Chapter 7. Experiment 4. Motion sickness and vection with a single and multiple dot display

7.1 Introduction

The model shown in the previous chapter has shown that vection and motion sickness are separate phenomena, modelled as separate outputs. This has been shown by the lack of correlations between vection and motion sickness scores and by the ability to manipulate motion sickness separately from vection, by the use of a fixation cross. The model predicts that not only can motion sickness be varied with no change in vection but also that vection can be varied independently of motion sickness. An experiment was devised to test this prediction. Subjects were presented with two conditions, one with a single moving dot which moved from left to right with a sudden jump back to its starting position, and one with multiple moving dots which moved continuously across the screen (see Figure 7.1). This method resulted in the same foveal stimulation in both conditions but different peripheral stimulation (see Section 7.2 for a full explanation).

Motion sickness was reduced with fixation in Experiment 2 (Chapter 5) and nystagmus has been shown in the literature review (Section 2.3.7.2) to be influenced dominantly by foveal vision. In the present experiment it was hypothesised that motion sickness would be similar in the two conditions because the foveal stimulus would be the same in each condition and eye movements would be the same. It was also hypothesised that vection would be higher in the full field condition because of the increased peripheral stimulation in this condition.

7.2 Method

Sixteen male subjects, aged 20-25 years participated in the experiment. Visual acuity was measured as in the previous experiments. Subjects viewed two conditions on the Virtual Research VR4 head-mounted display: (i) a single dot which moved from left to right over a distance of 18° at a rate of 27°/second before jumping back to its starting position and repeating on an infinite loop (ii) five horizontal rows of dots, with each dot 18° apart, moving continuously from left to right at a rate of 27°/second.

Figure 7.1. The two conditions. The picture on the left shows the start and end point for the single dot and the picture on the right shows the full field of dots.

Each subject experienced both conditions. Eight subjects commenced with the single dot and eight commenced with the multiple dot display. There were at least two weeks between exposure sessions to reduce any habituation effects and exposures were performed at the same time of day. During each exposure the following information was recorded at one minute intervals for a total of 30 minutes: the motion sickness rating on a 7 point scale (as used previously – Table 3.1) and a rating of the vection experienced, on a percentage scale (see Table 7.1). The vection scale had to be different to that used previously because there is no drum simulation in this experiment and a consistent scale was needed for the single and multiple dot conditions. At the end of each exposure, subjects filled out a post-exposure symptom checklist as before.

In condition one, subjects were asked to track the single dot continuously as it moved from left to right and then jumped back to its starting position. In condition 2, subjects were asked to track each dot in the middle row as it passed. In this way the foveal stimulus and eye movements were identical in the two conditions: a single dot moving from left to right at 27°/second for 18° followed by a rapid jump back of 18° to the next dot. The resulting eye movement was nystagmus with a smooth pursuit of 18° followed by a rapid return saccade, with a frequency of 1.5Hz, in each condition. During exposure, eye movements were recorded onto an *HVLab* data acquisition system at 30Hz sample rate using the Hortmann electro-nystagmograph described in Chapter 3.

Subjects gave their informed consent to participate in the experiment that was approved by the Human Experimentation Safety and Ethics Committee of the Institute of Sound and Vibration Research.

Table 7.1. New vection scale. Subjects report a percentage score between 0 and 100% each minute to indicate their perception of self motion.

Perception of motion (vection)	You report:
You feel like you are stationary and it is the dot(s) which appear to be moving only.	0%
You feel like you are moving a bit, but the dot(s) are moving more	1-49%
You feel like you are moving at the same speed as the dot(s)	50%
You feel like you are moving a lot and the dot(s) are moving a bit	51-99%
You feel like you are moving and the dot(s) appear stationary	100%

7.3 Analysis

Eye movements were studied by visual inspection and by time-frequency analysis to determine the dominant frequency component throughout the exposures. Average vection scores were calculated by taking the mean of the thirty responses, expressed as a percentage. Accumulated illness ratings were calculated as previously.

