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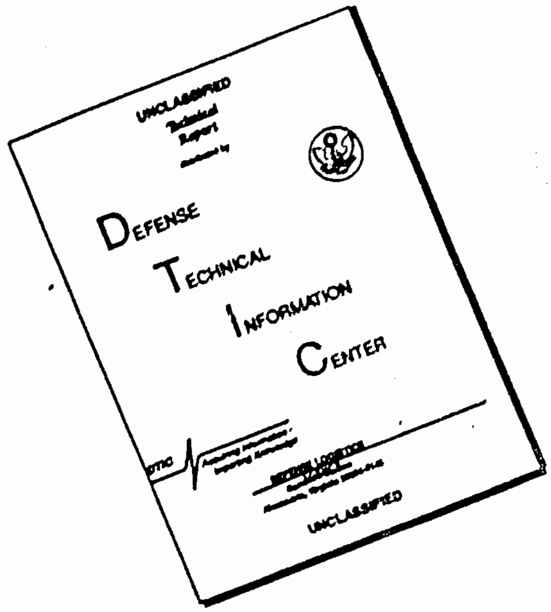

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Simulator Sickness in Passive Observers

by

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ABSTRACT

Fifteen women and sixteen men were given a 10-minute 'ride' in a fixed-base car simulator with a moving visual display (Sim-L-Car). These exposures were standardised, and included a considerable amount of implied (but not actual) vestibular stimulation. Approximately one half of the subjects wore 'blinkers' which restricted their field of view to the dynamic visual display. The principal findings were: (1) Some measurable decline in well-being was reported by 28 of the 31 subjects; (2) Women were significantly more susceptible than men; (3) Both previous passenger and car driving experience correlated positively with the degree of disturbance produced by the simulator; but driving experience appeared to exert the greatest influence upon susceptibility; and (4) Exclusion of the static features of the field of view appeared to have no effect upon susceptibility. These results were interpreted in the light of the 'sensory rearrangement' theory of motion sickness.

Motion sickness susceptibility; simulator sickness susceptibility; sensory conflict.

I

INTRODUCTION

It is now well established that a form of motion sickness, sometimes called 'simulator sickness', can be produced by the operation of fixed-base vehicle simulators incorporating an appropriately moving visual scene (Miller & Goodson, 1960; Sinacori, 1968; Barrett & Thornton, 1968). One explanation for this phenomenon has been provided by the 'sensory rearrangement' theory of motion sickness (Reason, 1970; Reason & Diaz, 1970) which argues that the essential provocation comes from a mismatch between the total pattern of information being signalled by the basic orientation senses - the eyes, the vestibular system, and the non-vestibular proprioceptors - and that held in store from previous stimulus exposures. Thus, motion sickness is thought to be triggered by a conflict between the prevailing inputs from the spatial senses and those expected on the basis of prior experience; with the all-important proviso that the current sensory influx must include a changing velocity stimulus of the sort normally detected by the vestibular system.

Within the terms of this theory, simulator sickness is presumed to arise from the absence of vestibular signals in the presence of visual information which, in conditions of actual vehicle motion, would be accompanied by corroborating signals from the semicircular canals or otoliths as well as from the non-vestibular proprioceptors. The basic assumption that simulator sickness is due to the unfulfilled expectations of a vestibular input created by the seen motion is partially borne out by the experimental finding (Miller & Goodson, op cit) that experienced vehicle operators are considerably more susceptible to this disorder than trainees, or those with little or no previous experience of real vehicle motion. This is presumably because the expectations of the former are more firmly entrenched than those of the latter, and hence conflict more drastically with the 'rearranged' sensory inputs encountered in the simulator.

The present investigation differed from previous studies of simulator sickness in that it employed passive rather than active observers. The car simulator used in this experiment was controlled by the investigator while the subject, seated beside him, passively observed the dynamic visual display through the 'windscreen'. The question which interested us was: 'How much does the absence of active vehicle control influence susceptibility to simulator sickness?' If a relatively high incidence of symptoms were observed in this passive mode, then it would be reasonable to assume that the sense of involvement created by actually handling the controls was not essential, or even particularly influential, in producing sickness. And on theoretical grounds, there was no reason to suppose that 'passengers' would be any the less susceptible than 'drivers', provided that they paid close attention to the moving visual scene (cf. 'Cinerama sickness').

