Chapter 5. Experiment 2. Motion sickness and vection with and without visual fixation.

5.1 Introduction

In the first experiment, subjects with poor acuity gave higher illness ratings: an effect that does not appear to have been previously reported. No correlation between vection and motion sickness was found. The influence of visual acuity on motion sickness was investigated in this experiment. Previous research (Stern *et al.,* 1990) has shown a reduction in motion sickness when eye movements are suppressed by the act of fixation on a stationary object in front of an optokinetic background. It has been hypothesised that motion sickness is controlled partly by eye movements (Ebenholtz *et al.,* 1994) but that vection is mainly controlled by the peripheral vision (Brandt *et al.,* 1973).

The second experiment therefore suppressed eye movements in one condition by providing a stationary fixation point while the remaining visual scene moved as in the first experiment. By examining model 2 (Section 4.6) it was hypothesised that the presence of the fixation point would reduce eye movements because of the dominance of the fovea on the control of eye movements. It was also predicted that motion sickness would be reduced, because the two possible paths in the model to motion sickness are via eye movements or via foveal image slip, both of which are reduced by fixation. Vection was predicted to be the same in both conditions because of the suggested dominance of the peripheral visual receptors on vection and the predicted independence of vection and eye movements.

It was also predicted that, without the fixation point, motion sickness would be correlated with visual acuity, as in the first experiment, but with fixation there would be no correlation between visual acuity and motion sickness because of the reduction in eye movements or the reduction in foveal image slip.

5.2 Method

Subjects watched two conditions on the Virtual Research VR4 head-mounted display: the same optokinetic drum simulation as used in Experiment 1 and a similar

condition but with the addition of a stationary cross in front of the moving stripes. The two conditions are shown in Figure 5.1. Both conditions simulated optokinetic drum rotation of 30°/second (5 r.p.m.). The images were presented with an improved video interface which removed the occasional glitches and appearance of stationary pixels found in experiment 1. It was possible to ensure that the eyes of subjects were open by looking through a gap in the side of the display.

Subject visual acuity was measured as in the first experiment. Eye movements in the horizontal plane were continuously recorded throughout both conditions using electro-oculography and acquired to computer using an *HVLab* data acquisition system at 30 samples per second, with a low pass frequency cut-off at 10Hz (see Chapter 3 for further information).

The exposure duration for each condition was 30 minutes, with subjects reporting motion sickness symptoms and vection each minute as described in the first experiment. Eighteen subjects took part in the study, with each subject experiencing both conditions separated by an interval of at least 2 weeks. Subjects experienced each condition at the same time of day. Nine subjects experienced the 'fixation' condition first and the other 9 subjects experienced the 'non-fixation' condition first. The heads of subjects were restrained by the use of a strap attached to the display and to the backrest of the chair. Subjects sat in the chair of the optokinetic drum used in experiment 1, but with the drum in its raised position. Subjects heard white noise through headphones during the presentation, and were spoken to through a microphone each minute. Motion sickness ratings and vection ratings were reported each minute as in Experiment 1 (see Tables 3.1 and 3.2).

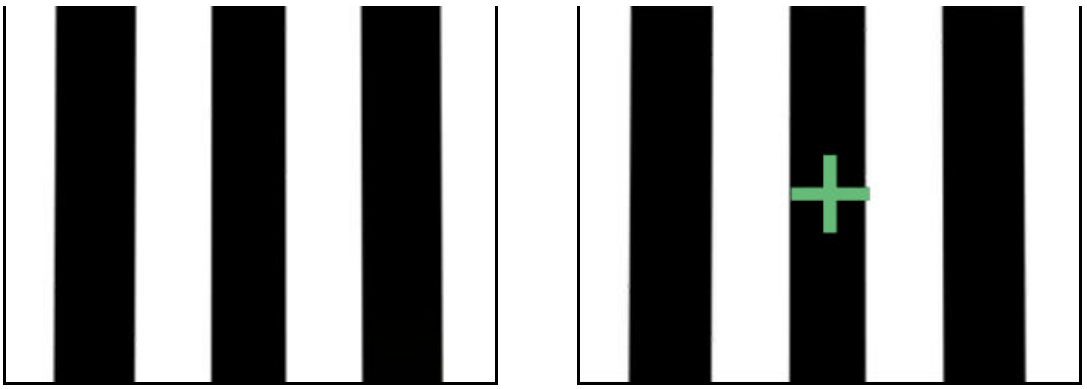

Figure 5.1. The normal condition and the fixation condition. In the fixation condition subjects focused on the stationary cross while the stripes moved behind it.

