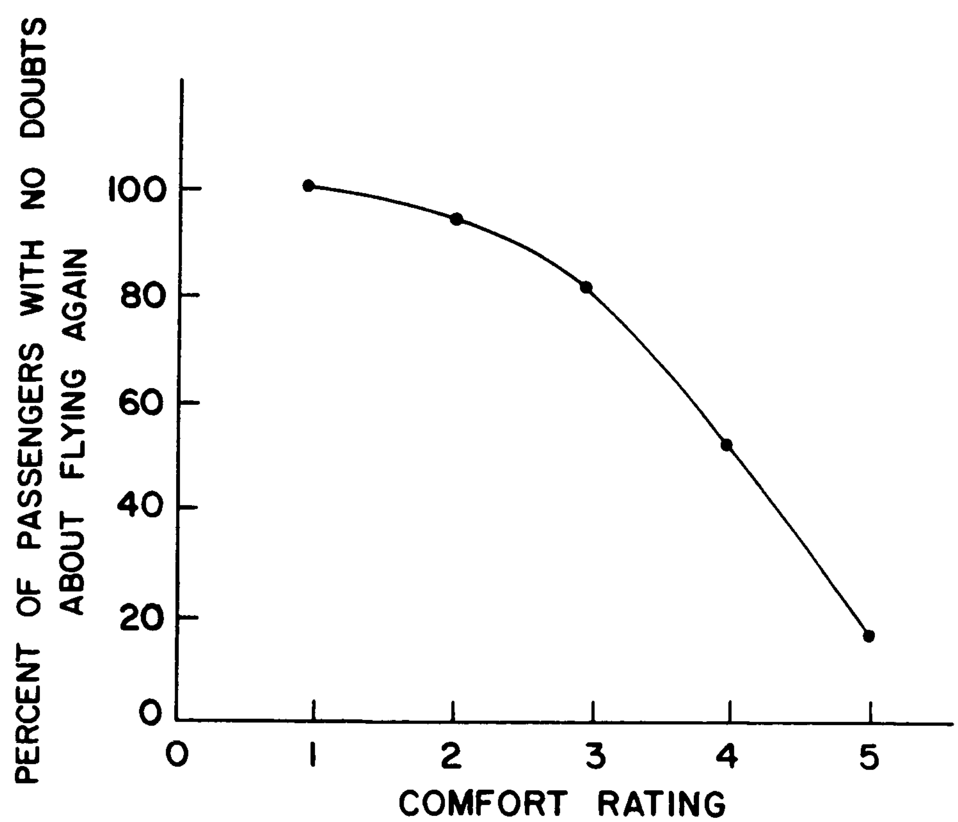

Figure 7.- Percent of passengers satisfied as a function of comfort level for the first flight program.

