

N76-16773

REACTION OF PASSENGERS TO PUBLIC SERVICE VEHICLE RIDE

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SUMMARY

The paper describes a series of questionnaire studies carried out on passengers in public service vehicles in the United Kingdom particularly cross-channel hovercraft, helicopter and train. It examines the effectiveness of the different rating techniques employed and demonstrates that useful and reliable information can be obtained on the effects of such physical parameters as vibration, vehicle motion and noise using rating methods which involve no external standards. It also presents some results obtained from analysis of the survey returns.

INTRODUCTION

In recent years problems caused by severe traffic congestion on many of the major road routes and in the hearts of most cities, assisted recently by the energy crisis, have given rise to pressures to increase the usage of public transport vehicles by travellers to whom alternative private transport is available. In addition, the developed social consciences of many legislators are insisting that even those to whom no alternatives are available are entitled to more enlightened treatment than they frequently receive at present.

Accordingly, pressure is on both designers and operators to ensure that new vehicles and new modes which use old vehicle designs in new ways shall provide travel which is cost effective, reliable, attains high block speeds and is comfortable.

The first three factors can be argued out and settled largely by designers and operators on the basis of existing information. The necessary data can be obtained without involving passengers in such systems directly, and effective decisions can often be made very early in the design process. The question of what constitutes a comfortable ride is, however, more difficult to settle and frequently involves the use of test subjects in prototype vehicles at a stage when major design changes are difficult and costly.

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The term "comfort" implies that some state of well-being exists within a person and it is this state of well-being which needs to be investigated. Such a subjective condition is generated by the combined effect of the many physical and psychological factors acting on the person, as well as by the physiological state of the man himself.

Generally speaking, the physical factors present in a transport environment fall into fairly well-defined groups. The psychological and physiological variables of the individual are, however, far more numerous and less definite. These may range from the passenger's attitude towards the particular vehicle and form of transport to his state of mind and state of health at the time. One of the notable characteristics of the psychological and physiological variables of individual passengers is the large variation which is possible within even a small group of travellers.

It is not surprising, therefore, that most of the previous work on the comfort of passengers in transport vehicles has been geared to discovering how the "passengers" react to the physical parameters of the environment. In the main such inquiries have been conducted in laboratory conditions, in an environment entirely divorced from the transport situation. There are only a few studies which were reported before about 1970 which referred to passengers in actual vehicles. Even now most investigators work almost entirely in laboratories.

It was with the aim of obtaining useful information from transport users themselves that a program of work was started at the University College of Swansea with the financial assistance of the Science Research Council of Great Britain, which included the use of questionnaire surveys carried out on different types of transport systems.

The basic objectives of the surveys designed and carried out by the Department of Mechanical Engineering and the Department of Psychology jointly are:

- (1) Development of questionnaire approach.
- (2) Identification of descriptors.
- (3) Evaluation of semantic and numerical rating techniques.
- (4) Correlation of ratings with measured motions.
- (5) Determination of effects of sex, age and journey time on important environmental factors.

The paper discusses the items roughly in the order in which they occur in this list, although there are so many cross links that they will be exploited where possible, hopefully to clarify the approach and the results. The paper also draws fully on the information presented in the earlier paper in the symposium by the same authors (ref. 1).

## STUDIES CARRIED OUT

During the period 1969-1973 a series of studies was performed on a variety of vehicle types. The principal surveys carried out are listed in table I. The first hovercraft survey using the SRN6 was a preliminary attempt carried out on a route between Southampton and Cowes (Isle of Wight). Unfortunately, the route carried more commuter traffic than had been expected so that after a few days all except one or two passengers per trip had been questioned previously. An attempt was made immediately after to sample a medium distance bus route between Swansea and Cardiff, but this was abandoned at an early stage because the buses were either so full as to make it impossible for passengers to complete the questionnaires or so empty as to make the returns per trip completely uneconomic.

The three SRN4 surveys were carried out on the cross-channel Dover to Boulogne/Calais route and formed a continuing programme of improvement, made possible by the extremely cooperative attitude of the staff of Seaspeed. Indeed, the cooperation received from all operators approached was very good. The helicopter survey was carried out on the British Airways (then British European Airways) route between Penzance and the Scilly Isles, and the train survey was done between Newport and Reading on the Swansea to Paddington (London) British Rail Intercity Service. Further questionnaires are hopefully planned for both helicopter and train but await the acquisition of financial support and final approval by the operators before they are carried out.

It will be noted that the time taken to analyze the questionnaires, which to some extent governed the interval between surveys, increased as time progressed. This was due to the increasing complexity of questionnaires which was made possible by the highly cooperative attitude of most of the passengers and by a gradually clearer questionnaire format.

On surveys V and VI recordings of the vehicle motion were made. These recordings were obtained by multiplexing six channels of acceleration information onto a UHER 4400 battery tape recorder via an encoding package, specially built by DYNATEL (also battery operated), which also provided the necessary signal conditioning for the half-bridge piezoresistive ENDEVCO accelerometers. The accelerometers were mounted in three boxes, one providing signals for the vertical, lateral and fore and aft directions, one for the vertical and lateral directions and one for the vertical direction only. These were mounted on the floor of the vehicle in suitable positions to give a reasonable indication of the overall vehicle movements, at any point in the vehicle, in three mutually perpendicular directions. In all cases the recordings were made during the whole of the period for which passengers were actually completing questionnaires. For survey V (train) recordings were taken for about 20 minutes in each of a succession of coaches, whilst for survey VI (hovercraft) this was done for the whole of the hovercraft flight.

## QUESTIONNAIRE DESIGN AND RESPONSE RATES

### Objectives

The basic objective of the questionnaire studies was to obtain quantitative subjective reactions of passengers to the motion and vibration present in moving vehicles in a form which could be correlated with objective measurements of the vehicle motion and vibration. A preliminary aim had to be, however, to develop a questionnaire format which would enable reasonably precise, repeatable, numerical information to be obtained from untrained fare-paying passengers about their reaction to environmental factors, particularly to factors which were not those about which they habitually thought or made comments.

As the surveys progressed it became increasingly apparent that passengers found great difficulty in extracting and considering just one or two physical parameters (particularly motion and vibration) from all the others present. In addition, the usefulness of any information obtained is diminished if other information concerning aspects of the passenger's reaction to the journey is not obtained at the same time.

As a result the questionnaire was enlarged both in its scope and its aims to include as many as possible of the physical and psychological factors thought to be important in determining passenger comfort. Following this enlargement the problems of analysis and interpretation increased considerably. It should be emphasised, however, that the surveys carried out, some of which are to be discussed in some detail in this paper, were not pieces of unrelated work but were part of an on-going sequence in which the successes and failures of one were used to improve the design and operation of the next.

### Layout

Figures 1 to 3 indicate how the design and layout of the questionnaires changed during the surveys. The questionnaires designed for the first two surveys were printed in horizontal format on small card since it was thought that card would provide more support for passengers to write on than would larger sheets of paper (fig. 1). The next survey, and half of the fourth were printed in larger type, but still using the horizontal format (fig. 2). A new vertical format was tried for the other half of survey IV and in slightly modified form for the final two surveys (fig. 3). The final column of table I shows the percentages of the questionnaires accepted by passengers which were returned fully completed. This demonstrates the improvement in overall returns obtained as the questionnaire design and the approach of the interviewers improved.

## Use of Free Response Questions

During preliminary studies it very soon became apparent that non-technical and untrained people did not always understand very clearly what was intended when the words "vibration" and "motion" (defined to exclude the forward motion of the vehicle) were used. It was also found that problems arose in asking passengers to provide ratings of the intensity of vibration since there was no readily understood term which could describe this.

Accordingly, in addition to trying out different methods of obtaining subjective ratings of the environmental factors of interest, a considerable amount of effort was put into finding the words which could hopefully be used to describe vibration or motion intensity (as analogues of "loudness" for noise or "brightness" for lighting). In the course of this work it was found that many passengers described vibration and motion intensity in terms of situational phrases. Attempts were made to determine which phrases could be used realistically to describe end points on a scale of subjective intensity of vibration.