5.3 Analysis

5.3.1 Eye movements

The eye movement data were visually inspected. No repetitive eye movements occurred during the fixation condition, indicating that nystagmus was completely suppressed. In the condition without the fixation cross, a variability in eye movements was observed between subjects, with high variation in the duration for which nystagmus occurred. Some subjects had periods with no eye movements and other periods when eye movements were typical of tracking the black and white stripes (i.e. nystagmus: smooth pursuit followed by a rapid return saccade). Nystagmus generally occurred for between 30% and 100% of the exposure when there was no fixation. An approximate percentage time in which nystagmus occurred and an approximate nystagmus frequency was found for each subject in the non-fixation condition. The average frequency was determined only from the periods in which nystagmus occurred. The inspection of eye movements was performed without knowing which subject was being analysed.

5.3.2 Statistics

Motion sickness and vection scores were analysed using the Wilcoxon matched-pairs signed ranks test. Spearman's rank correlation test was used to test the relationships

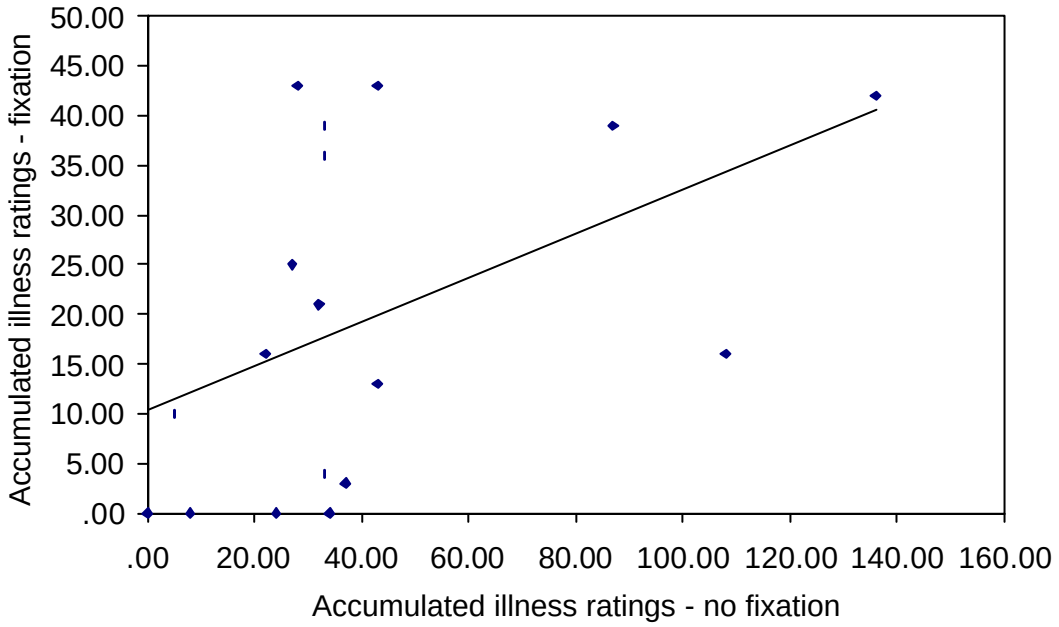

Figure 5.2. Accumulated illness ratings in the two conditions.

between vection, motion sickness and past susceptibility. Survival analysis was performed as in experiment one.