In addition to studying the incidence of simulator sickness in passive observers, this investigation also considered the effects of three variables which, on a priori grounds, were likely to influence susceptibility. These were:

a. Sex. There is a wealth of evidence (see Reason, 1968) to show that women are generally more prone to most conventional forms of motion sickness than men, and it was expected that similar sex differences in susceptibility would be revealed in the present experiment.

b. Restriction of vision. Approximately half of the subjects wore 'blinkers' which restricted their field of view to the screen displaying the moving visual scene. It was thought that eliminating the 'unrealistic' aspects of the environment - such as the stationary surroundings - might enhance susceptibility.

c. Previous car experience. The subjects' prior experience as both car passengers and drivers was measured. From previous findings, it was expected that the degree of both kinds of experience would be positively related to the amount of disturbance created by the simulator session; although it was of theoretical interest to discover which of these two forms of experience, passenger or driver, would have the greater influence.

METHOD

Subjects

Fifteen female and sixteen male undergraduates and technical staff were used as subjects. Their ages ranged from 17-23 years, the modal age being 19. The majority of the subjects were volunteers from a first year Psychology degree course, the remainder being junior technicians. All the subjects were asked to complete a Motion Sickness Questionnaire (MSQ) at the completion of the experiment (see Reason, 1968, for details of the MSQ and scoring procedures). The mean MSQ score for the women was 53.4, and for the men, 44.9.

Subjects were also asked to estimate how many hours per week, on average, they spent as car passengers and car drivers. Comparative mean experiences for women and men were:

a. Women as passengers: 4.1 hours a week
range 0-14 hours a week.

b. Women as drivers: 1.5 hours a week
range 0-12 hours a week.

c. Men as passengers: 3.5 hours a week
range 0-10 hours a week.

d. Men as drivers: 2.0 hours a week
range 0-10 hours a week.

Simulator

The driving simulator was the Sim-L-Car, a point light source device manufactured by General Precision Systems of Aylesbury, Bucks. It was a closed loop system which relied for its visual display on a point light source projection system. The body of the simulator was made up of A-40 components and fascia. It was instrumented with standard car controls: steering wheel, gear lever, clutch, accelerator, brake pedals, handbrake, and key-operated ignition. Two seats were situated side by side in the car body 'mock-up'. The simulator was also equipped with a sound source which, when turned down to its lowest volume, provided a fairly convincing background noise and 'tickover'.

The visual display was presented to the occupants of the car on a 6 x 12 ft rear projection screen located just ahead of the bonnet at a distance of 6 ft from the driver and subject. The display consisted of the refracted image produced when the illumination from a high intensity point source of light passed through a transparent, circular 'Plexiglass' disc. A roadway network, comprising a winding perimeter road with intersecting transverse roads, was painted on to the surface of the disc. Added 'realism' was provided by trees (fashioned from cotton wool and wire), perspex buildings, and a stationary toy bus. The impression of vehicle movement was created by the controlled motion of the road disc beneath the stationary light source; the motion of this disc was governed by the speed and direction controls of the car in a realistic fashion.

The overall effect was that of driving on the perimeter track and intersecting roads of a deserted airfield. The optics were such that the car always appeared to be driving into a wintry sunset. From the investigator's point of view, the greatest realism was achieved with a combination of low, 'twilight', illumination and fairly high apparent speeds. In addition, the display characteristics were most satisfactory on a lefthand (anti-clockwise) circuit of the perimeter track. However, right turns were made at junctions on the transeverse roads.

Procedure

Subjects sat in the passenger seat of the simulator, and were told that this experiment was part of general investigation designed to evaluate the simulator as a training device. They were informed that it could, on occasions, produce mild symptoms of travel sickness such as dizziness, queasiness, and nausea. The purpose of this particular experiment, they were told, was to find out how many people were affected and to what extent. To this end they were asked to keep their eyes fixed on the screen ahead and to ignore any distractions in the room around them.

Each subject was then driven over a standard course for a period of 10 minutes. The course was chosen both to maximise the realistic features of the device (i.e. high average speed and lefthand circuits when on the perimeter road) and to include a large amount of implied vestibular stimulation (i.e. sharp cornering at speed, rapid acceleration and braking, stopping and starting). During the run, the only source of illumination was that from the visual display itself.

At the end of the run, subjects were asked to rate their general state of well-being (at that time), to describe their symptoms (if any), and to rate the realism of the car simulator. Details of the rating scales and symptom scores are given in a separate section below.

Restriction of Vision

As mentioned earlier, approximately one-half of the subjects were provided with 'blinkers' to screen out all but the moving display from the field of view. The 'blinkers' consisted of an oval rubber tube which was held by the subject over his eyes. One end of the tube was moulded to fit the nose and forehead. Subjects were instructed to adjust the shape of the tube so that it excluded all but the projection screen from the visual scene. To avoid unnecessary eye-strain or pressure headache, they were instructed to hold the 'blinkers' very lightly against the face.