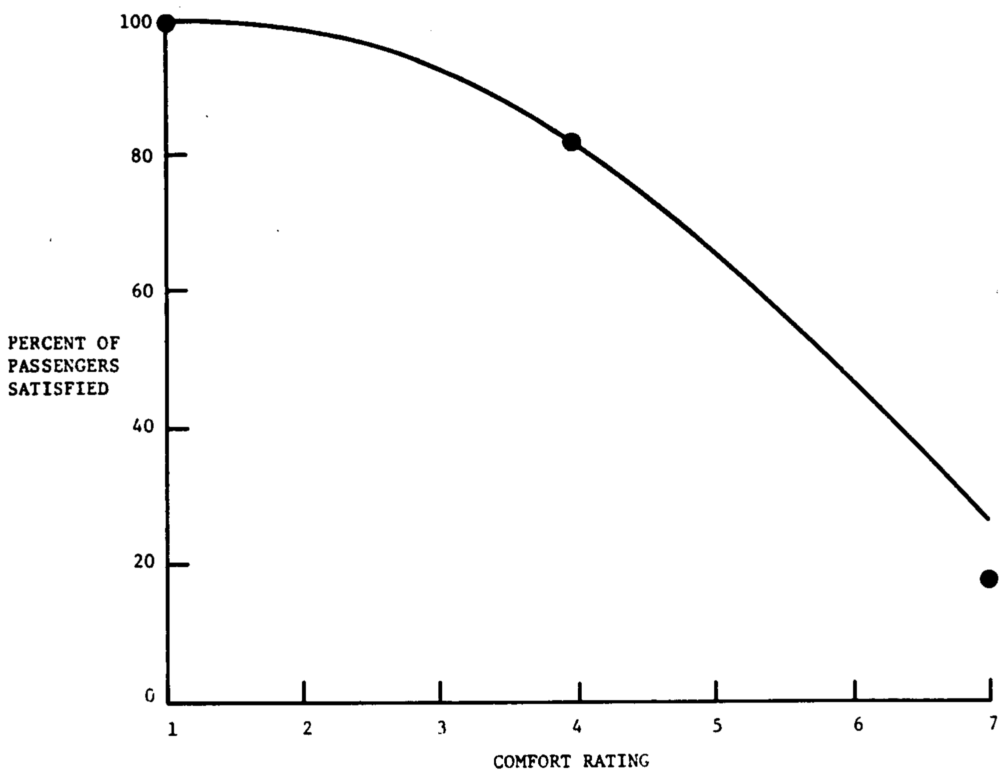

Figure 8.- Percent of passengers satisfied as a function of comfort level for the second flight program. (The dots represent results from the first flight program.)

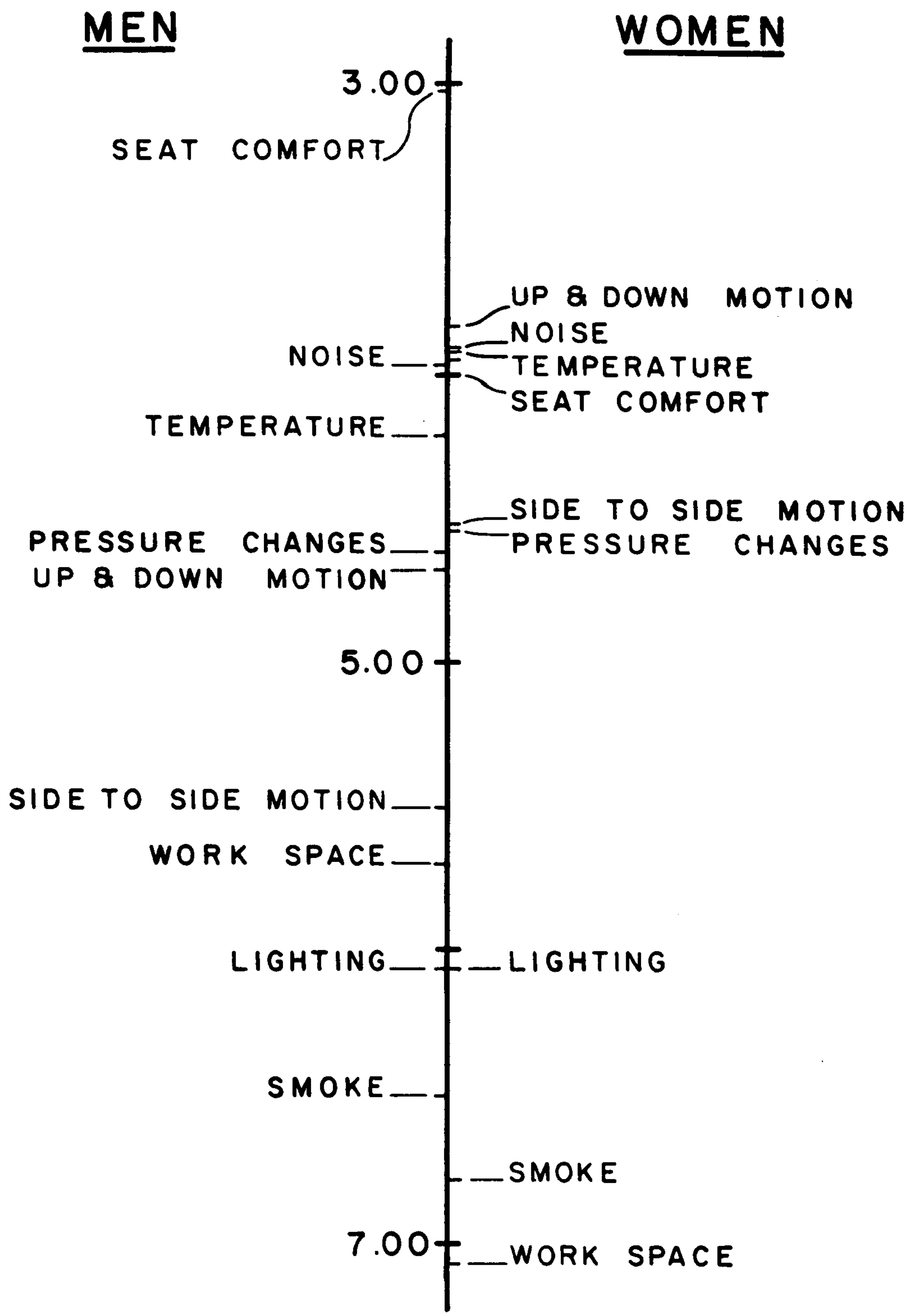

Figure 9.- Mean rankings of physical factors in comfort according to sex. (Low numbers indicate greater importance.)