5.4 Results

5.4.1 Motion Sickness

The mean accumulated illness rating over 30 minutes was significantly less in the fixation condition: 19.4 with fixation compared to 40.7 without fixation (Wilcoxon, $p<0.01$). Post exposure symptoms as measured by the questionnaire were also lower with fixation (Wilcoxon, $p<0.05$). Mean motion sickness scores against time are shown in Figure 5.3. Total illness ratings for individual subjects in the two conditions were marginally significantly correlated ($\rho=0.445$, $p<0.10$) and are shown in Figure 5.2.

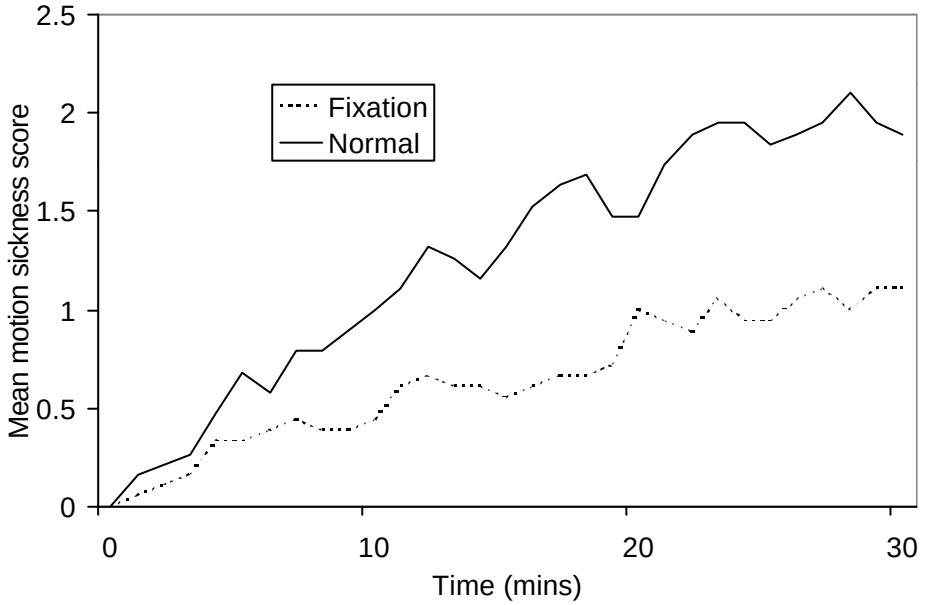

Figure 5.3. Mean motion sickness ratings against time for the two conditions.

5.4.1.1 Survival analysis - normal condition

A marginally significant correlation was found between visual acuity at the near point and survival time ($\rho= 0.432$, $p<0.10$) with poor acuity being associated with shorter survival times (i.e. earlier onset of symptoms). Figure 4.4 shows survival time for varying visual acuity. Visual acuity at the far point was not significantly correlated with survival time ($\rho= 0.186$, $p>0.10$). Past susceptibility to motion sickness was not