Motion sickness and vection scores across conditions were analysed using the Wilcoxon matched-pairs signed ranks test. Spearman's rank correlation test was used to test the relationships between vection and motion sickness in conditions. Survival analysis was performed as in experiments 1 to 3.

7.4 Results

7.4.1 Eye movements

The electro-oculography data was inspected by eye, for indications that the eye movements were similar in each of the conditions. Figure 7.2 shows sample eye movement data from each condition.

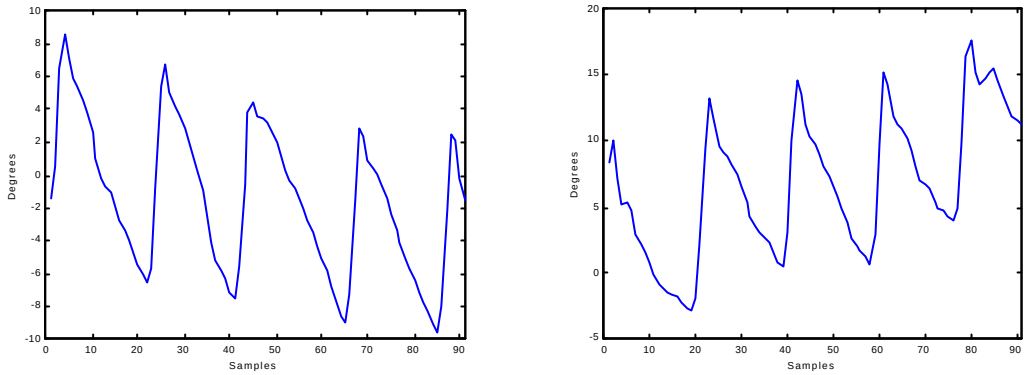

Figure 7.2. Sample eye movement data for one subject in the single (left) and full field (right) conditions. Sample rate is 30.3 samples per second, low pass filtered at 10Hz. Data above is the first 3 seconds of data in each condition.

Inspection of the eye movements for subjects revealed that eye movements were continuous throughout each exposure condition, indicating that tracking of the dots for long periods was possible. Time-frequency analysis revealed that the power in each set of eye movements was at around 1.5Hz in each condition throughout the exposures. This indicated that the experimental design was successful in generating eye movements that were similar in each condition. The foveal stimulation (of a single moving dot) was hence very similar in each condition, whilst the peripheral stimulus varied from nothing (single condition) to 14 continuously moving dots (full field condition).

7.4.2 Motion sickness

The mean accumulated illness ratings were 19.9 for the single dot and 22.8 for the full field of dots condition. There was no significant difference between the illness ratings in the two conditions (Wilcoxon, $p>0.10$). The post exposure symptoms questionnaire also showed no difference between the two conditions (Wilcoxon, $p>0.10$). Subject motion sickness scores were correlated between the two conditions ($\rho=0.516$, $p<0.05$). There were no correlations found between vection and motion sickness in the single dot condition ($\rho=0.191$, $p>0.10$) or the full field condition ($\rho=0.184$, $p>0.10$). Mean illness ratings against time for the two conditions are shown in Figure 7.3.