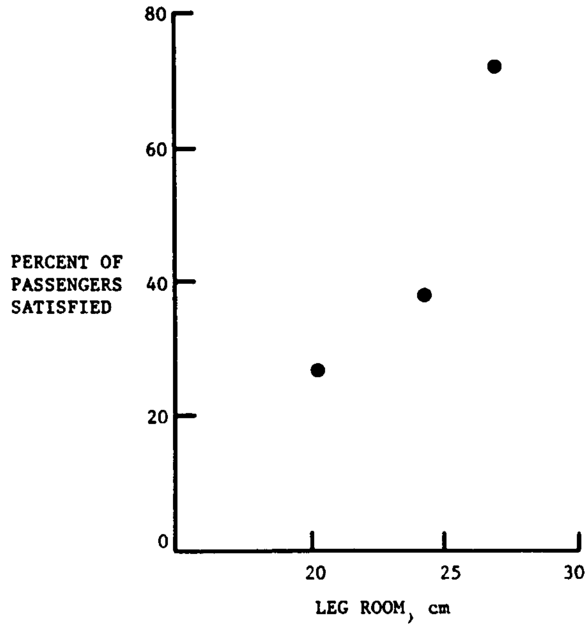

Figure 10.- Percent of passengers satisfied as a function of leg room.

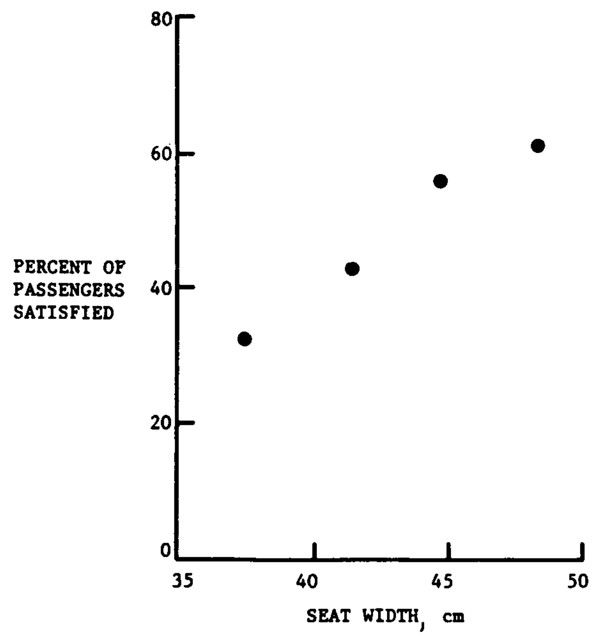

Figure 11.- Percent of passengers satisfied as a function of seat width.