These efforts involved the use of unstructured questions (for example, the latter part of question 4 in fig. 1). Some of the changes in the early surveys were made in attempts to improve the response of passengers to these open-ended questions. The relative success of these changes can be inferred from the information given in table II.

During surveys IV, V, and VI the last page of the questionnaire was left blank with an invitation to the passenger to make whatever remarks he or she wished. Responses obtained referred to the whole range of services associated with the mode of transport being surveyed as well as providing comments on environmental factors within the vehicles and comments on the questionnaires. A great deal of useful information was gleaned from these remarks.

The next two sections of the paper describe the results of the attempts to obtain simple word descriptors and situational phrases and indicate the rating methods used to obtain passenger reactions. Inevitably there is a certain amount of cross linking between them.

### IDENTIFICATION OF VIBRATION AND MOTION DESCRIPTORS

The questionnaires used in the early surveys contained either open-ended questions in which passengers were asked to record descriptions of the vibration felt, preferably using single words or very short phrases, or more structured questions to obtain words which could be used to describe the subjective intensity of vibration in the same way as the words loudness and brightness are used in connection with noise and lighting respectively.

Analysis of the early responses came up with very few words or phrases which could be usefully reduced to single-word descriptors, the majority of the responses being phrases which related the vibration or motion of the vehicle

under investigation to another situation. Car and aircraft ride appeared very frequently in these situational comparisons, particularly a bad flight to represent an extreme in the vehicle under survey.

Table III(a) shows an analysis of the 43 single-word responses, from a total of 295 questionnaires in survey I, obtained to a question asking for single words to represent the "least" and the "most" end of a vibration rating scale. It is readily seen that all of them have connotations other than simple vibration response - pleasantness, comfort, peace, and so on. Some of these words, and others gleaned from the comments supplied by passengers on a "graffiti page" already referred to, were provided as a list on later surveys (for example, survey III, question 14 in fig. 2) and passengers were asked to select the best description of their feelings. The results of this are shown in table III(b) and are shown to be even more inconclusive since the words chosen to have a high priority really appear to relate to the quality of the vibration rather than its intensity.

The investigators were left to themselves to make a choice from inconclusive data. After some laboratory studies (ref. 2) they decided to use the concept of smooth to rough to form the ends of a rating line in a later survey (survey VI), primarily on the grounds that roughness was a concept less tied (in their opinion) to peculiarities of the ride motions of particular vehicles than the other words selected. Additionally, from analysis of the free style response produced by many passengers, some situational experiences, which were thought to be readily understandable by a majority of people questioned, were drafted for use as end points on rating scales. The use of these is described in some detail in the latter part of the next section. The situational scale ends devised for and used in survey III, IV and V are shown in table IV.

## EVALUATION OF RATING TECHNIQUES

### Limitations of Techniques Available for Field Studies

As has been stated earlier, the primary objective of the questionnaire surveys was to obtain numerical estimates of the severity of the relevant environmental factors from passengers in actual service vehicles. These could then be compared with objective measures of the physical parameters deemed to be those most relevant to the factors under consideration.

There are two fundamental limitations which are inevitably imposed on an quantitative scaling method under field conditions. The first is that the method used will probably be of the pencil and paper variety. Theoretically it would be possible to use certain psychophysical techniques such as cross-modality matching of riding vibration by the use of noise signals. However, there are usually practical difficulties involved in using such techniques, either difficulties of application or difficulties of calibration and interpretation.

The second difficulty is that during the course of the survey the stimuli within the passengers' environment are generally at one predominant level with

only relatively short term excursions from that level. Train noise, for example, is generally of about the same order except when the train is crossing points or moving through a tunnel. Even for vehicle types such as the cross-channel hovercraft, major changes in weather do not usually occur within the space of a week or so, and one to two weeks was the time allotted for most of the surveys on financial grounds.

### Effect of Scale Ends On Line Rating and Magnitude Estimation

There are three methods which can readily be used to obtain numerical ratings of subjective reaction to environmental parameters. These are listed briefly in table V, and typical forms of questions are shown in figure 4.

The methods categorized as "line rating" and "magnitude estimation" are obviously going to be severely affected by the choice of ends for the scales they are supposed to rate. Tentatively the authors have chosen to divide the scale ends into groups:

- (1) Aesthetic (for want of a better word)
- (2) Perception
- (3) Tolerance
- (4) Physical.

The Aesthetic group includes all pairs of scale ends which relate to subjective reactions which do not tend to make the passenger think specifically of one end of the scale or the other but are likely to attract reactions over the whole range. Perception and Tolerance groups tend to bias thoughts to one end or the other of a subjective scale and may also tend to include ideas related to the physical or physiological effects. The Physical group, as its name implies, refers pretty clearly to physical attributes of the environment without really asking for a relationship with a subjective feeling.

Figures 5 and 6 show the effects on ratings of a particular environment. (Each bar indicates the median and interquartile range of ratings for each scale end). The group classed as Aesthetic are centered with medians close to the rating of 5. The perception line shows a significantly higher rating, implying that the passengers were thinking about whether or not they could perceive vibration at all, whilst the tolerance line shows a significantly low rating with the implication that the passengers were considering whether or not they were being subjected to extreme physical effects.

The other factor which can affect the rating of environmental effects by the "line rating" method is the type of line used, particularly the way in which the line is divided into sections and whether or not the sections are labelled. A series of experiments was performed which convinced the authors that the differences in ratings caused by differences in line types were of negligible importance. These experiments have been fully reported in Osborne and Clarke (ref. 2).

## Situational Scale Ends

Figures 7 and 8 show comparisons between ratings made along a 10 cm rating line and those made by ascribing a number to the stimulus of the same vehicle using the same scale ends. Ratings were generally made at the same time by different people using parallel forms of questionnaires, the numbers being carefully matched so that equal numbers of each form were distributed on each journey. It can be seen that the relationship between the line and magnitude estimation ratings is very good for noise (fig. 7), but not so good for vibration (fig. 8).

It was the authors' intention in selecting the scale ends to try to find situations which could be clearly understood and accepted by as many people as possible. The hope was that they could also be used as a physical scale (with in reason) by using averages of physical measurements appropriate to the situations as the scale ends. Thus, standing next to a heavy lorry going uphill would usually result in a noise level of about 90 to 95 dB(A). Hence, there could also be hidden in the use of situational scale ends a method of providing passengers with a pseudocalibration on a physically recoverable basis. This has not been investigated yet in view of the fact that the scale ends of interest in riding investigations need to be refined to get better agreement between answers obtained by different rating methods.

## Graphic Rating

The third type of rating referred to in table V is the graphic rating in which guiding phrases are placed along the line. In the earlier surveys considerable attention was given to the possibility of using such a rating technique in a similar way to Shackel and others (ref. 3) who had used it for the study of seat comfort. However, some testing, which is fully reported in Osborne and Clarke (ref. 4), convinced the investigators that it was not a particularly good method because of possible confusion as to the meanings of the steps on the scale.

Figure 9 shows a five-point comfort scale which has been used, both in a defined and in an undefined form, in both laboratory studies and field studies. The laboratory studies are discussed in Clarke and Osborne (ref. 1) and in more detail in Osborne and Clarke (ref. 5). The relevant point to be raised here is that the laboratory studies showed that the scatter between individual responses of subjects to vertical sinusoidal excitation could be reduced by providing definitions of the points on the five-point rating scale.

## CORRELATION OF RATINGS WITH MEASURED MOTIONS

Survey VI (see table I) was conducted during September 1973 on the Seaspeed route operated between Dover (England) and Boulogne (France) using SRN4



hovercraft. During the course of this survey recordings were made of six components of acceleration at the following three places on the floor of the passenger spaces:

- (1) Rear port side cabin; vertical, lateral and fore-and-aft acceleration
- (2) Front port side cabin; vertical and lateral acceleration
- (3) Front starboard side cabin; vertical acceleration

The positions of the accelerometer boxes were selected so as to enable a reasonable estimate of vibrations in three directions experienced by small groups of passengers to be made. All that has been done so far has been to assume the levels of vertical acceleration to be roughly constant over the rear of the rear cabin and over the front cabin, with a very simple assessment of root-mean-square vertical acceleration being made for the time segments of each journey in which the majority of passengers completed questionnaires. Programs to enable more sophisticated analysis of the tape recordings to be carried out on a PDP11/10 computer with Micro Consultants A/D convertor, which has been recently bought by the Mechanical Engineering Department, are still being prepared.