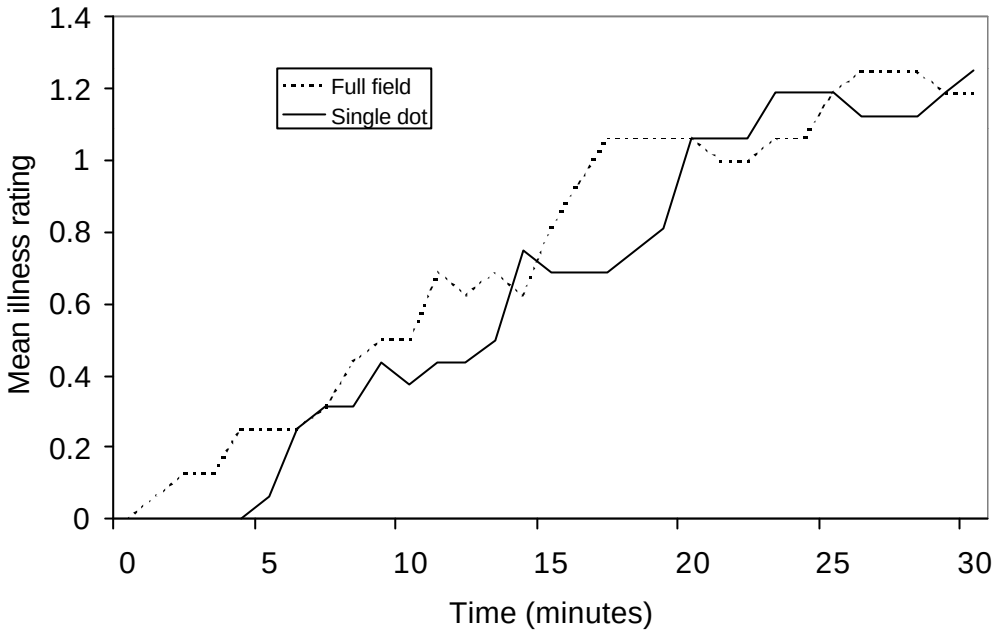

Figure 7.3. Mean illness ratings for the single and multiple dot conditions against time.

7.4.3 Vection

Mean vection scores were 12.6 (%) in the single dot condition and 27.4 (%) in the full field condition. The difference was significantly different (Wilcoxon, $p<0.05$). Vection scores for subjects across conditions were significantly correlated ($\rho=0.551$, $p<0.05$). This indicates that subjects reporting vection in one condition were likely to report vection in the other condition, but with generally higher vection in the full field condition. The small amount of vection in the single dot condition could possibly be due to the way in which the single dot was displayed. There were two frames each second ($1/30^{th}$ of one second) where the two dots shown in Figure 7.1 were simultaneously visible. This may have resulted in some stimulation of the peripheral retina.

7.4.4 Survival analysis – single dot condition

There was no correlation between survival time and visual acuity at the near point ($\rho=0.411$, $p>0.10$). There was no correlation between the visual acuity at the far point and survival time ($\rho=0.360$, $p>0.10$). Past susceptibility was not correlated with

survival time (ρ=-0.407, p>0.10). Visual acuity and survival time for the single dot condition are shown in Figure 7.4.