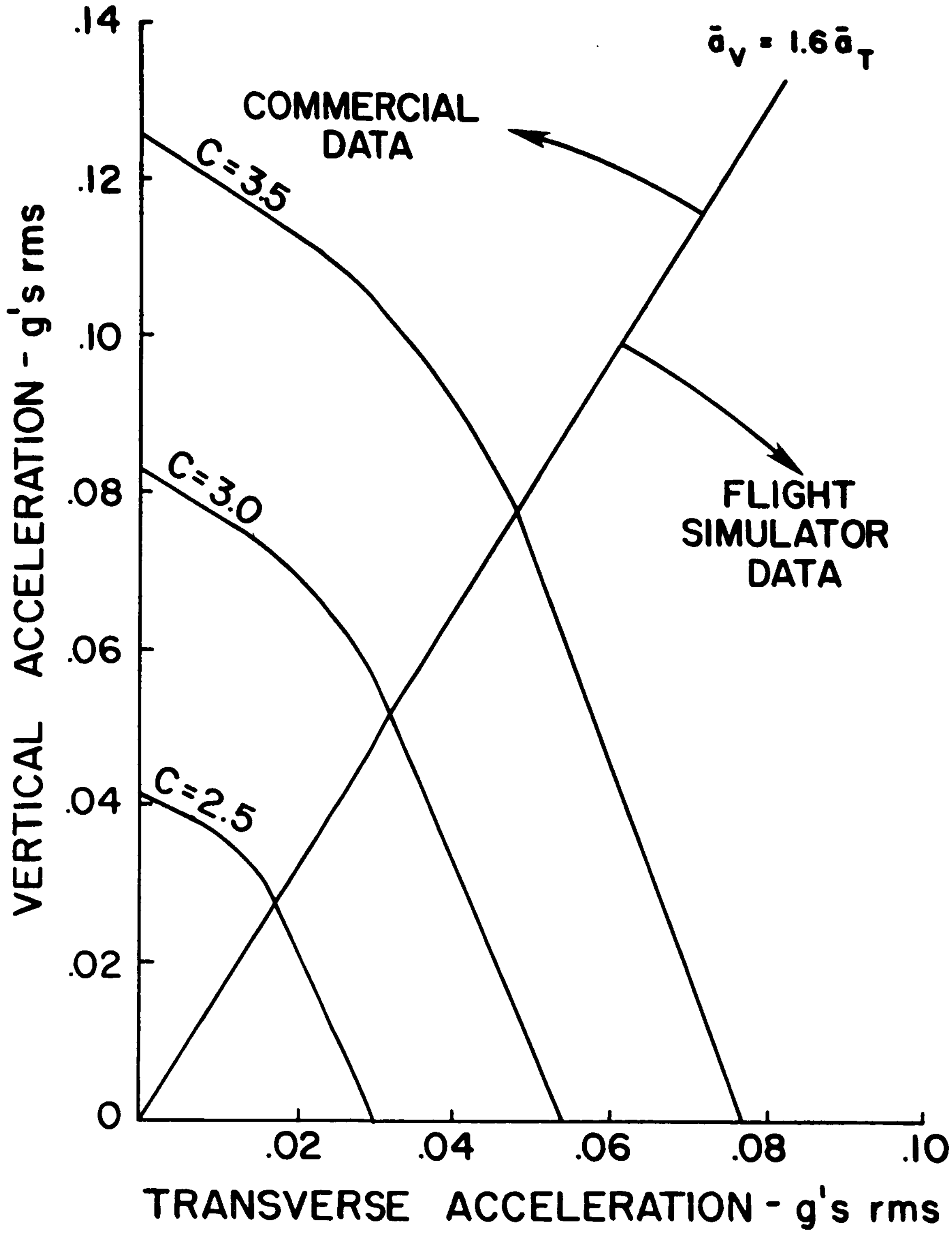

Figure 12.- Iso-contours for comfort responses based on 5-point scales.

