Chapter 4. Experiment 1. Comparison of motion sickness and vection in a real and virtual reality optokinetic drum

4.1 Introduction

The purpose of the first experiment, presented in this chapter, was to record vection and motion sickness scores in a standard optokinetic drum and in a virtual reality simulation of an optokinetic drum and to investigate correlations among subjects between vection and motion sickness scores.

Another objective of this experiment was to investigate whether circular vection and motion sickness could be generated using the restricted field of view of a virtual reality head-mounted display, and whether motion sickness ratings in this 'virtual drum' were correlated with those obtained with the same field of view in a standard optokinetic drum. Virtual reality allows flexibility in varying the visual display and has the potential to replace traditional optokinetic drums, mirror systems and other optical display devices (e.g. film projectors) that have been used to investigate motion sickness and vection.

It was predicted that, for individual subjects, the two environments would produce similar sickness. Consequently, across the group of subjects, it was hypothesised that there would be a correlation between sickness ratings obtained in the two conditions. It was also hypothesised that, within conditions, ratings of motion sickness would be correlated with ratings of vection.

4.2 Method

In part of the experiment, subjects were seated inside the optokinetic drum (as described in Chapter 3). A strap connected to the backrest of a chair restrained the head of each seated subject. Subjects wore spectacles designed to restrict their field of view to 48º horizontally and 36º vertically, which matched the field of view of the virtual reality display.

In the other part of the experiment, an animation of the optokinetic drum was presented on the head-mounted display (Virtual Research VR4). The same sequence of images was presented to both eyes simultaneously. The animation was programmed so as to give a similar visual experience to the viewer as being in the real drum. Each black and white stripe subtended approximately 8° visual angle and the stripes moved across the screen at 30° per second, equivalent to 5 r.p.m. of the optokinetic drum. Subjects did not wear vision correction in either the real or the virtual condition.

Whilst watching the animation, subjects sat inside the real drum (which was rotating) so that the environment (i.e. sound, temperature and enclosed feeling) was similar in both conditions. The same system was used to restrain the head.

Sixteen male subjects, aged 20 to 28 years (mean 22.9 years) participated in the experiment. Visual acuity without correction was measured using the Keystone visual skills profiles (see section 3.3.1) conducted at the near point (2.5 dioptres, 0.4 m) and far point (0.25 dioptres, 4m). Prior to experiencing the visual motion, all subjects completed a motion sickness history questionnaire providing details of travel history and previous motion sickness experience (Griffin and Howarth, 2000). The responses were used to derive motion sickness susceptibility ratings for each subject.

All subjects experienced both the real and the virtual optokinetic drum for up to 30 minutes. Eight subjects commenced with the real drum and eight commenced with the virtual drum. There was at least one week between exposures to reduce effects of habituation. Subjects experienced each condition at the same time of day. At half-minute intervals during each exposure, subjects provided ratings on the 7-point motion sickness scale (Table 3.1) and on a 4-point vection scale (Table 3.2). Following each exposure, subjects completed a symptom checklist (see section 3.5.3).

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.

4.3 Analysis

The motion sickness ratings were summed over the 30-minute exposure period to give an 'accumulated illness rating' for each subject. If a subject terminated the session (i.e. reached a rating of 6 on the motion sickness scale), a rating of 6 was assigned for the remaining period. Vection ratings were allocated scores: 0 for ‘drum only’, 1 for ‘drum and self intermittent’, 2 for ‘drum and self continuous’ and 3 for ‘self only’ (see Table 3.2). The ‘accumulated illness ratings’ and the ‘accumulated vection ratings’ were compared across conditions (i.e. between the real and the virtual drums) using the Wilcoxon matched-pairs signed ranks test. Correlations for ‘accumulated illness ratings’ across conditions, correlations between ‘accumulated vection ratings’, ‘total illness ratings’ and ‘past susceptibility’ within conditions were determined using the Spearman’s rank correlation.