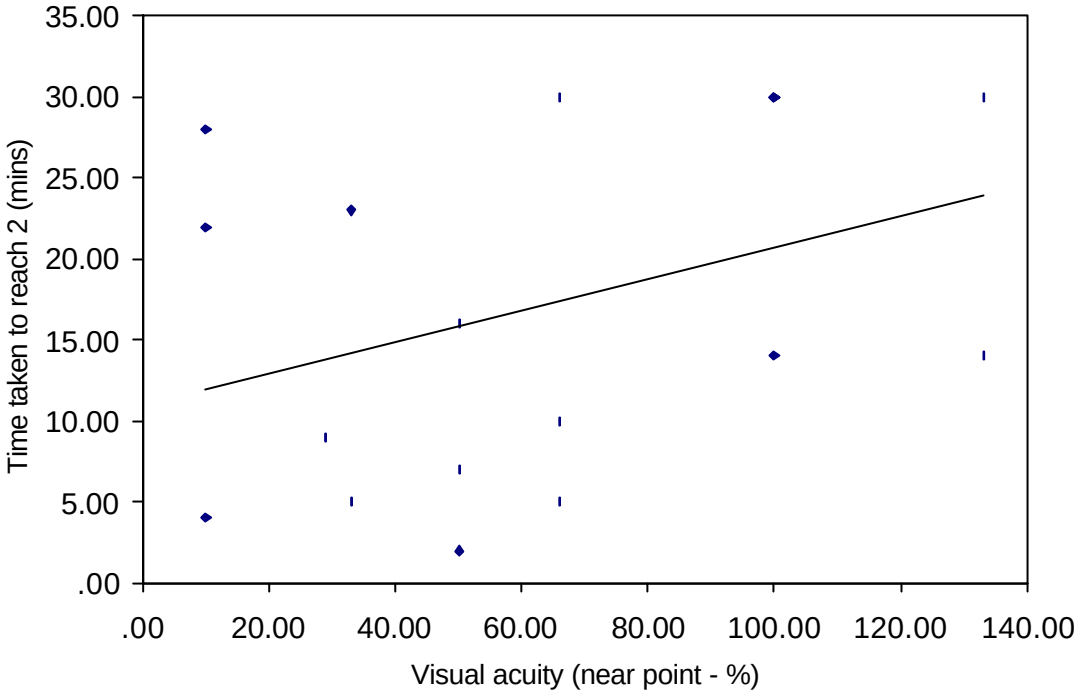

Figure 5.4. Variation of survival time with visual acuity for the non-fixation condition.

significantly correlated with survival time (ρ= -0.044, *p*>0.10). There was an effect of the percentage time of eye movements on survival time (Spearman rho = -0.574, *p*<0.05): an increase in nystagmus was associated with a reduced survival time. There was no significant correlation between survival time and average nystagmus frequency (ρ = -0.158, *p*>0.10).

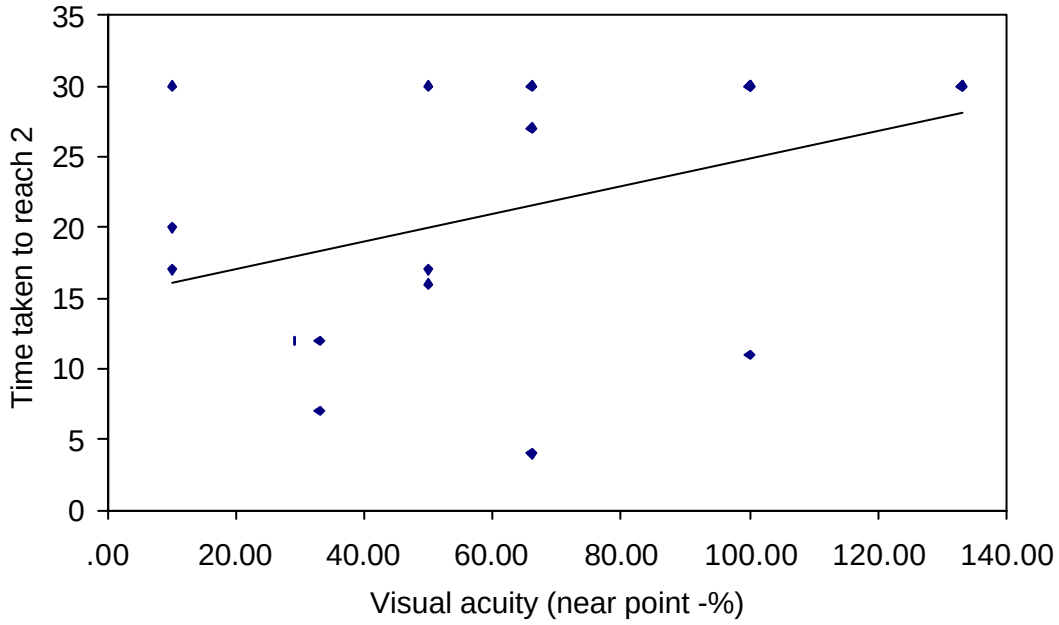

Figure 5.5. Variation of survival time with visual acuity for the fixation condition.