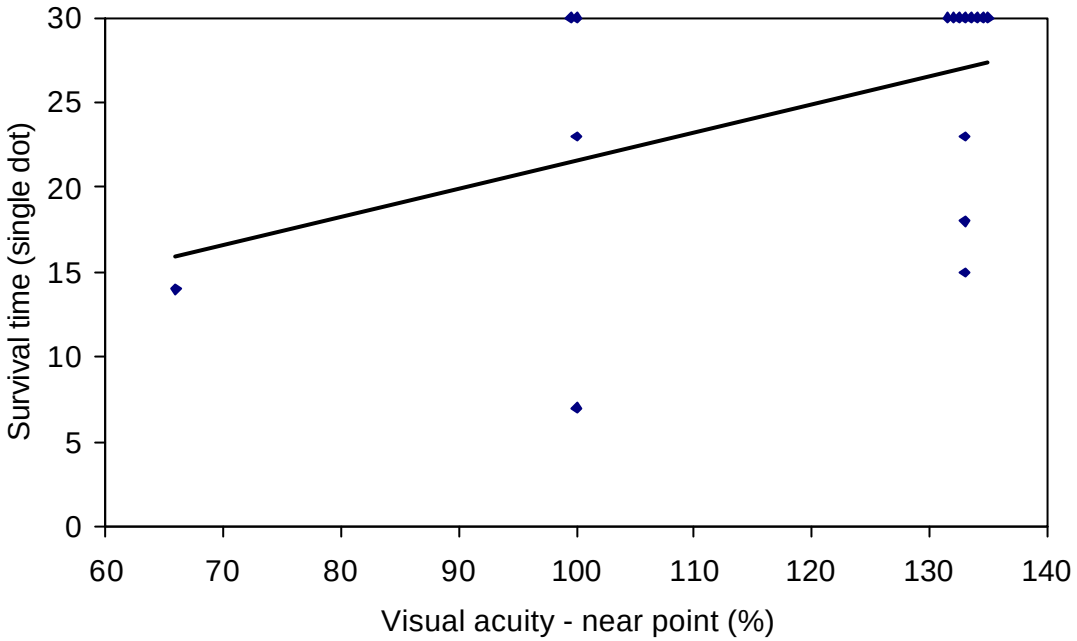

Figure 7.4. Survival time shown for varying visual acuity at the near point (single dot condition).

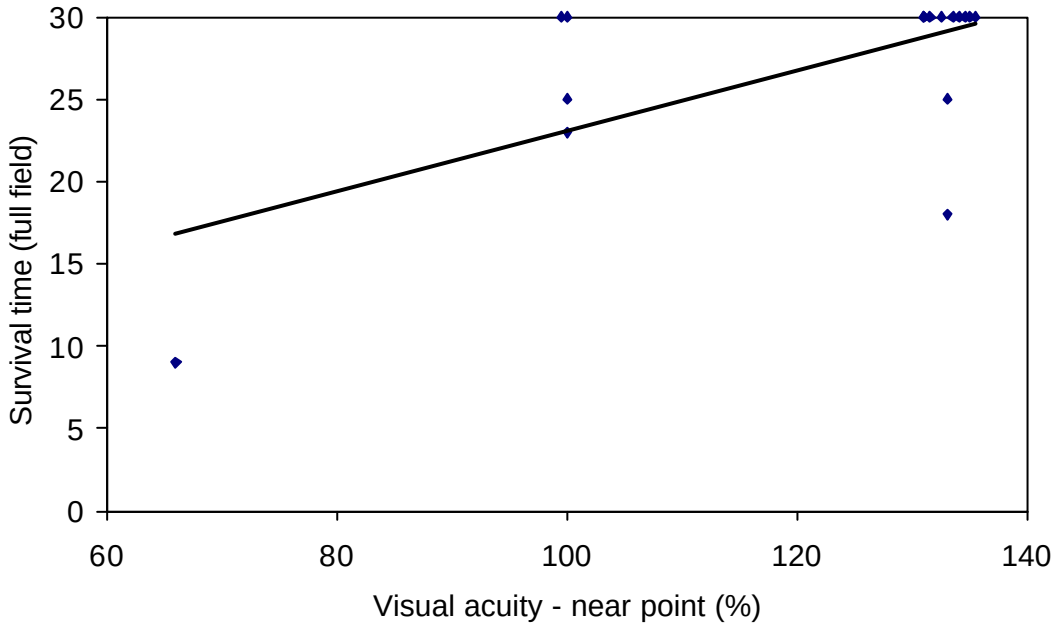

Figure 7.5. Survival time shown for varying visual acuity at the near point (full field condition).

7.4.5 Survival analysis – multiple dot condition

There was a marginally significant correlation between survival time and visual acuity in the full field condition (ρ=0.479, p<0.10) with subjects having shorter survival times if they had lower acuity. There was no correlation between the visual acuity at the far point and survival time (ρ=0.205, p>0.10) or past susceptibility and survival time (ρ=-0.388, p>0.10). Again, the visual acuity correlation should be treated with caution because of the limited range of visual acuity among the subjects and the influence of one outlier on the correlation. Figure 7.5 shows visual acuity at the near point and survival time.