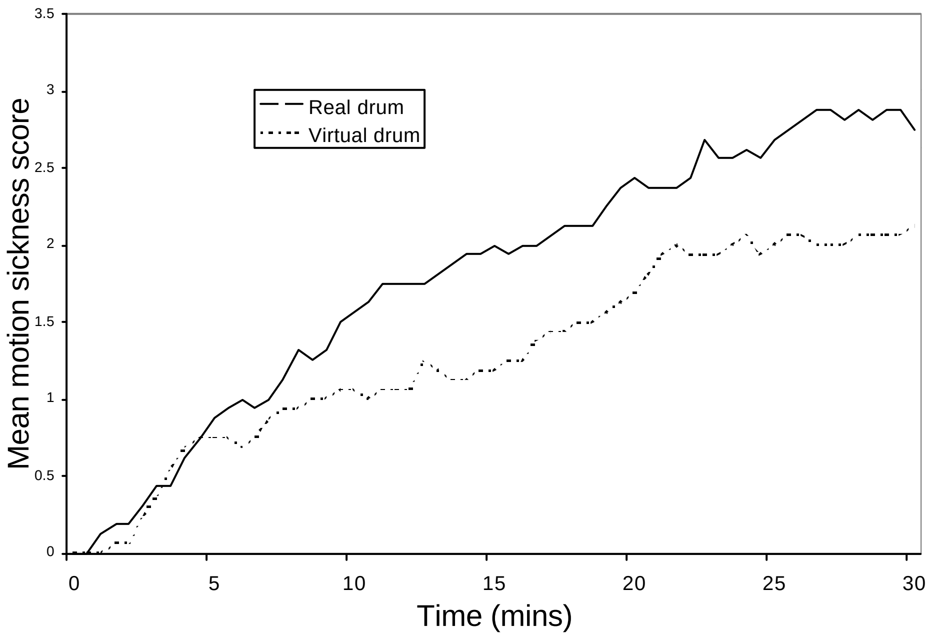

Figure 4.1. Mean motion sickness ratings for the real and virtual drum (motion sickness ratings in the real drum are greatest).

Additional analysis was carried out using subject survival times. The time taken for a subject to reach a rating of 2 (“mild symptoms e.g. stomach awareness but not nausea”) on the motion sickness scale was used as the event of interest in this analysis. Initially, Spearman’s rank correlation test was used to find significant interactions and then Cox regression analysis was used to determine more about the nature of the correlations found. Survival analysis using Cox regression was chosen as it allowed all data to be included in the analysis (e.g. a subject who withdraws from the experiment because of nausea could be included by analysing the time when a rating of 2 was reached), while taking into account the responses of subjects who did not reach a rating of 2. Subjects who withdrew from the experiment because of nausea were included without having to make assumptions about sickness ratings at later times.

4.4 Results

There was no difference between the vection ratings in the two conditions (Wilcoxon, *p*>0.10). However, the accumulated illness ratings (summed over 30 minutes within the two conditions) differed significantly, with mean values of 38.9 in the virtual