Survey VI combined questions asking for ratings of overall comfort, motion comfort (motion being defined in the questionnaire as "motion of the craft due to the waves") and vibration comfort, using the five-point scale shown in figure 9. It also contained questions asking for ratings of overall comfort on a 10 cm rating line with scale ends "Very Comfortable" and "Very Uncomfortable" and for ratings of motion comfort and vibration comfort on a similar line with scale ends "Smooth" and "Rough".

#### Relationship Between Category Ratings and Line Ratings

The first exercise was to relate the category ratings to appropriate line ratings. For example, the mean and standard deviation were calculated for the ratings on the comfort line of all passengers who checked the overall comfort of the vehicle as "Just Comfortable". The values of the mean plus or minus the standard deviation were taken as being rough boundaries of the "Just Comfortable" region in the rating line. This was repeated for the other four categories of overall comfort. The line was then sectioned by taking the boundaries thus obtained and halving the overlaps and underlaps of the rough ranges. The final result is shown in figure 10. Also shown are the results for the vibration comfort and the motion comfort rating lines.

From these results figure 11 is produced by matching the boundaries of the categories for overall comfort against the same categories for motion comfort and vibration comfort. The curves indicate, for example, that someone rating overall comfort at 6 is likely to have rated motion comfort at about 5.6 and vibration comfort at 6.5.

## Relationship Between Motion/Vibration Ratings and Vibration Measurements

The next stage is to obtain some relationship between mean motion rating and measured accelerations. As a first attempt it was assumed that the passengers were identifying the motion due to the waves and the vibration as separate effects and were able to rate the two effects separately without trouble. Some uncalibrated power spectra have been obtained for the hovercraft recordings. Figure 12 gives the general pattern of these, indicating a high value of spectral density in the lower frequency range, between 0 and 3 Hz say and a high narrow peak, generally occurring between 10 and 12 Hz. Accordingly it was tentatively decided to identify the motion effect with low frequency effects and for convenience to filter the recordings in the frequency range 0 to 4 Hz. The vibration was tentatively identified with the peak at about 12 Hz on the grounds that for frequencies up to about 50 Hz this peak generally stood out well above the noise floor, and for convenience the recordings were filtered to pass the octave band 8 to 16 Hz.

Segments of the tapes were identified which covered time intervals during which a sufficient number of ratings were made. For each of these segments the mean motion and mean vibration rating were obtained and compared with the root-mean-square acceleration of the record filtered between 0 and 4 Hz and between 8 and 16 Hz respectively. The results are the regression lines shown in figures 13 and 14 respectively. It can be seen that the straight line relationship is the best simple fit that could be achieved between either of the pairs of variables and that despite the fact that the correlation coefficients achieved are not particularly high there is a good indication that more sophisticated analysis of the recordings could be expected to achieve better fits.

### Effect on Overall Comfort of Vibration in Different Frequency Ranges

The final stage is to make use of figure 11 and produce figure 15 which shows how the overall comfort rating varies with the root-mean-square acceleration in the two bandwidths from 0 to 4 Hz and from 8 to 16 Hz. At this stage all that can really be obtained from figure 15 are some general deductions about the relative equivalences between motion effects and vibration effects.

As a check of sorts on the rather tortuous argument which has produced figure 15 an attempt was made to reconcile overall comfort ratings and vibration and motion ratings directly. Some results from the survey carried out on the train service from Newport to Reading were added for good measure. Figures 16 and 17 show the plots of mean values of overall comfort rating against mean values of vibration rating and mean values of motion rating respectively. It can be seen from figure 16 that the plots for vibration rating from train surveys and hovercraft surveys are similar, and that for all those plots a simple straight line regression is likely to be a good fit.

Figure 18 shows the regression line obtained from making such a fit. It is not suggested, incidentally, that the close match between train and hovercraft vibration lines is other than coincidence. However, examination of the points on figures 13 and 14 indicates that the root-mean-square acceleration values which actually occur in the hovercraft lie within the range 0.2 to 1.5 m/sec<sup>2</sup> for both frequency bands examined, and it seems reasonable to suggest that extremes of passenger ratings on the journeys sampled would coincide approximately with extremes of physical values.

On this basis the agreement between the hovercraft lines of figure 18 and the lines of figure 15 is quite good. The only obvious discrepancy is that the relative positions of the motion and vibration lines are interchanged between the two figures.

The fact that reasonable looking curves can be obtained from the sort of arguments which have been used in this section is encouraging. Agreement of a sort between two different uses of the data is fairly good and indicates that there is good reason to believe that passengers can be induced to provide information about vibration and motion effects. The pursuit of more elaborate techniques for analysis of the data is therefore worthwhile, and in due course, when equipment and programmes are working properly, this will be done.

#### EFFECTS OF AGE, SEX AND JOURNEY TIME ON IMPORTANT ENVIRONMENTAL FACTORS

This section will discuss some aspects of the passenger and his journey and their effect on the passenger's overall assessment of his journey comfort. The overall intention was to evaluate more clearly the importance to passengers of the various factors which make up the total comfort effect and how these change with time.

#### Relative Importance of Environmental Factors

In the train study it was decided to try to discover whether passengers were confusing two types of questions. The first type asks how important a particular environmental factor is to a passenger's feeling of comfort. The second type asks for a specific subjective rating of the level of that factor in a particular vehicle. There had been some doubt from reading passenger comments in previous studies as to whether passengers were actually providing ratings of intensity levels when asked to do so, or whether they were really indicating importance of a parameter relative to some undefined datum.

To do this, a separate single-sheet question set was issued to the passengers on the train in addition to the questionnaire. The relevant portion of the separate sheet is shown in figure 19, and the histograms of

the responses are shown in figure 20. It can be seen that the results from the five environmental factors listed fall distinctly into two groups. A surprising result is that seat comfort is listed with temperature and ventilation in view of the strong effect which it is thought seat comfort (or seat design at any rate) will have on reactions to motion. The interesting point is that passengers feel that seat comfort, ventilation and temperature are more important than vibration and noise as environmental factors, whilst at the same time they feel that suitable criteria have been set for the first three but not for the last two. The different shapes of the "importance" and "level" responses indicate quite clearly that passengers are able to rate the levels of environmental factors as a separate issue from the expression of feelings about relative importance of the same factors. The high response which indicated that train vibration and noise are too high can also be taken as adequate justification for continuing with investigations such as this.

Figure 21 shows information on the relative importance of different environmental factors which was gleaned from the comments made by passengers during the course of survey IV. Here four out of the first seven factors listed as having upset passengers in connection with a total service are vehicle environmental factors, with vibration and motion being near the head of the list.

#### Effect of Age of Passengers

The effect of age on comfort rating of the hovercraft is shown in figure 22 and 23. Figure 22 indicates a very slight decrease in sensitivity to overall ride at ages 50 and above (high comfort ratings mean less comfortable ride). Figure 23, on the other hand, indicates a greater age response to motion and to vibration. Both factors appear to show a general trend in which sensitivity decreases with increasing age. The overall effect is one showing a sharp decrease from a high number of objections at ages below 10 with the effect then flattening out for overall craft motion but continuing to decrease for vibration. The effects at extreme ages may be coloured by relatively low proportions of passengers in these age groups. Generally speaking, however, there is an indication that the very young find both the overall craft motion and the vibration unpleasant.

#### Effect of Sex of Passengers

The effects of sex on reactions were more difficult to establish overall since the population sampled was very unbalanced. Considerably more men than women were questioned over the whole range of surveys. However, there are indications that whereas men and women appear to have much the same reactions to vibration and motion, women tended to react more favourably to the overall comfort level provided than men.