Experimental Measures

The principal dependent measures were the Well-being Scale (Reason & Graybiel, 1970; Reason & Diaz, 1970), and a Symptom Score derived from a standardised symptom check-list. The well-being estimates were made on the basis of an eleven-point category scale, ranging from 0 - 'I feel fine' to 10 - 'I feel awful, just like I'm about to vomit'. To obtain the Symptom Score, subjects were asked whether they had experienced any of the following symptoms either during or immediately after the run: dizziness, bodily warmth, headache, increased salivation, stomach awareness, and nausea. Two further symptoms were mentioned by subjects during the post-run interview: dry mouth and drowsiness. In addition, the presence and degree of pallor and cold sweating were assessed by the investigator. To achieve the overall Symptom Score, the presence of any of these signs or symptoms was categorised as 'mild', 'moderate', and 'severe'. A score of 1 was given to all reactions classified as 'mild', 2 to those classified as 'moderate', and 3 to 'severe' reactions. The final Symptom Score for each subject was obtained by summing these individual weightings.

In addition, the subjects were asked to rate the realism of the Sim-L-Car on a 10-point scale from 0 - 'Not at all like a real car', to 10 - 'Just like a real car'. At the completion of the interview, subjects were asked to fill in the MSQ.

RESULTS

Incidence

In three subjects only did both the Well-being Rating and the Symptom Score indicate a complete absence of any ill-effects. The remaining 28 subjects reported varying degrees of disturbance ranging from mild dizziness to the presence of all listed reactions including severe nausea. One subject gave a well-being rating of 10 and asked for the run to be stopped after 9 minutes because she felt close to fainting. A percentage breakdown of the proportion of subjects reporting each kind of reaction is shown in Table 1.

Table 1

Percentage of Women, Men, and Total Sample Reporting each Sign or Symptom.

Signs and Symptoms	(N=15) % Women	(N=16) % Men	(N=31) % Total
Dizziness	73	69	71
Bodily warmth	47	50	48
Headache	53	38	45
Stomach awareness	53	31	42
Nausea	60	25	42
Pallor	53	6	29
Sweat	33	25	29
Increased salivation	13	25	19
Dry mouth	13	0	6
Drowsiness	7	0	3

From Table 1, it is clear that the most frequently occurring symptom was dizziness, and this was true for both men and women. The next most frequent symptoms were bodily warmth, headache, stomach awareness, and nausea. The only really marked discrepancy between the sexes was in the presence of pallor, something that was detected far more often in women than in men.

It is also clear from Table 1 that all but one symptom, increased salivation, occurred more frequently among the women, a discrepancy that was predicted on the basis of known sex differences in susceptibility. A more detailed analysis of these sex differences is given below.

Sex differences

Table 2 shows the mean Well-being Ratings and Symptom Scores for men and women. Mann-Whitney 'U' tests calculated for both measures indicated that women were considerably more disturbed by the simulator than the men; W-B Ratings, $U=48.5$; $p<.01$ (one-tailed test); Symptom Scores, $U=65.5$; $p<.025$ (one-tailed test).

Table 2

Mean Well-Being Ratings and Symptom Scores for Men and Women

	Women		Men	
	Mean	Range	Mean	Range
Well-Being Rating	4.7*	0-10	1.7	0-5
Symptom Score	6.6	0-18	3.1	0-7

*The higher the Well-Being Rating, the more severe the disturbance. The same is true of the Symptom Score.

In view of their marked differences in susceptibility, men and women were treated separately in all subsequent analyses.

The Effect of 'Blinkers'

Table 3 shows the mean Well-Being Ratings and Symptom Scores for female and male subjects with and without blinkers. For neither sex did the restriction of vision make any significant difference to the degree of disturbance produced by the simulator ride. In view of this, the presence or absence of blinkers was ignored in subsequent analyses.

Table 3

Mean Values for Subjects with and without 'Blinkers'

	With (N=7)	Without (N=8)
Women		
Well-Being Rating	4.4	4.8
Symptom Score	6.8	6.5

	With (N=8)	Without (N=8)
Men		
Well-Being Rating	1.1	1.8
Symptom Score	3.0	3.5

The Effects of Previous Car Experience

Spearman rank order correlation coefficients were computed between the two sickness measures and the average time per week spent as a car driver and passenger. This was done for men and women separately, and the results are summarised in Table 4.