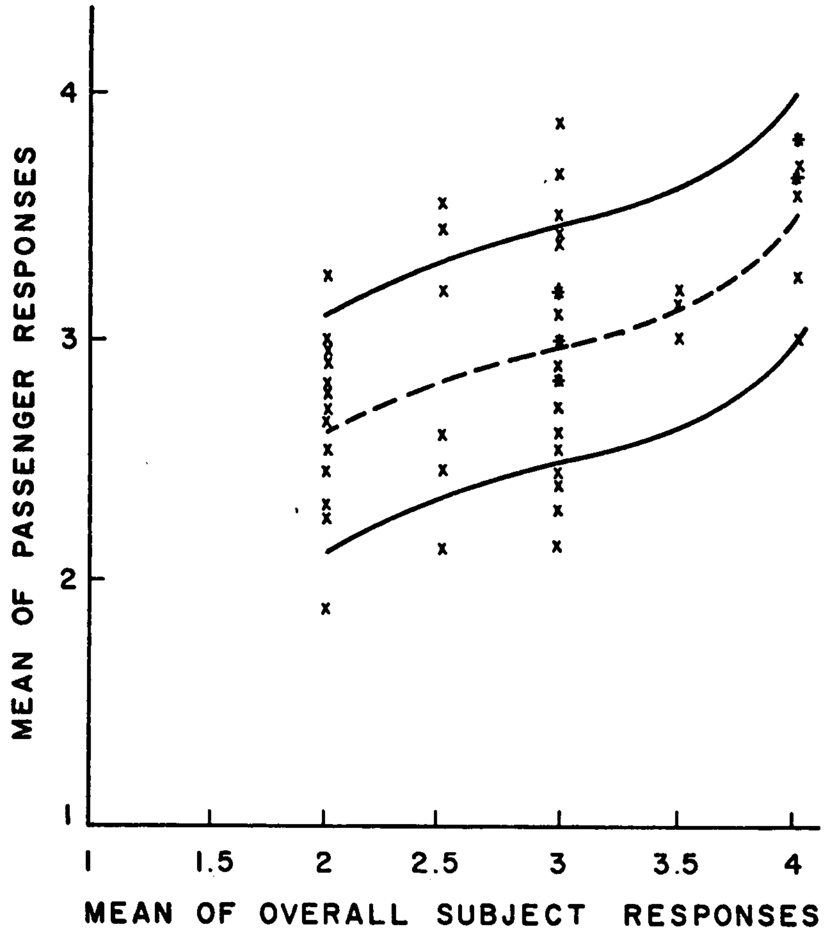

Figure 13.- Plot of mean passenger responses against mean subject responses.

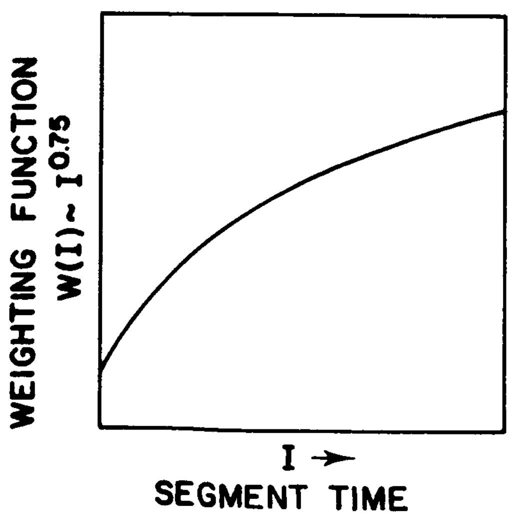

Figure 14.- Weighting function for integrating test subject responses.

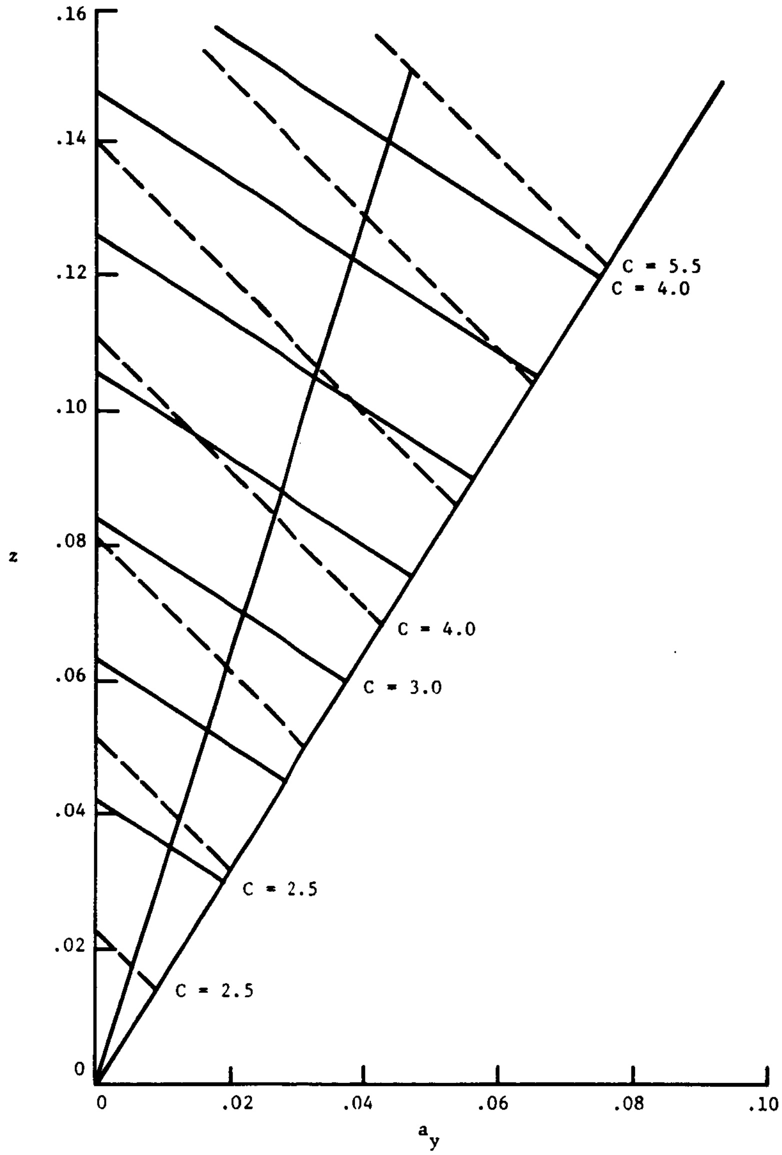

Figure 15.- Iso-contours from both comfort models. (Dotted lines are 7-point scale; solid are 5-point scale.)