## Effect of Journey Time

Finally, some information about the effects of time of exposure can be deduced. On questionnaires distributed during surveys V and VI passengers were asked to write the time at which they completed a certain part of the task. By subtracting the journey start time from this some guidance as to length of exposure to that particular journey could be obtained. The exposure time varied from 0 to 20 minutes for the hovercraft trip, and from 0 to 150 minutes for the train ride. Correlation of the estimated trip duration with ratings of vibration effect, overall motion effect and with overall comfort indicated no discernable change for a period up to 150 minutes. This is in complete contradiction to the predictions in ISO 2361 (ref. 6) which indicates a change from 100 percent acceptance at 4 minutes to about 30 percent acceptance at 150 minutes, thus indicating, in the view of the authors, the falsity of the ISO time dependence predictions for reduced comfort at these levels of vibration.

There are, however, indicated changes over long journey times in the relative importance of different environmental factors on comfort. Figures 24 and 25 indicate cumulative plots of the quoted dominant factors for the hovercraft (up to 20 minutes) and for the train (up to 140 minutes). Allowing for variations due to small group sizes, there is no significant change over the indicated 16 to 17 minutes, but there is an indication that there may be an increase in the importance of seat comfort towards the end of the journey, with vibration and motion decreasing in importance accordingly. For the longer train journeys the marked change is the increase, as time goes on, of the rating of temperatures at the expense of noise and vibration.

### CONCLUDING REMARKS

The work described set out to determine whether or not questionnaire studies of ordinary fare-paying passengers in public service vehicles could be used to provide repeatable and reliable information about individual environmental parameters.

The results have exceeded expectations. They show that, provided due care is taken in the design of the questionnaires, high response rates can be obtained. The use of a format in which the same question is asked in different ways, or the use of parallel forms in which different groups of people are asked the same question in different ways, enables cross checks on numerical ratings to be carried out in a way which enhances their value and meaning.

The surveys have also provided an appreciable amount of information about the effects of different physical, demographic and personal factors in ride comfort, much of this being in an understandable numerical form which can be used directly in further analyses.

Finally, the surveys have resulted in the collection of a large number of passenger comments on all aspects of the service provided and of the vehicle design. Much of this information is still waiting to be extracted and used.

#### ACKNOWLEDGEMENTS

Thanks are due to the Science Research Council of Great Britain for financial support, to Mrs. Susan Osborne and others for much hard work in gathering and preparing data for processing and to Professor C. E. M. Hansel and Professor F. T. Barwell of the University College of Swansea for advice and support.

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TABLE I. - SURVEYS CARRIED OUT BETWEEN  
SEPTEMBER 1969 AND OCTOBER 1973

Survey	Vehicle	Date	Number of questionnaires completed	Percent of questionnaires issued and returned completed
I	Hovercraft SRN6	Dec. 1969	295	74
II	Hovercraft SRN4	Apr. 1970	519	71
III	Helicopter S-61	Aug. 1970	483	81
<sup>a</sup> IV	Hovercraft SRN4	Feb. 1971	1066	78
V	Train	Feb. 1971	1602	97
VI	Hovercraft SRN4	Sept. 1973	691	80

<sup>a</sup>Survey IV was in two parts of nearly identical size. Survey IV(a) was a repeat, apart from one or two modifications to the wording, of survey III but applied to the SRN4 hovercraft, thus giving a questionnaire which had been applied to two different vehicles. Survey IV(b) was a new design run parallel with survey IV(a) to give comparisons between two layouts. Survey IV(b) led directly to surveys V and VI.

Table II. - RESPONSE RATE TO QUESTIONS  
ASKING FOR DESCRIPTION

Survey	Type of information required	Response rate, percent	Mean response rate to other questions, percent
I	Motion	50	} 77
	Provide scale ends	53	
	Scale ends	45	
II	Motion	45	} 91
	Provide scale ends	35	
III	Motion	27	} 93
	Noise	60	
	Fuselage vibration	16	
IV(a)	Motion	26	} 84
	Noise	49	
IV(b)	Motion	75	93
V	Vibration	94	98



Table III. - STUDY OF MOTION AND VIBRATION DESCRIPTORS

(a) Single Word Descriptors Offered as Vibration Scale Ends

[Forty-three passenger responses from survey I]

"Least" scale end		"Most" scale end	
Descriptor	Number of responses	Descriptor	Number of responses
Smooth	24	Rough	14
Pleasant	6	Bumpy	12
Comfortable	5	Uncomfortable	4
Gliding	2	Shake	4
Relaxing	2	Jarring	3
Peaceful	2	Nauseating	2
Enjoyable	1	Bounce	2
		Unpleasant	1
		Lurching	1

(b) Ordering of Descriptors by Passengers

Descriptor	Survey III, helicopter		Survey IV(a), hovercraft	
	Place	Percent of passengers	Place	Percent of passengers
Bumpy	5	4	1	28
Shaky	1	41	5	12
Bouncy	3	5	2	14
Judder	2	39	3	14
Jolty	4	4.5	4	14
Rough	6	3	6	7
Lurch	7	2	8	3
Plunge	8	1	7	7
Heave	9	0.5	9	11

TABLE IV. - SITUATIONAL PHRASES SELECTED  
AS SCALE ENDS

Scale	"Least" scale end	"Most" scale end
Noise	Sitting in a soundproof room	Standing next to a heavy lorry going uphill
Vibration	Complete rest	Travelling in an old car over an unmade road

TABLE V. - RATING TECHNIQUES

Rating method:

Magnitude estimation

Rating on line:

Unsectioned line

Sectioned line

Graphic Rating

Scale ends:

Descriptors:

Aesthetic type

Perception type

Tolerance type

Physical type

Situational phrases

3. Are you aware of any sideways or up-and-down movement in this Hovercraft (other than the forward movement)?

Definitely   Possibly   Not sure   Probably not   Definitely not

If you have answered "definitely not" to Question 3 then end the questionnaire here; otherwise continue.

4. Would you describe the motion (other than forward) that you are experiencing on this Hovercraft as:-

a) A type of vibration                      Yes                      No

OR

b) Another type of motion                      Yes                      No

If you answer yes to 4b then please describe:-

Figure 1. - Format of questionnaire for survey I.

(Questions printed on both sides of card.)

Please do not attempt the next question till nearer the end of your journey.

13. When you have considered all the factors that might affect your reaction to the journey, could you please rate this particular journey on the scale opposite, by putting a cross on the vertical line.

IT WAS FRIGHTENING  
IT WAS UNPLEASANT  
IT WAS UNCOMFORTABLE  
IT WAS TOLERABLE  
IT WAS PLEASANT  
IT WAS RELAXING  
IT WAS VERY SMOOTH

14. The amount, or intensity, of sound is commonly described in terms of its 'loudness'. Similarly the intensity of light can be described in terms of its 'brightness'. The following is a list of words which could be used to describe the intensity of an up-and-down motion or 'vibration'. Please tick those which you consider to be relevant and then ring the one word which you consider to be most applicable.

Bouncyness	Jolty	Plunge	Heave
Shake	Bumpyness	Lurch	Judder
Roughness	Any others (Please specify).		

Figure 2. - Format of questionnaire for survey III.  
(Questions printed on one side of paper only.)

<p>8. Please rate the levels of (a) MOTION OF THE CRAFT DUE TO THE WAVES and (b) CABIN VIBRATION that you are at present experiencing, by putting a cross on the line corresponding to your judgement.</p> <p>N.B. You do not have to keep to the sectioning on the line.</p> <p style="text-align: center;">(a) MOTION DUE TO THE WAVES</p> <p>SMOOTH <span style="float: right;">ROUGH</span></p> <p>_____</p> <p style="text-align: center;">(b) CABIN VIBRATION</p> <p>SMOOTH <span style="float: right;">ROUGH</span></p> <p>_____</p>	<p>15</p> <p>17</p> <p>16</p>
<p>9. In terms of the following scale, where do you think the COMFORT level of this particular journey would fall?</p> <p>Please tick the appropriate box.</p> <p>Very comfortable <input type="checkbox"/></p> <p>Comfortable <input type="checkbox"/></p> <p>Just comfortable <input type="checkbox"/></p> <p>Uncomfortable <input type="checkbox"/></p> <p>Very uncomfortable <input type="checkbox"/></p>	<p>18</p>
<p>10. In terms of the following scale, where do you think the TEMPERATURE of this hovercraft would fall?</p> <p>HOT <span style="float: right;">COLD</span></p> <p>_____</p>	<p>19</p> <p>-</p> <p>-</p> <p>22</p> <p>-</p>

Figure 3. - Format of questionnaire for survey VI.  
 (Questions printed on one side of paper only.)

a) Line rating

Please rate the level of noise that you are at present experiencing in this compartment, by putting a cross on the line corresponding to your judgement.