Table 4

Relations between Degree of Sickness and Previous Car Experience

Women N=15

	rho
Well-Being Rating/Driving experience	+0.51*
Well Being Rating/Passenger experience	+0.22
Symptom Score/Driving experience	+0.50*
Symptom Score/Passenger experience	+0.45*

Men N=16

	rho
Well-Being Rating/Driving experience	+0.32
Well-Being Rating/Passenger experience	+0.05
Symptom Score/Driving experience	+0.43*
Symptom Score/Passenger experience	-0.12

(*indicates $p < .05$)

Realism Ratings

For women, the mean realism rating was 5.8, the modal value 6, and the range 2-9. The pattern for men was very similar: a mean of 5.6, a modal value of 7, and a range from 2-8.

Casual inspection of the data suggested that there was a negative relationship between the realism ratings and the two measures of sickness. To check this, rank order correlation coefficients were computed, and are set out in Table 5.

Table 5

Relations between the Degree of Sickness and the Realism Rating

Women

	rho
Well-Being Rating/Realism Rating	-0.31
Symptom Score/Realism Rating	+0.01

Men

	rho
Well-Being Rating/Realism Rating	-0.46*
Symptom Score/Realism Rating	-0.34

Predictive Value of MSQ

To assess the value of the MSQ for predicting individual differences in susceptibility to simulator sickness, rank order correlations were computed between the total MSQ score and the two measures of simulator sickness. The resulting coefficients are shown in Table 6.

Table 6

Relations between the Degree of Sickness and MSQ Score

Women

	rho
MSQ/Well-Being Rating	+0.10
MSQ/Symptom Score	+0.15

Men

	rho
MSQ/Well-Being Rating	+0.36
MSQ/Symptom Score	+0.62**

(**indicates $p<.01$)

Relationship between Well-Being Ratings and Symptom Scores

Positive and significant rank order correlations were obtained for both men and women between these two measures of simulator sickness. The values of the coefficients are shown below:

Women : $r_s = +0.77^{**}$ (N=15)

Men : $r_s = +0.82^{**}$ (N=16)

DISCUSSION

The high incidence of simulator sickness observed in this experiment clearly shows that active participation in the control of the simulated vehicle is not necessary for the production of symptoms. In this respect, simulator sickness seems to be closely akin to 'Cinerama sickness' in which the victims are invariably passive observers. It seems reasonable to conclude, therefore, that the essential stimulus for visually-induced motion sickness is the presence of a moving scene which, during real vehicle motion, would be accompanied by a stream of vestibular signals. To be provocative, the visual scene must be one that implies changes in the speed or direction of the observer relative to the environment. Although the present experiment provided no direct grounds for stating this, it seems highly improbable that symptoms could be evoked by seen motion that does not implicate the vestibular system; such as, for example, the kind of view obtained from the front of a laterally stable train moving at constant speed along a perfectly straight track. In this investigation, it was certainly true that manoeuvres such as cornering at speed, travelling fast along a winding stretch of road, and sudden braking were the ones most frequently cited as responsible for loss of well-being.

The rather surprising finding that the presence of the 'blinkers' had no effect upon susceptibility to simulator sickness is of particular interest since it suggests that cognitive factors, such as the knowledge derived from seeing the stationary surrounds, play little or no part in the production of symptoms. Evidently, the presence of incompatible elements in the visual scene does not appreciably reduce the nauseogenic properties of the dynamic visual display.

Both this and the demonstration that passive observers are equally prone to sickness point to the involvement of a fairly low-order central mechanism: one that is more attuned to signals from the relatively primitive orientation senses than to subtle nuances of cognition. Such a conception is very much in accord with the 'sensory rearrangement' theory of motion sickness in which psychogenic factors are considered to be of secondary importance only. The essence of this theory is that symptoms are triggered (exactly how is not understood) by inconsistencies between the prevailing influx from the spatial senses and stored traces from comparable exposures in the past. If the brain centre concerned with integrating spatial inputs has come to 'expect' (on the basis of prior experience, that is, through the process of perceptual adaptation) that a particular movement of the visual scene will be correlated with specific vestibular inputs, then the absence of these vestibular signals on a subsequent presentation of the same visual stimulus will evoke the symptoms of motion sickness. Why these reactions should take the particular form that they do, and what functional purpose they serve, is not understood; but there seems little doubt that unfulfilled 'vestibular expectations' are the primary cause.