5.4.1.2 Survival analysis – fixation condition

In the fixation condition it was found that visual acuity at the near point was not correlated with survival time ($\rho = 0.389$, $p > 0.10$) nor at the far point ($\rho = -0.067$, $p > 0.10$). There was a marginally significant correlation between survival time and past susceptibility to motion sickness ($\rho = -0.437$, $p < 0.10$). Figure 4.5 shows survival time for varying visual acuity in the fixation condition.

5.4.1.3 Cox's proportional hazards model

In the normal condition the percentage time in which nystagmus was occurring was found to have a significant influence on survival time and the visual acuity data recorded at the near point showed a marginally significant association with survival time. A Cox regression analysis was performed to find out more about the associations, with the visual acuity data at the near point split into high (20:20 or greater) and low (less than 20:20) and the nystagmus time variable. There were 12 subjects with low acuity and 6 subjects with high acuity. It was found that visual acuity had a significant effect on survival time (Cox regression, $p < 0.05$) but the nystagmus time variable was not found to be significant when included with visual acuity (Cox regression, $p > 0.10$).

In the fixation condition visual acuity was not found to be significant but the past susceptibility ratings showed a strong trend towards a significant influence. The effect of past susceptibility was investigated in a Cox regression model and was found to be significant ($p < 0.01$). Table 5.1 shows the Cox's proportional hazards model for the significant variables in both conditions.

Table 5.1. Cox proportional hazards model.

Condition	**Independent variables**	**e^b**	**Sig (b)**
Expt 2 – Normal Cond.	Visual acuity at the near point in two groups – high (>=20:20), low (<20:20)	5.1058	0.0358
Expt 2 – Fixation Cond.	Past susceptibility	1.0624	0.0098

5.4.2 Vection

Individual subject accumulated vection scores did not correlate with accumulated illness ratings in either the normal condition (ρ=0.178, p>0.10) or in the fixation condition (ρ= 0.086, p>0.10). There was no significant difference in the accumulated vection ratings with or without fixation (Wilcoxon, p>0.10) or the time taken to first experience vection (Wilcoxon, p>0.10). Inspection of the raw results showed that nine subjects reported greater vection with fixation while nine subjects reported greater vection without fixation. Eye movements during the condition without fixation were compared with vection ratings. There was no apparent difference in vection ratings when the eyes were moving or stationary: vection was reported when the eyes were moving and when the eyes were stationary.