Loud

Quiet



b) Magnitude estimation rating

Please try to imagine the levels of vibration which would be experienced:

- a) At complete rest, and
- b) Whilst travelling in an old car over an unmade road.

If the former (complete rest) was valued at 0, and the latter (travelling in an old car) was valued at 100, what value would you give to the present level of vibration in this compartment?

c) Graphic rating

In terms of the following scale, where do you think the noise level in the compartment would fall?

Please tick the appropriate box.

Very quiet      Fairly quiet      Moderate      Fairly loud      Very loud

Figure 4. - Rating methods used in questionnaire studies.

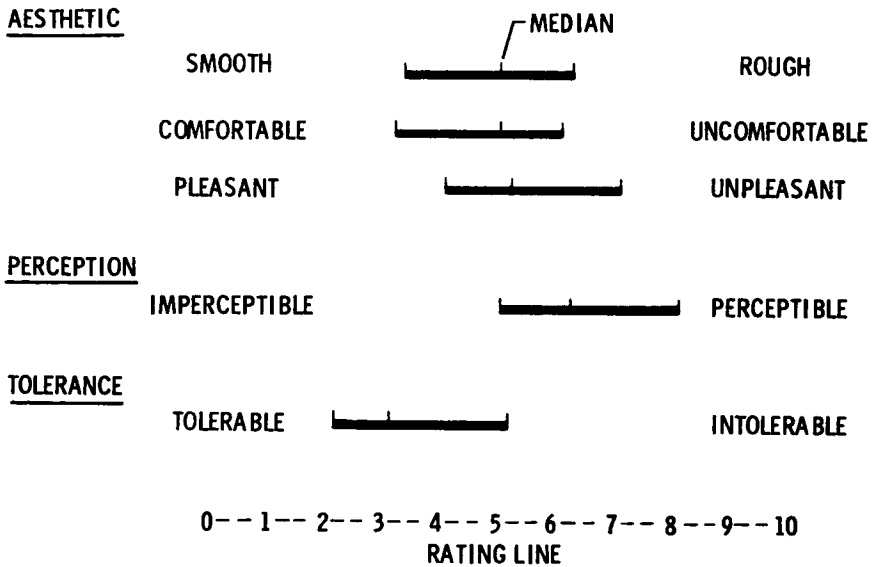


Figure 5. - Effect of scale ends on rating line responses to ride vibration of SRN6 hovercraft.

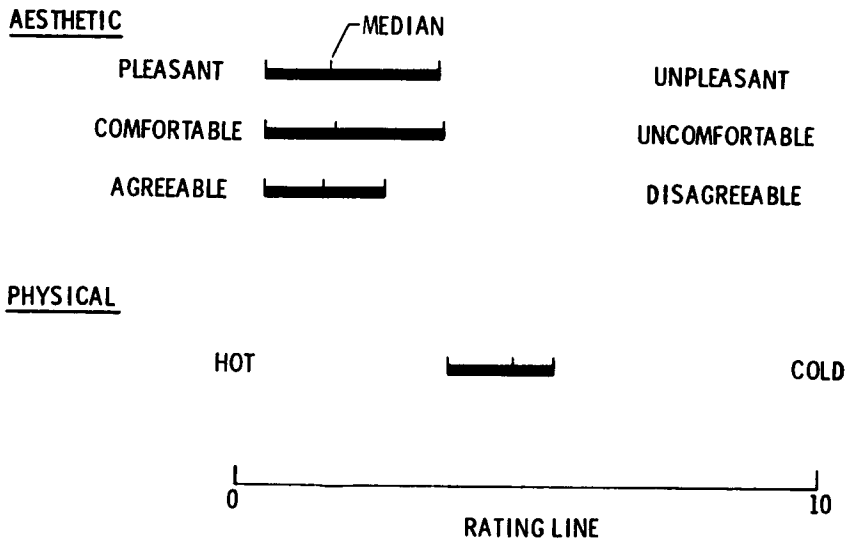


Figure 6. - Effect of scale ends on rating responses to temperature of SRN4 hovercraft.

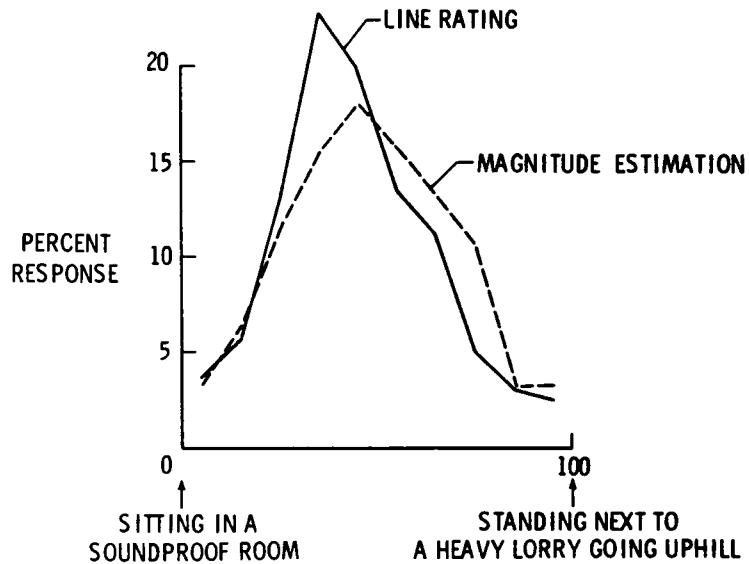


Figure 7. - Comparison of ratings of hovercraft noise obtained by means of line rating and magnitude estimation using situational end points for scales.

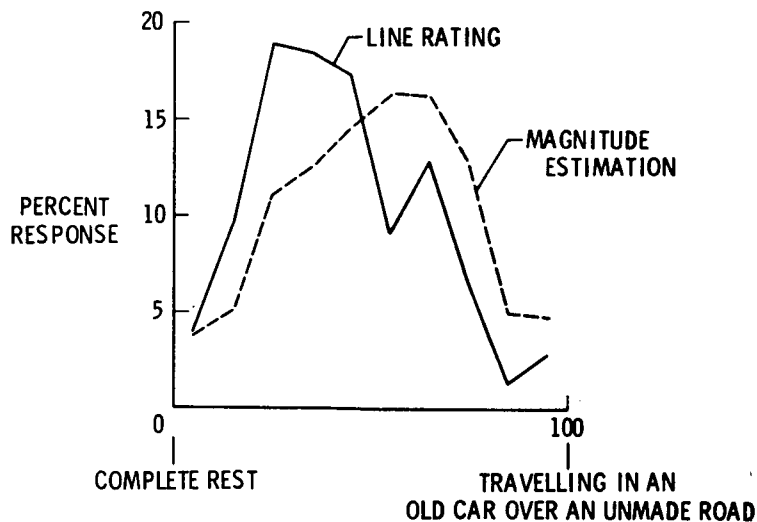


Figure 8. - Comparison of ratings of hovercraft vibration obtained by means of line rating and magnitude estimation using situational end points for scales.



DEFINED		
UNDEFINED		
VERY UNCOMFORTABLE	(VU)	WOULD NOT USE THAT FORM OF TRANSPORT
UNCOMFORTABLE	(U)	WOULD ONLY USE FOR SHORT JOURNEYS
JUST COMFORTABLE	(JC)	FOR A JOURNEY OF NOT MORE THAN 1/2 HOUR
COMFORTABLE	(C)	FOR A JOURNEY OF ABOUT 1 1/2 HOURS
VERY COMFORTABLE	(VC)	FOR A LONG JOURNEY

Figure 9. - Defined and undefined semantic rating scales.