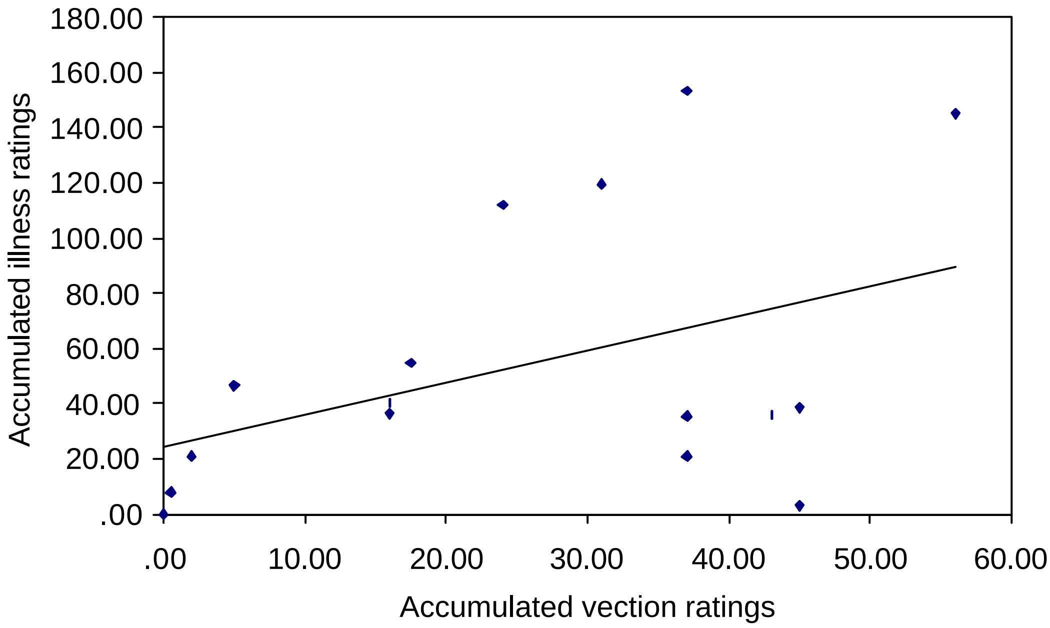

Figure 4.2 Accumulated vection and illness ratings – real drum

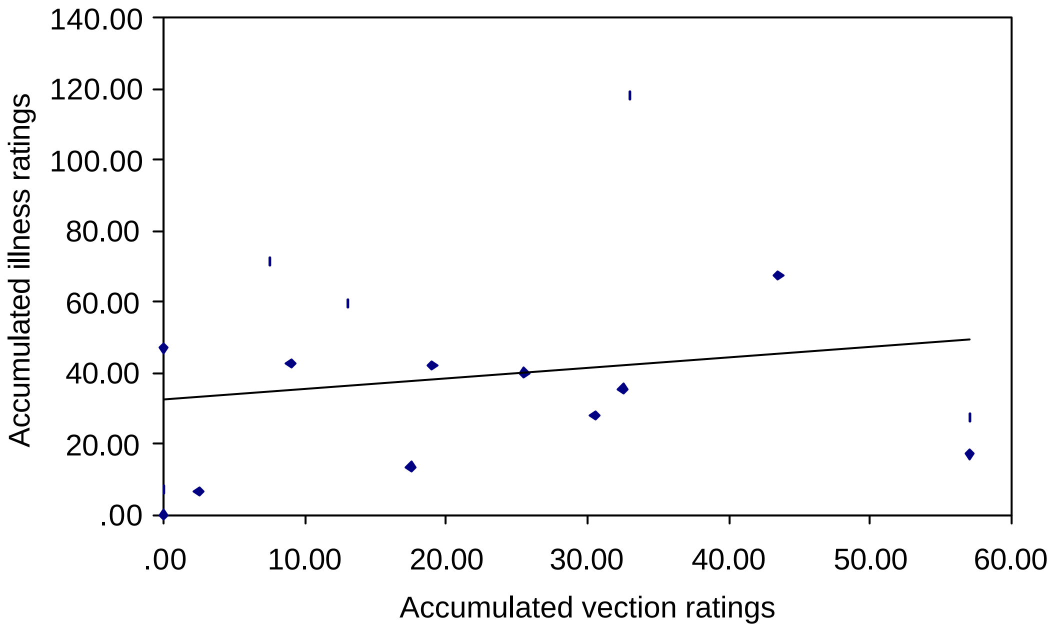

Figure 4.3 Accumulated vection and illness ratings – virtual drum.