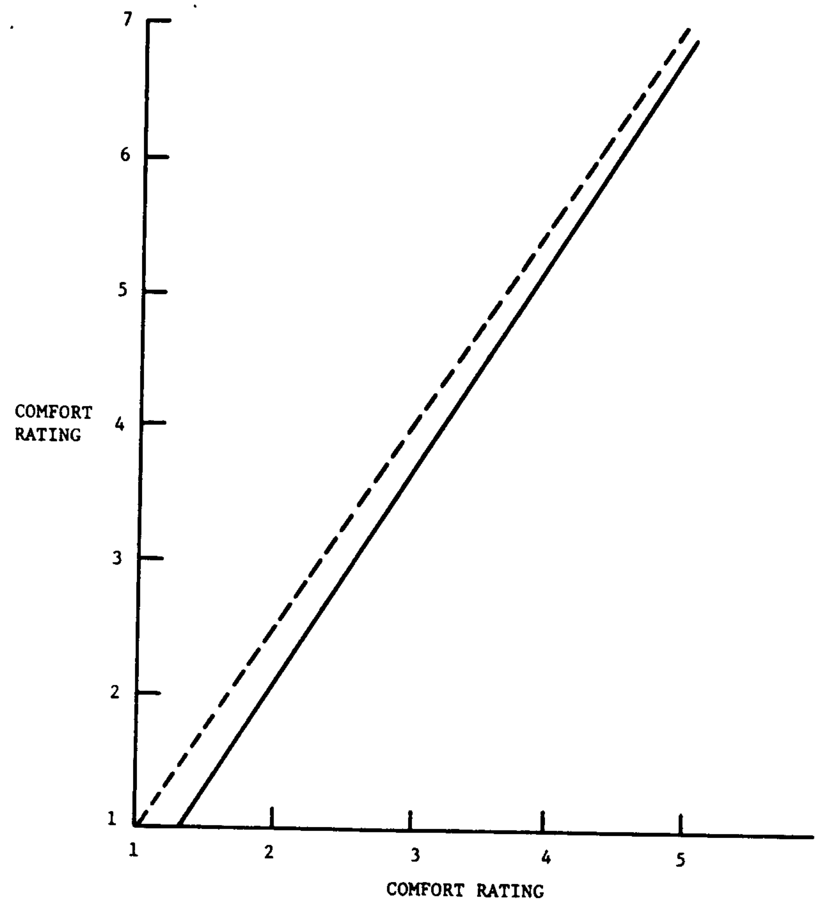

Figure 16.- Relation between comfort responses predicted from the two models (7 point and 5 point).

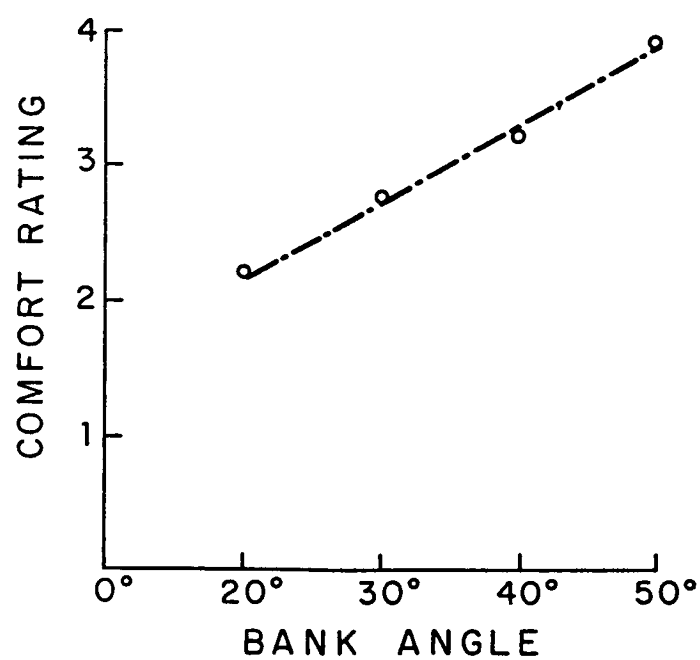

Figure 17.- Passenger responses to bank angles.