7.4.6 Cox's proportional hazards model

A Cox regression model, with survival time defined as the time taken to reach 2 (mild symptoms, e.g. stomach awareness but not nausea), was formed for each of the two conditions, with visual acuity at the near point as a covariate. The data was not split into low and high categories because there was only 1 subject in the low category (less than 20:20 vision). The visual acuity data were entered into the model as the individual scores recorded for subjects. There was 1 subject with 20:30 vision, 4 subjects with 20:20 vision and 11 subjects with 20:15 vision.

In the full field of dots condition, a significant effect of acuity was found, with subjects with poor acuity surviving for a shorter period of time (Cox regression, p<0.05). The Cox's proportional hazards model for the full field condition is shown in Table 7.2. In the single dot condition, there was a marginally significant effect of visual acuity on survival time (Cox regression, p<0.10) with subjects with poor acuity surviving for a shorter period before reaching 2 on the motion sickness scale. The Cox's proportional hazards model for the single dot condition is also shown in Table 7.2.

Table 7.2. Cox's proportional hazards model.

Condition – expt 4	**Independent variables**	**e^b**	**Sig (b)**
Single dot	Visual acuity at the near point (%)	0.9648	0.0692
Multiple dots	Visual acuity at the near point (%)	0.9478	0.0332

7.5 Discussion and conclusions

In previous experiments, vection and motion sickness have been shown to be separate phenomena which were not correlated. Motion sickness was shown to be reduced with a fixation point, without varying the vection perceived. The model presented at the end of Chapter 6 predicted that vection could also be varied without varying the symptoms of motion sickness. This experiment confirmed that possibility. Vection was found to be significantly different between the two conditions, with more vection found in the full field condition where there was a greater stimulation of the periphery.

Motion sickness was not significantly different between the two conditions. The stimulation of the fovea and the eye movements made in response to the two conditions were similar. It is not possible to state on the basis of this experiment whether image slip on the fovea or eye movements themselves are responsible for the motion sickness.

A correlation between visual acuity and survival time was noted again in this experiment in the full field condition, with a marginally significant correlation found in the single dot condition. The finding, on the basis of this experiment alone, should be treated with extreme caution because of the influence of a single subject on the correlations. There was only one subject with visual acuity below 20:20. This subject had relatively low survival times in each of the two conditions, which resulted in the significant, or marginally significant correlations being found. Removing the subject from the correlations decreased the level of significance to levels of $p>0.10$.

7.5.1 Comparison of the accumulated illness ratings with previous experiments

The accumulated illness ratings in this experiment were quite low by comparison with the previous experiments. The mean illness ratings were 19.9 (single dot) and 22.8 (multiple dots) compared to 38.9 (virtual condition – experiment 1) and 40.7 (no fixation – experiment 2). The difference in motion sickness incidence cannot be easily explained. The subjects in each experiment were largely independent, the stimulus velocity was slightly lower in this experiment, the stimulus was easier to track because of the discrete dots supplying obvious fixation points and all but one subject had 20:20 vision or greater in this experiment. The reduction in peripheral

vision in both conditions (discrete dots as compared to the full screen of stripes used previously) should not be ruled out as a possible cause of the difference, although vection was significantly greater with the full dot condition, indicating that there was significantly greater stimulation of the peripheral vision.

7.6 Updated model

The model is unchanged from chapter 6. Two possible routes to motion sickness still exist, via eye movements or foveal image slip, and will need further experimentation to discover which of the two is the dominant route. Vection and motion sickness are confirmed as separate outputs which can be manipulated independently of each other. Vection is confirmed as a mainly peripheral phenomenon while motion sickness has been shown to be foveally influenced, either by foveal image slip or via nystagmus (which shows foveal dominance). The model is shown in Figure 7.6.