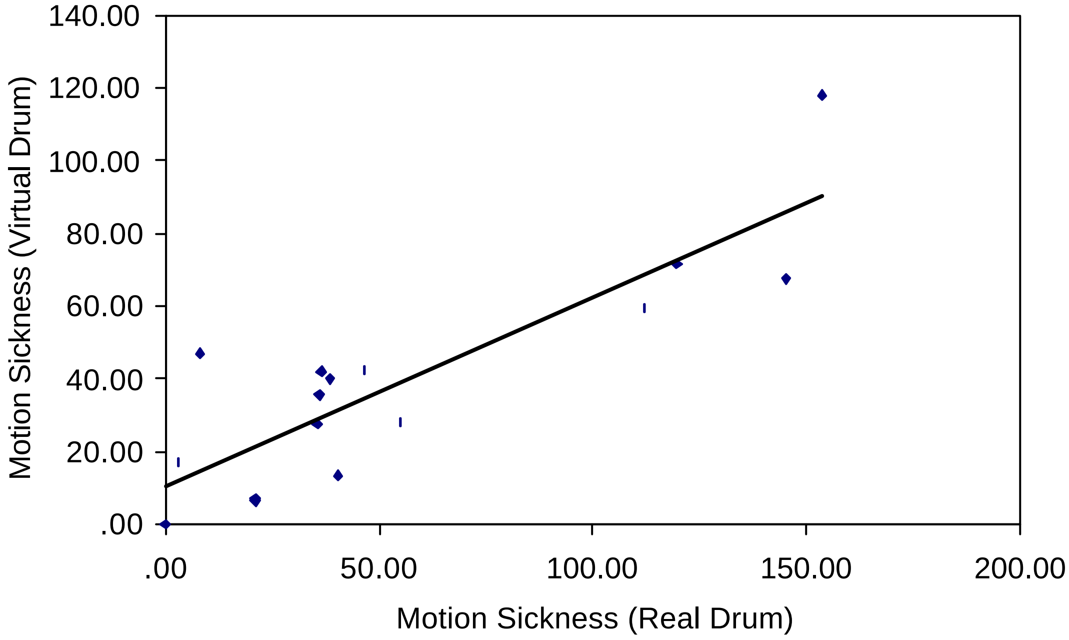

Figure 4.4. Motion sickness scores in the real and virtual drums

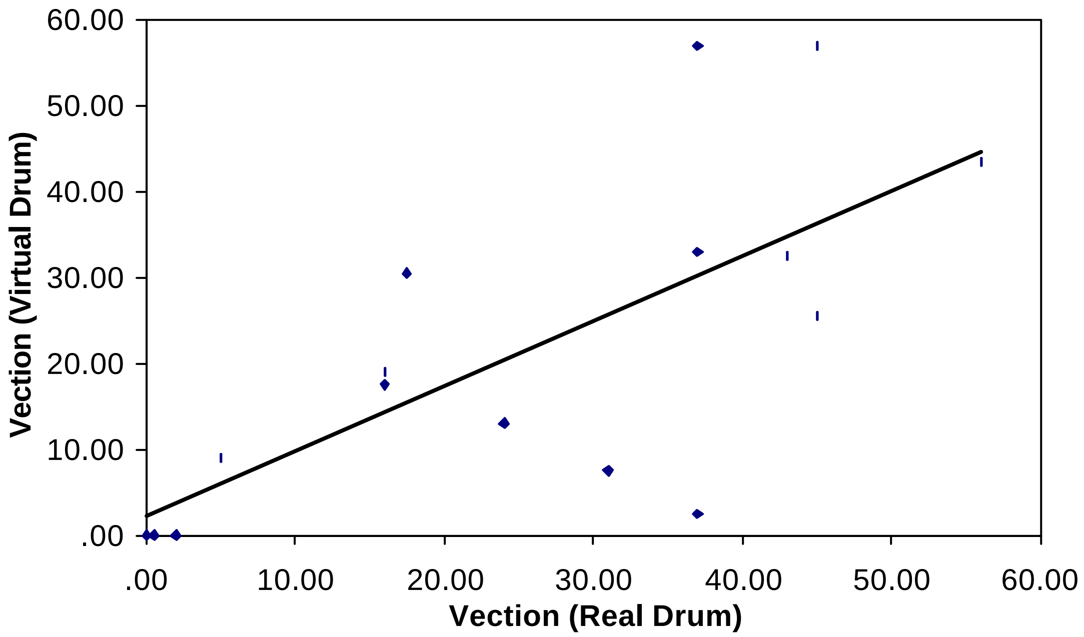

Figure 4.5. Vection scores in the real and virtual drums.