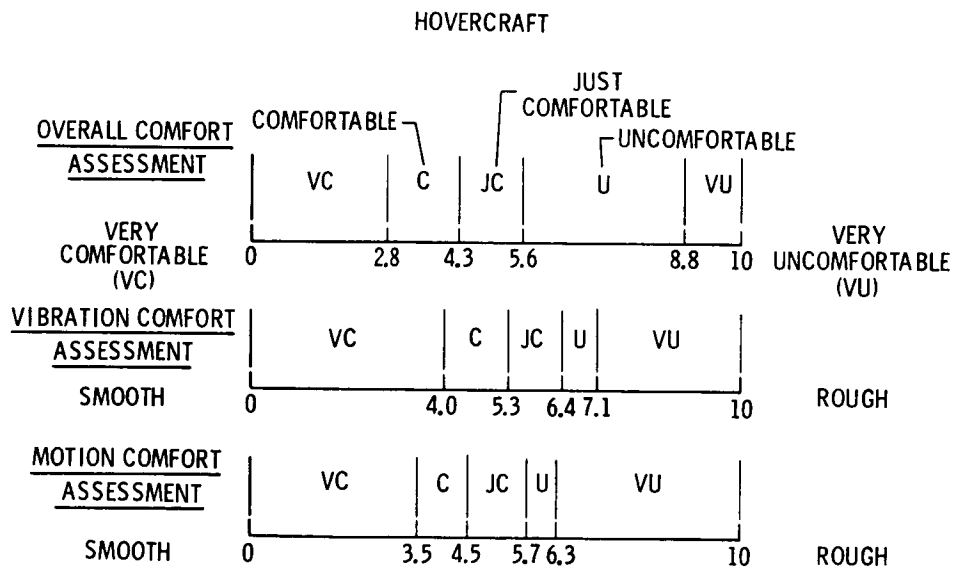


Figure 10. - Linking of semantic assessments with line ratings.

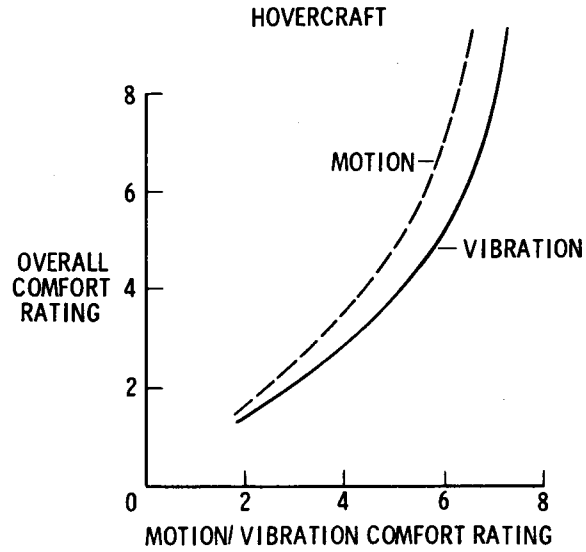


Figure 11. - Relationship between overall comfort rating and motion or vibration comfort rating.

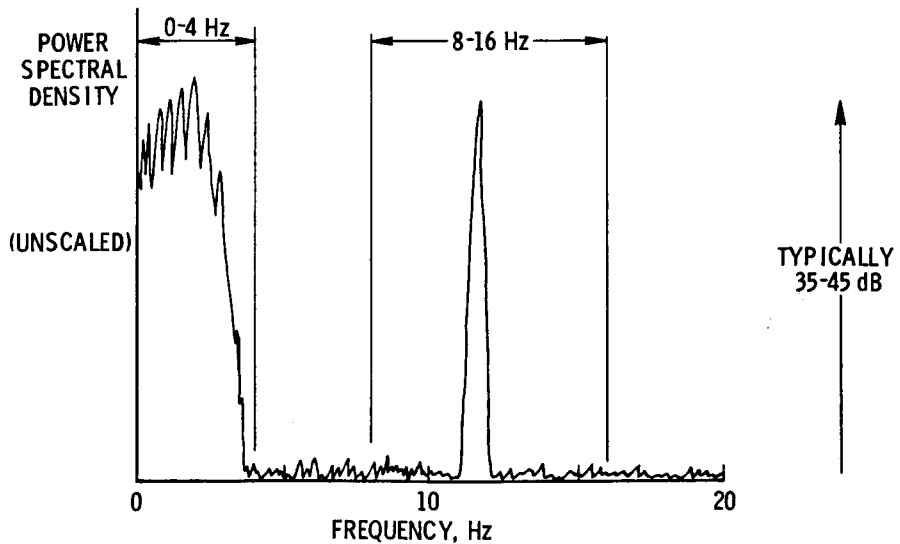


Figure 12. - Typical spectral density shape for vertical hovercraft motion.

HOVERCRAFT

REGRESSION LINE RATING = 2.56 (ACC.) + 2.18

CORRELATION COEFFICIENT = 0.73

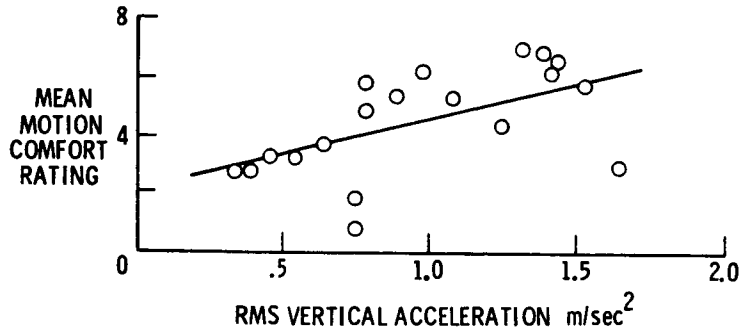


Figure 13. - Relationship between mean motion comfort rating and vertical vibration in the 0 to 4 Hz band.

HOVERCRAFT

REGRESSION LINE RATING = 1.95 (ACC.) + 3.75

CORRELATION COEFFICIENT = 0.5

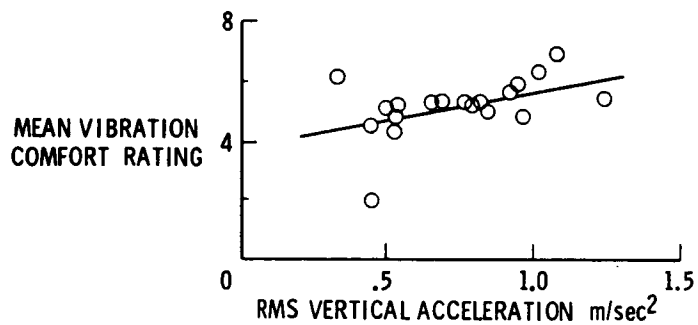


Figure 14. - Relationship between mean vibration comfort rating and vertical vibration in the 8 to 16 Hz band.

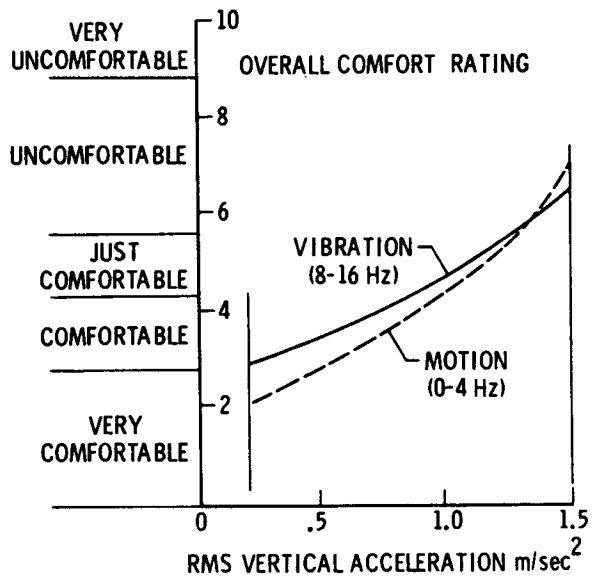


Figure 15. - Relationship between overall comfort rating and vertical vibration/motion for SRN4 hovercraft.