Two factors that clearly did influence susceptibiluty were sex and previous car travel experience. That women were more disturbed by the simulator than men was not surprising considering that women are known to succumb more readily to most forms of motion sickness. But this finding does not bring us any nearer to understanding why these sex differences exist. Are women simply more liable to present the nausea syndrome than men? Is it linked in some way to their hormonal make-up? Or do the differences in susceptibility originate from the spatial integrating centre itself?. These important questions remain unanswered.

Equally predictable, though perhaps less difficult to understand, is that susceptibility to simulator sickness, both for men and women, was positively related to the amount of previous experience with car travel, both as passengers and as drivers. This general relationship can be explained, as stated earlier, by suggesting that, in experienced travellers, the stored stimulus traces are more firmly consolidated in the 'spatial memory store'. However, on the basis of this argument it would be expected that driver experience should count for more than passenger experience because, like the subject in the present experiment, the car driver is forced to maintain the 'eyes-forward' mode of looking: whereas the passenger is not constrained in quite the same way, i.e. some of the time he will be looking out at the road ahead, but at other times he will be glancing out of the side windows or within the car. By comparison, therefore, the car driver has a much better opportunity of building up stimulus traces appropriate to the simulator situation, and so should be more disturbed by the rearranged sensory inputs in the simulator. Do the present findings support these predictions? Examination of the correlation coefficients displayed in Table 4 shows that, for both men and women, the relationships between the two measures of simulator sickness and driver experience were better than those with passenger experience; although, except in one instance, these were also positive. The small samples used in this experiment, and the relatively limited range of driving experience of the subjects, mean that a great deal of reliance cannot be placed on these particular data; but they do conform with the arguments set out above. If such a finding were replicated using larger numbers and a wider range of driving experience, it would provide very strong support for the 'unfulfilled expectation' aspect of the sensory rearrangement theory.

Two other findings are worthy of brief comment. First, the rather curious fact that those subjects who were most disturbed by the simulator ride tended to rate the device as being less realistic than those who were relatively unaffected. Were they 'punishing' the simulator (or the investigators) for making them sick? Or was it that they were not normally car sick so that the presence of unfamiliar reactions like dizziness and nausea rendered the simulator less like the real thing? It is hard to say. But whatever the cause, it casts some doubt on the validity of the realism ratings per se.

Secondly, it is clear from the coefficients displayed in Table 6 that the MSQ (a personal history inventory) would not have been particularly successful in predicting the degree of simulator sickness. However, the relationships were much higher for men than women; and for both sexes, they were higher with the Symptom Score than the Well-Being Ratings. Considering the very imprecise nature of the measures, correlations of this order are perhaps the best that can be expected. At best, the MSQ is a very blunt instrument, and its greatest usefulness is in screening out highly susceptible individuals. It is known to be far less effective in discriminating between individuals of moderate susceptibility (Reason, 1968).

Finally, what are the practical implications of these findings? So long as fixed-base simulators incorporating dynamic visual displays continue to be used extensively for training, information that throws some light on the origins of the distressing and time-wasting condition of 'simulator sickness' can always be put to good use. But, perhaps more importantly, these results reveal a little more of the general mechanisms involved in the production of the motion sickness phenomenon, and it is only from a clear understanding of these underlying processes that effective preventive measures can be formulated.

PRINCIPAL FINDINGS

1. Some decline in well-being was reported by 28 of the 31 unselected subjects passively exposed to a 10-minute ride in a closed-loop car simulator.

2. Women were significantly more susceptible than men.

3. Previous car experience, both as passenger and driver, correlated positively with the degree of disturbance produced by the simulated ride. However, there was some evidence to suggest that driver experience exerted a more powerful influence upon susceptibility to simulator sickness.

4. 'Blinkers' which excluded the static features of the surroundings appeared to have no effect upon susceptibility.

REFERENCES:

BARRETT, G.V. & THORNTON, C.L. (1968). Relationship between perceptual style and simulator sickness. J. Appl. Psychol. 52: 304 - 308.

MILLER, J.W. & GOODSON, J.E. (1960). Motion sickness in a helicopter simulator. Aerospace Med. 31: 204 - 211.

REASON, J.T. (1968). An Investigation of some Factors Contributing to Individual Variation in Motion Sickness Susceptibility. Flying Personnel Research Committee Report No 1277.

REASON, J.T. (1970). Motion sickness: a special case of sensory rearrangement. Advancement of Science. 26: 386 - 393.

REASON, J.T. & GRAYBIEL, A. (1970). Changes in subjective estimates of well-being during the onset and remission of motion sickness symptomatology in the Slow Rotation Room. Aerospace Med. 41: 166 - 171.

SINACORI, J.B. (1968) - Northrup Notair Division, Hawthorne, California, USA, personal communication.