drum and 54.5 in the real drum (Wilcoxon, $p<0.05$). Figure 4.1 shows how the mean sickness ratings vary with time in both conditions. Post exposure symptoms were not significantly different in the two conditions (Wilcoxon, $p>0.10$). There was no correlation between the accumulated vection scores and the total illness scores in either the real drum (ρ= 0.306, p>0.10) or the virtual drum (ρ= 0.223, p>0.10) - see Figures 4.2 and 4.3.

There was a significant correlation between the accumulated illness ratings of subjects in the two conditions – see Figure 4.4 (ρ= 0.755, p<0.001). There was also a significant correlation between the accumulated vection scores of individual subjects in the two conditions – see Figure 4.5 (ρ= 0.768, p<0.001). These results indicate that subjects who experienced motion sickness in one condition tended to experience motion sickness in the other condition and those who experienced vection in one condition also tended to experience vection in the other.

There was no apparent effect of order of presentation on the motion sickness ratings. This was tested by comparing the group of 8 subjects who experienced the real drum first and those who experienced the real drum second and likewise for those who experienced the virtual drum first and second. These comparisons showed that there was no significant difference between first or second groups in either case (Mann-Whitney U test, p>0.10).

4.4.1 Survival analysis – real drum

The time taken for a subject to reach '2' on the motion sickness scale 'mild symptoms e.g. stomach awareness but no nausea', the subject visual acuity at near (0.4m) and far points (2.5m) and the rating of past susceptibility derived from the motion sickness questionnaire ('total susceptibility to motion sickness', M_{total}, as per Griffin and Howarth, 2000) were tested with Spearman's rank correlation test. It was found that there was a significant influence of visual acuity at the near point on survival time (ρ= 0.678, p<0.01) poor acuity being associated with shorter survival times (i.e. earlier onset of symptoms). Visual acuity at the far point was not significantly correlated with survival time (ρ= -0.330, p>0.10). Past susceptibility to motion sickness was not significantly correlated with survival time (ρ= -0.039, p>0.10). Figure 4.6 shows the scatter plot of visual acuity and survival time for the real drum.

4.4.2 Survival analysis – virtual drum

In the virtual reality drum, survival time was again correlated with visual acuity at the near point (ρ= 0.577, p<0.05) but not at the far point (ρ= -0.067, p>0.10). Past susceptibility was not significantly correlated with survival time but there was a trend towards significance (ρ= -0.437, $p<0.10$). Figure 4.7 shows the scatter plot of visual acuity and survival time for the virtual drum.