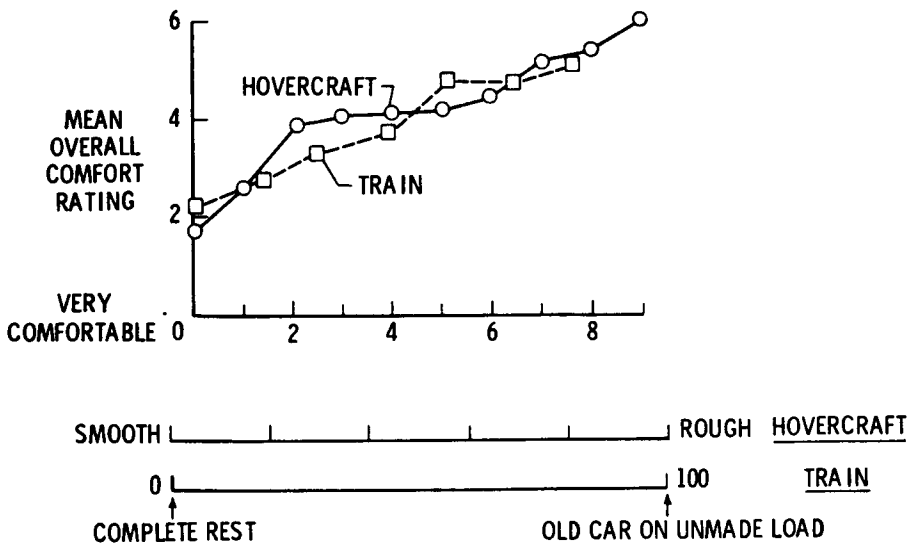


Figure 16. - Relationship between overall comfort rating and vibration rating (SRN4 hovercraft and train).

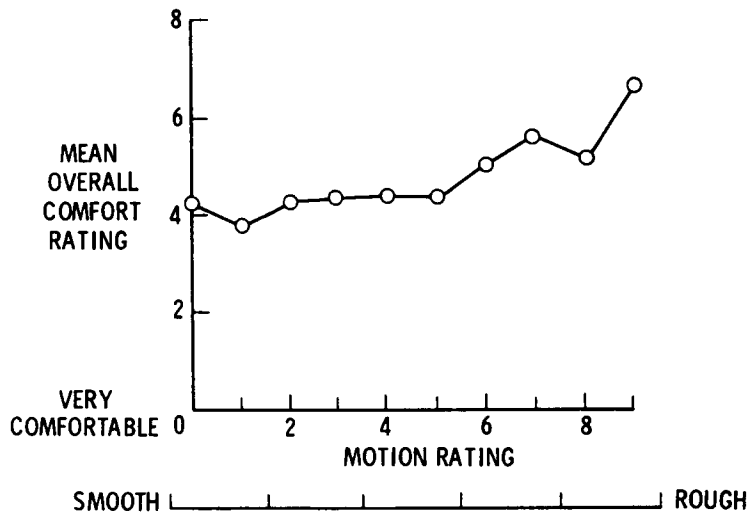


Figure 17. - Relationship between overall comfort rating and motion rating (SRN4 hovercraft).

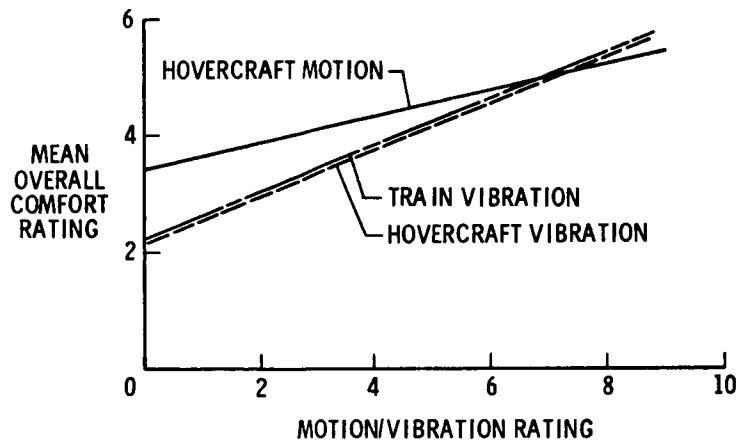


Figure 18. - Relationship between overall comfort rating and motion/vibration ratings (regression lines for data in figures 16 and 17).



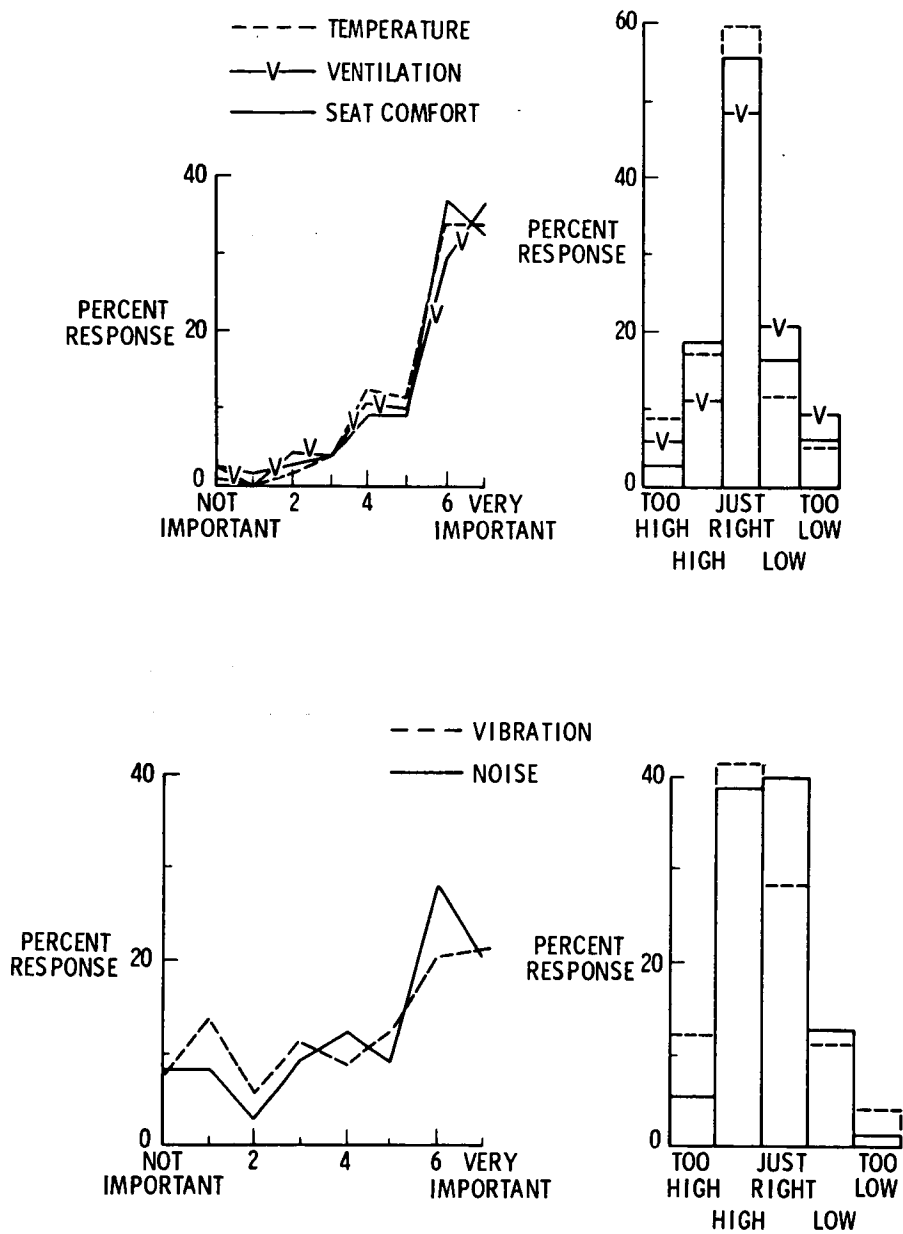


Figure 20. - Comparison of assessed importance of train environmental factors with ratings.