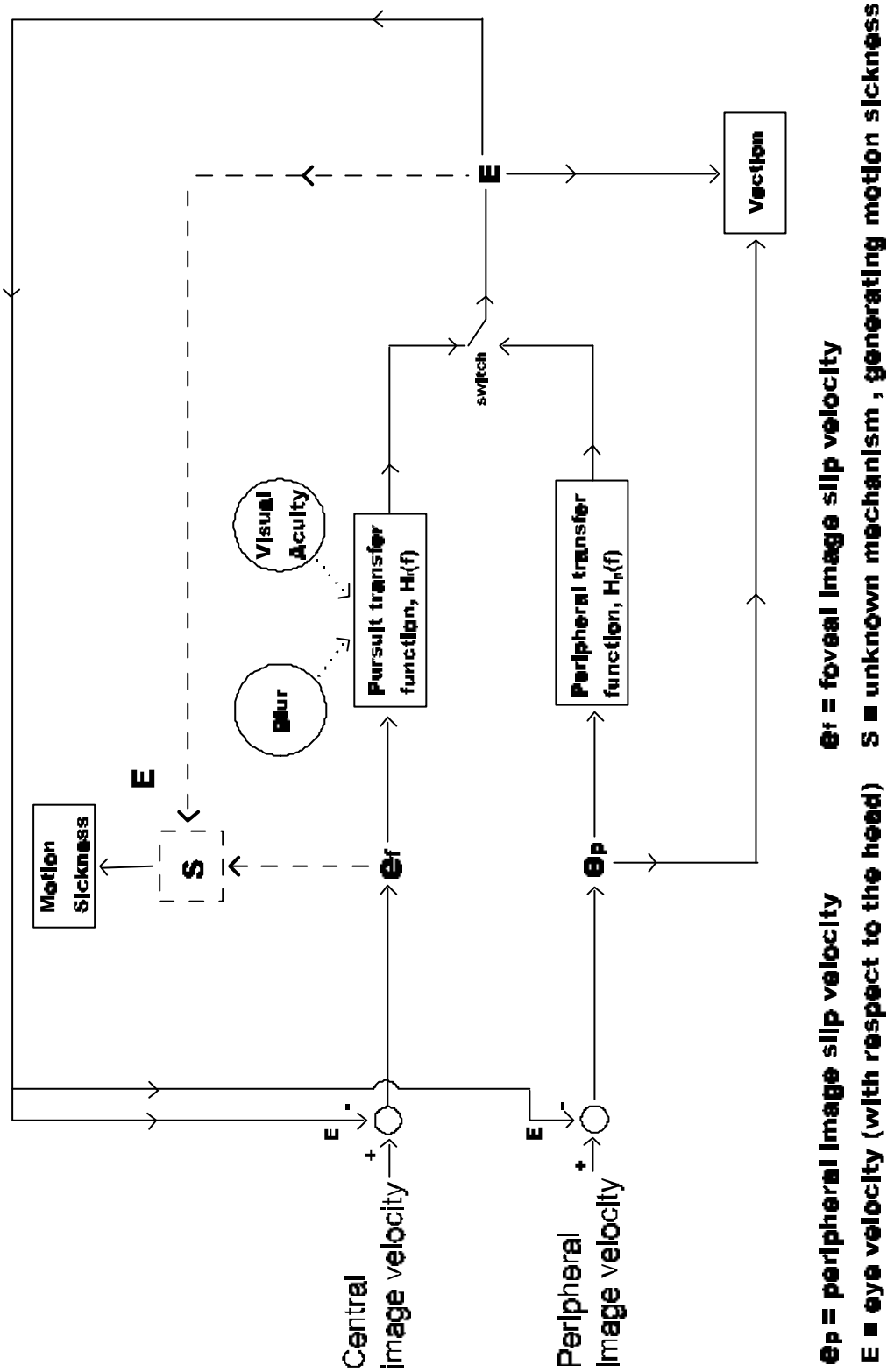

Figure 7.6. Model version 3. The model is unchanged from Chapter 6. The prediction that vection could be changed without changing motion sickness was confirmed.