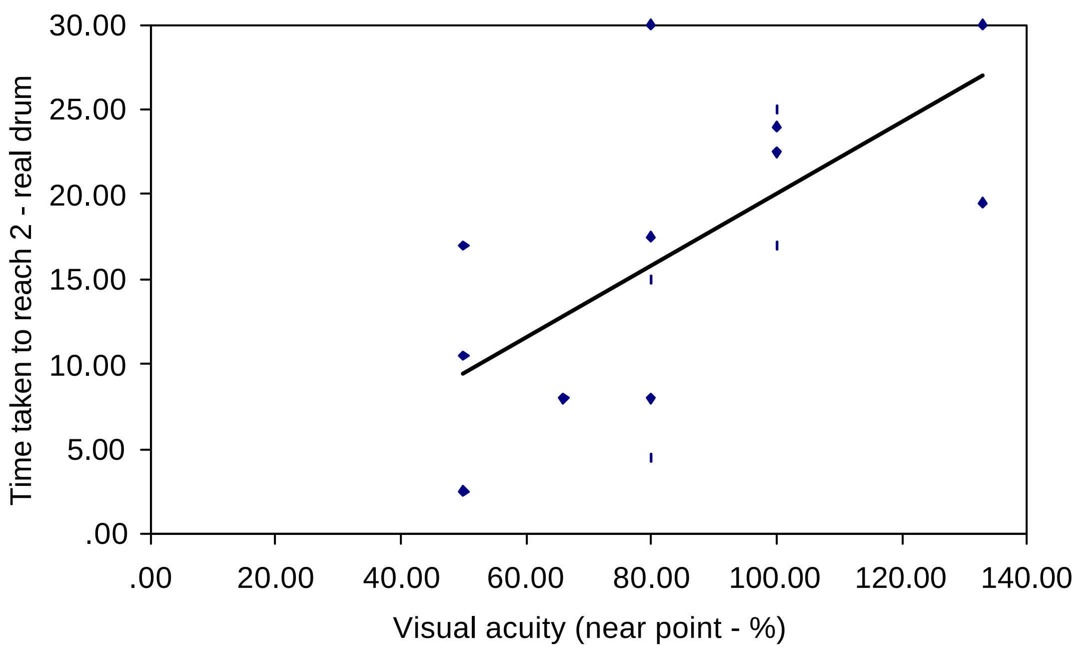

Figure 4.6. Visual acuity vs. survival time – real drum.

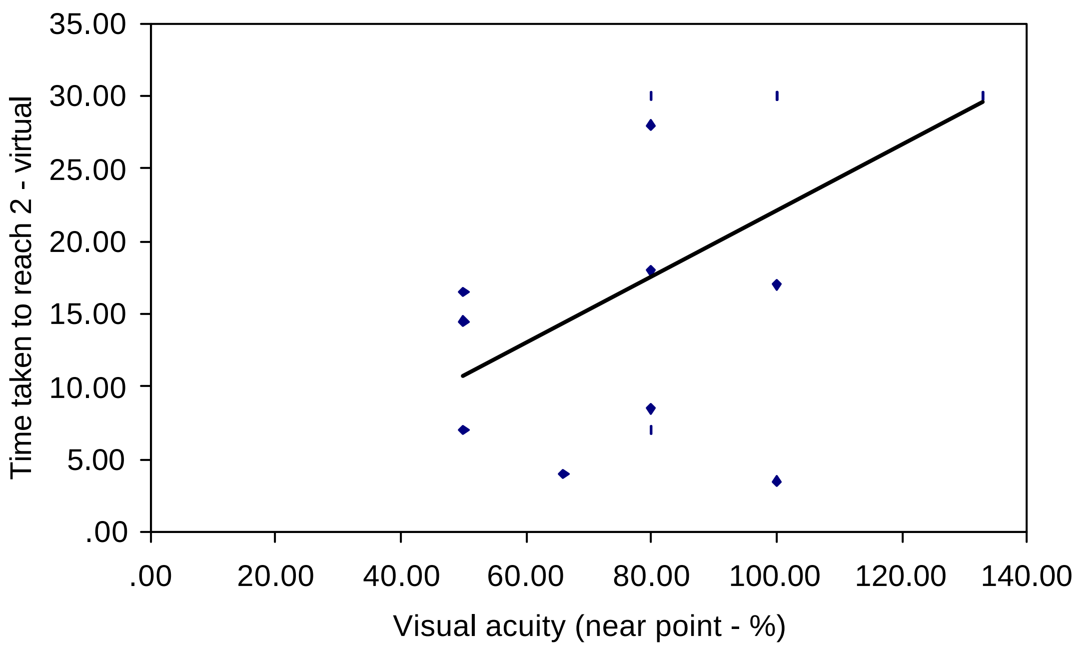

Figure 4.7. Visual acuity vs. survival time – virtual drum.