FROM UNSTRUCTURED COMMENTS, 300 QUESTIONNAIRES

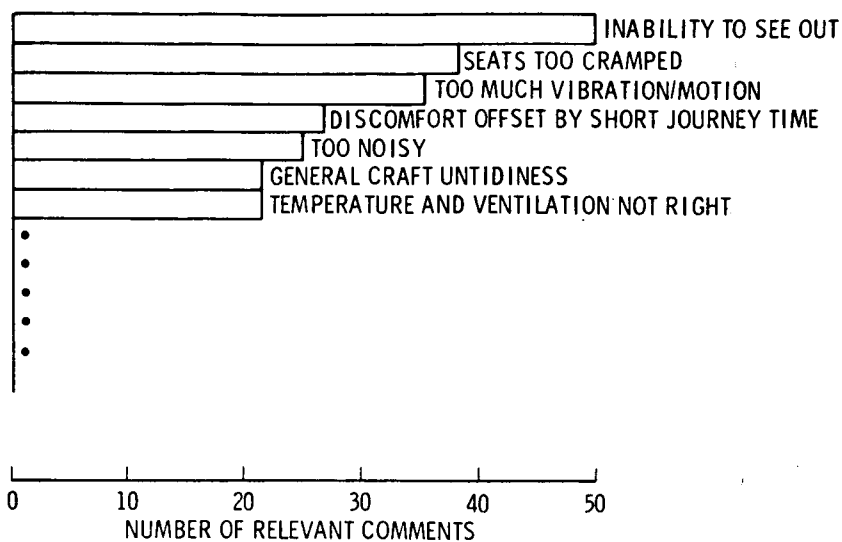


Figure 21. - Factors assessed as being important by hovercraft passengers.

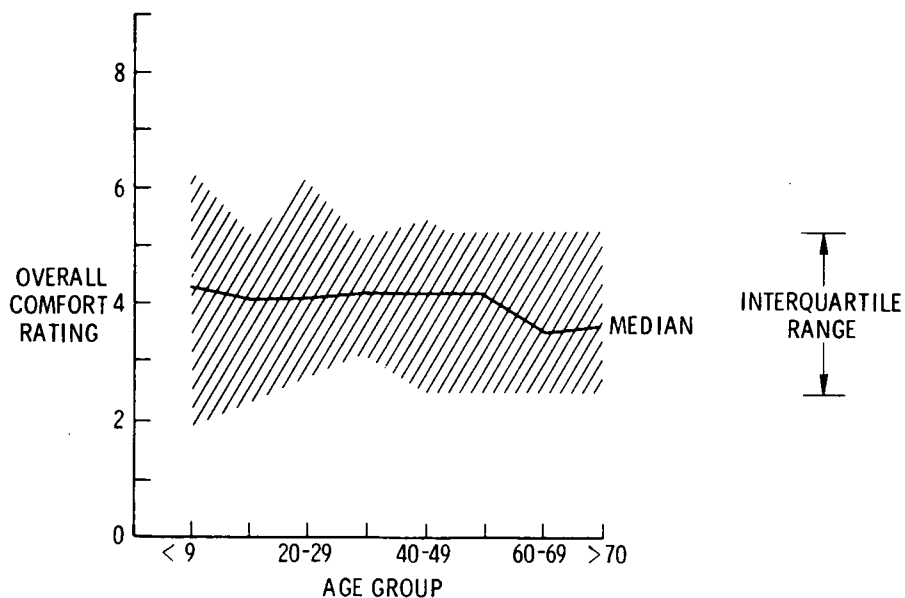


Figure 22. - Effect of passenger age group on overall comfort rating (line represents median; hatched area represents interquartile range) from hovercraft survey IV.



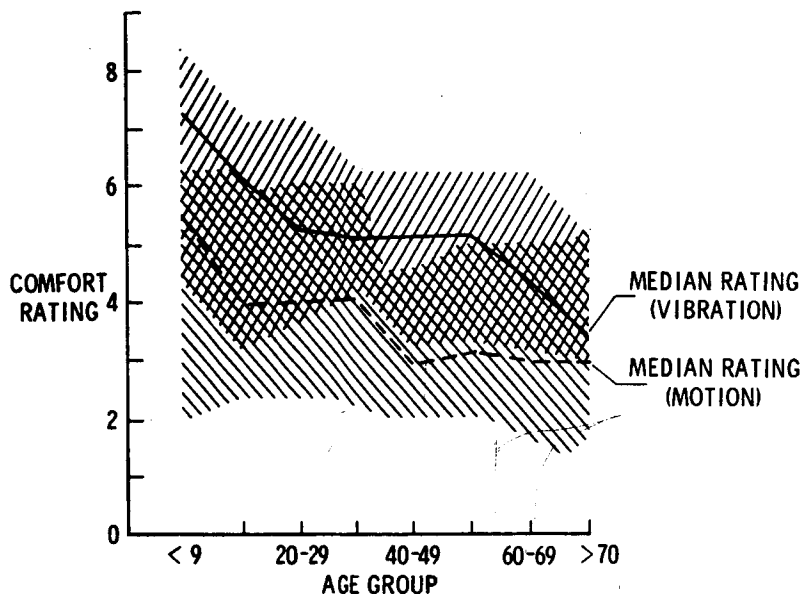


Figure 23. - Effect of passenger age group on vibration and motion comfort ratings (lines represent medians; hatched areas represent interquartile ranges) from hovercraft survey IV.

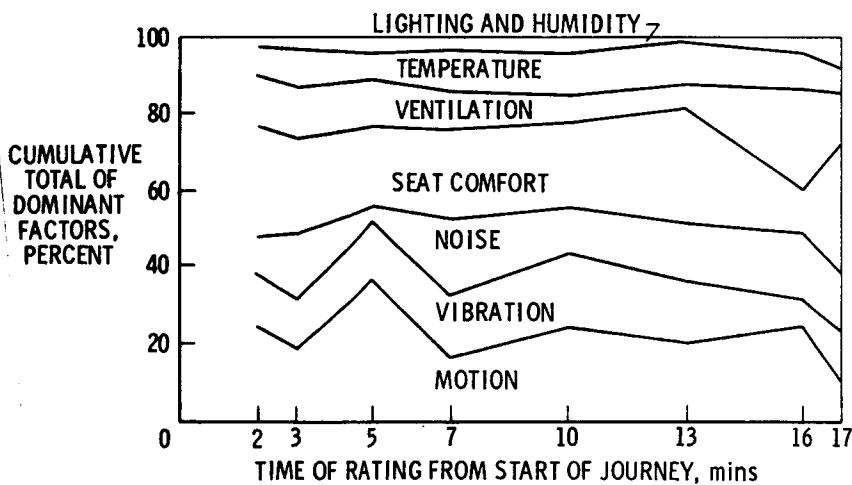


Figure 24. - Variation with time of exposure of proportion of passengers rating environmental parameters as dominant (from hovercraft survey IV).

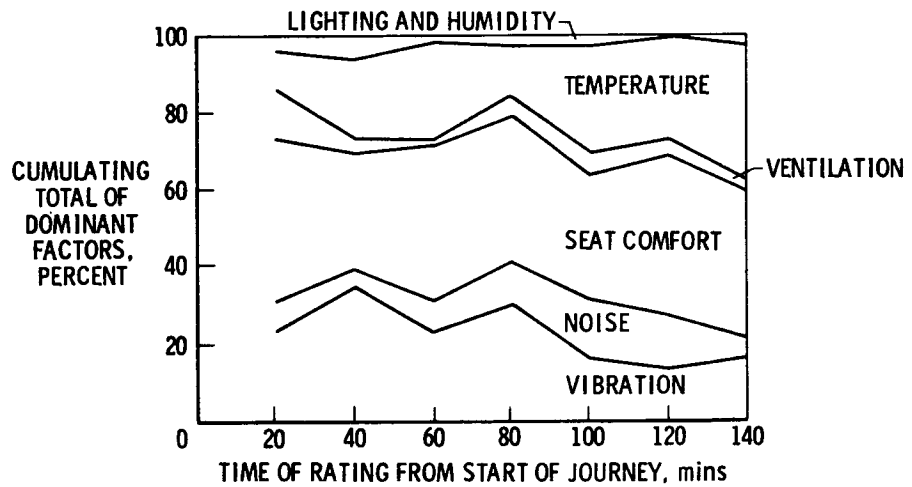


Figure 25. - Variation with time of exposure of proportion of passengers rating environmental parameters as dominant (from train survey V).