4.4.3 Cox's proportional hazards model

The factor found to significantly influence survival time in both the real and virtual reality drums was found to be visual acuity at the near point (0.4m) with lower survival times (more sickness) with poorer acuity. The visual acuity data were investigated with Cox regression to yield further information about the nature of the relationship. The visual acuity data was split into two groups for each of the conditions – low (lower than 20:20) and high (20:20 or higher). There were 9 subjects with low and 7 subjects with high acuity. A significant influence of visual acuity on survival time was found in the real drum (Cox regression, $p<0.05$) and in the virtual drum (Cox regression, $p<0.05$). Table 4.1 shows the Cox's proportional hazards model results for the real and virtual drums. The e^{β} values shows that a subject in the real drum was 3 times more likely to reach '2' on the motion sickness scale during the 30 minute exposure period if their visual acuity was less than 20:20. A subject in the virtual drum was nearly 5 times more likely to reach '2' on the motion sickness scale if they had lower than 20:20 vision.

Table 4.1. Cox proportional hazards model.

Condition	Independent variables	e^{β}	Sig (β)
Expt 1 – Virtual Drum	Visual acuity at the near point in two groups – high (>=20:20), low (<20:20)	4.9137	0.0476
Expt 1 - Real Drum	Visual acuity at the near point in two groups – high (>=20:20), low (<20:20)	3.0555	0.0436

4.4.4 Visual acuity and vection

Individual subject visual acuity scores were not correlated with individual accumulated vection ratings in either the real condition ($\rho=0.306$, $p>0.10$) or the virtual condition ($\rho= 0.223$, $p>0.10$). The relation between vection and acuity could not be investigated in the same way as the relation between sickness and acuity (with a Cox regression model) because vection comes and goes during optokinetic stimulation.

4.5 Discussion and conclusions

The results indicated that perceptions of vection did not significantly influence the motion sickness symptoms experienced in either the real or the virtual reality optokinetic drum. Further experiments will also separately measure motion sickness and vection, in order to understand more about the relationship between them and to test whether they can be independently manipulated.

Visual acuity was found to be significantly correlated with motion sickness survival time, with poorer acuity resulting in greater sickness. This is not something which has been previously been reported in the literature and occurred in the real and virtual reality versions of the optokinetic stimulus. The effect of visual acuity on motion sickness is investigated further in Experiment 2.

Motion sickness scores in the real and virtual drums differed significantly. However the motion sickness scores for individual subjects across the two conditions were correlated significantly as were the vection scores across the two conditions. The correlations indicate that the virtual reality display may be a useful tool for the study of motion sickness where it can present a large variety of different visual scenes which would be impossible or expensive with other traditional means such as optokinetic drums or projector systems.

The small difference in motion sickness scores between the two conditions may have been due to slight imperfections in the virtual model where there were occasional jumps in the playback and some stationary pixels which were visible in the background of the display. These minor deficiencies in the display were fixed in the second experiment presented in Chapter 5.

4.6 Updated model

The model has been updated to take into account the influence of visual acuity and the lack of a correlation between vection and motion sickness. The model is shown in Figure 4.8.

The tentative link between vection and motion sickness in the first model is broken so that vection and motion sickness appear in the model as separate outputs. The two remaining routes to 'motion sickness' in the model are via eye movements directly influencing motion sickness or via foveal image slip.

The finding that visual acuity was significantly correlated with motion sickness survival times, with poor acuity associated with increased motion sickness, is included in the model. Visual acuity as measured in this experiment, was a measure of the ability of the fovea to discriminate fine detail at high contrast, so this influence is included acting upon the foveal pursuit path of the model. Here it may act to decrease the influence of the foveal pursuit component on the slow phase of nystagmus.

This updated model predicts that visual acuity will only be significantly associated with motion sickness when the eyes are free to move or there is foveal image slip. In a condition with fixation (e.g. where the eyes are focusing on a stationary cross in front of moving stripes) it would be expected that the influence of visual acuity would not occur. This is investigated further in the next Chapter.

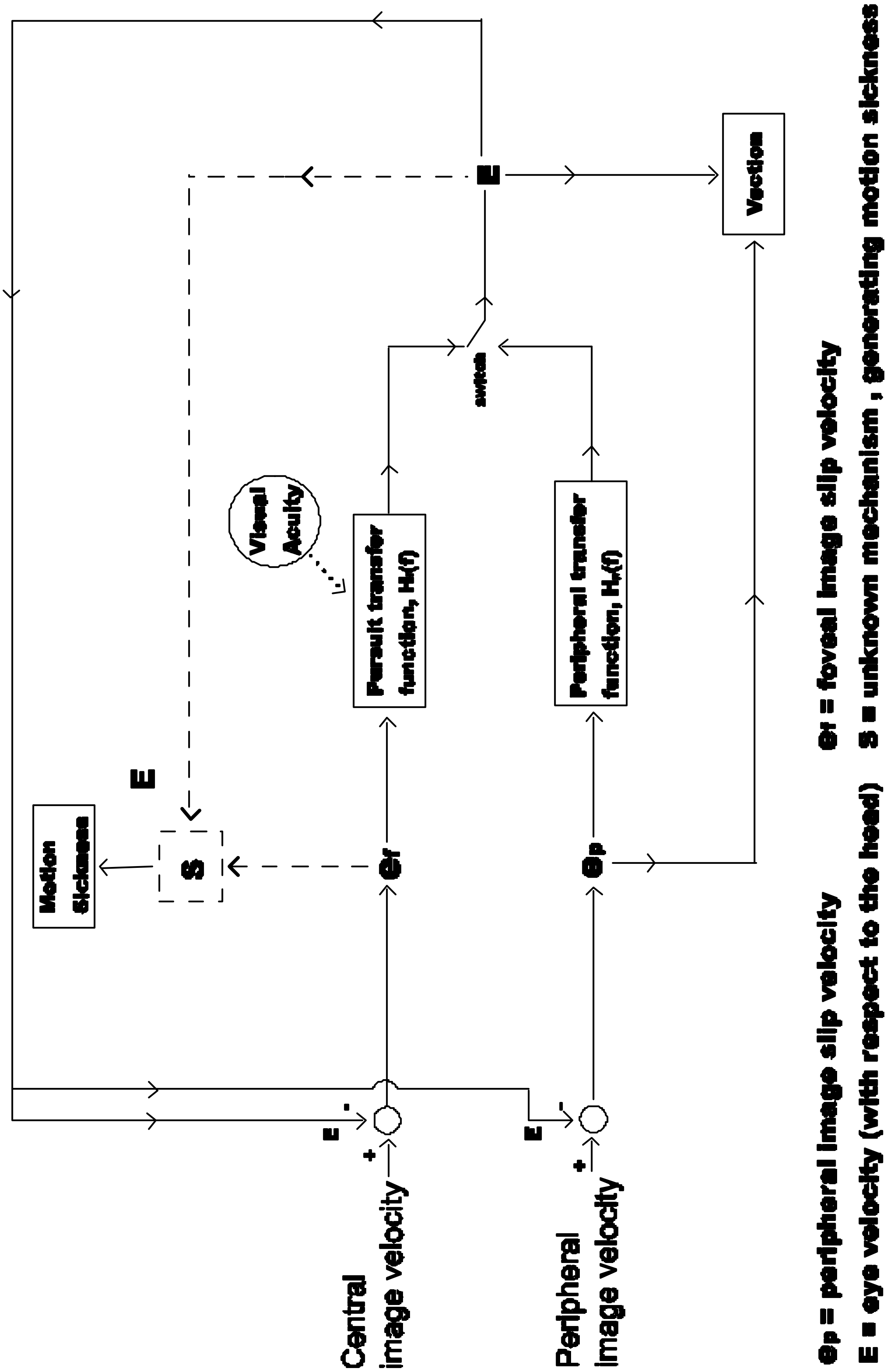

Figure 4.8. Model version 2. The proposed influence of visual acuity on the pursuit component of the slow phase velocity and the lack of a correlation between vection and motion sickness have been included.