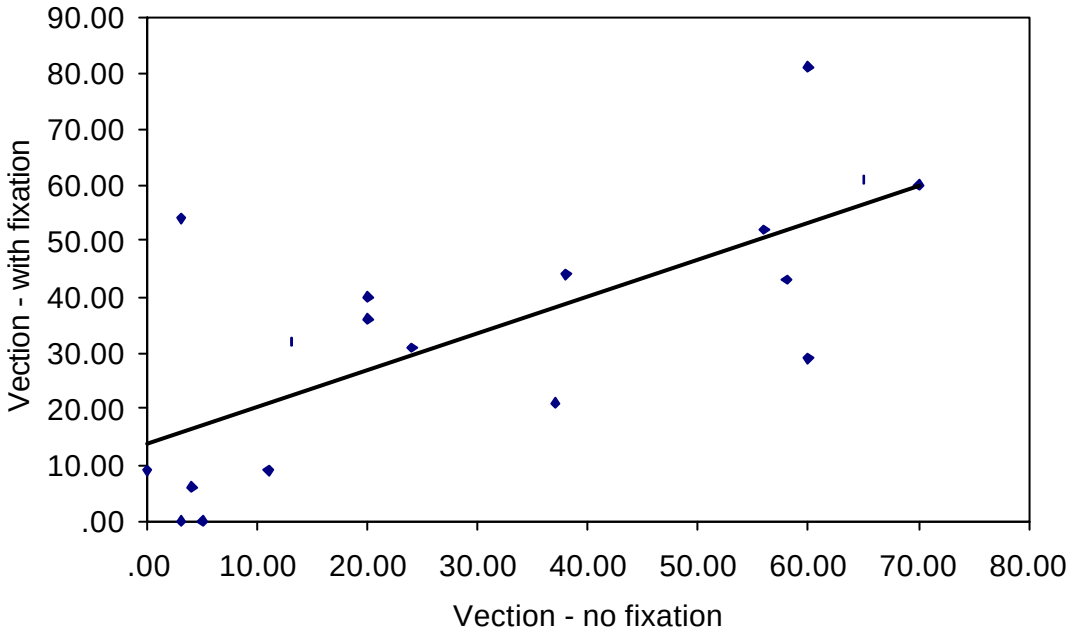

Figure 5.6. Vection scores in the two conditions.

There was a significant correlation between subject accumulated vection ratings in the two conditions (ρ= 0.674, p< 0.01) indicating that those subjects who experienced vection in one condition also experienced vection in the other, despite eye movements occurring during the normal condition but not during fixation (see Figure 5.6).

5.5 Discussion and conclusions

The reduction in sickness with fixation is consistent with reductions in eye movements or a reduction in motion on the fovea reducing motion sickness. Although visual fixation reduced motion sickness it did not affect vection. This suggests that vection does not have a large influence on motion sickness with this type of moving visual scene. It also suggests that vection was not greatly influenced by eye movements. This is consistent with vection being mainly determined by motion in the periphery of the visual field and being independent of eye movements as predicted by the model.

Vection ratings were similar in both conditions despite the difference in motion sickness. The ratings of vection in both experiments were uncorrelated with ratings of motion sickness. This is consistent with the findings of experiment one and this suggests that 'sensory conflict' brought about by the illusion of motion was not the cause of sickness. The results show that vection and sickness are not simply related: they appear to be distinct phenomena that can occur together but may also occur independently, depending on the properties of the display and the nature of the task.

There was a correlation between accumulated vection ratings in the two conditions but there was only a marginal correlation of accumulated illness ratings in the two conditions. This indicated that subjects who experienced motion sickness in one condition did not necessarily experience motion sickness in the other condition, but those experiencing vection in one condition were likely to experience vection in the other. This, again, is consistent with motion sickness being influenced by foveal vision or eye movements (which differed between conditions) and vection being influenced by peripheral vision (which was similar in the two conditions) and independent of eye movements.

The association of visual acuity with motion sickness has occurred so far in both conditions of experiment one (real and virtual reality) and in the non-fixation condition of this experiment. The association was not found in the fixation condition. Two things are different during fixation: (i) there are no eye movements (ii) there is no motion of images on the fovea. This suggests that visual acuity may possibly influence eye movements which are in turn influencing motion sickness in an unknown way, or that image slip detected on the fovea is influencing motion

sickness. However, the difference between the correlation coefficients found between visual acuity and motion sickness without fixation (ρ=0.432, p<0.05) and between visual acuity and motion sickness with fixation (ρ=0.389, p>0.10) is not large. Caution in the interpretation of the results is necessary, as the correlation between visual acuity and motion sickness may possibly be found to be significant in a further experiment.

Ratings of past susceptibility were not found to be a significant influence on motion sickness survival except during the fixation condition. This allows for the possibility that visual acuity is an influence on motion sickness when there is motion on the fovea or eye movements, and that past susceptibility to other forms of motion sickness may be important when this influence of acuity is diminished by the act of fixation.

5.6 Updated model

The model, presented in Figure 5.7, is identical to that shown in Chapter 4. The correlation between visual acuity and motion sickness, when the eyes are free to move, or when there is motion on the fovea may have been confirmed by this experiment. Further investigation will be required.

The finding that vection and motion sickness are distinct phenomena has been confirmed by the ability of motion sickness symptoms to be manipulated separately from vection perceptions, and by no correlations being found between vection and motion sickness in subjects.

The influence of visual acuity is investigated further in the third experiment presented in the next chapter.

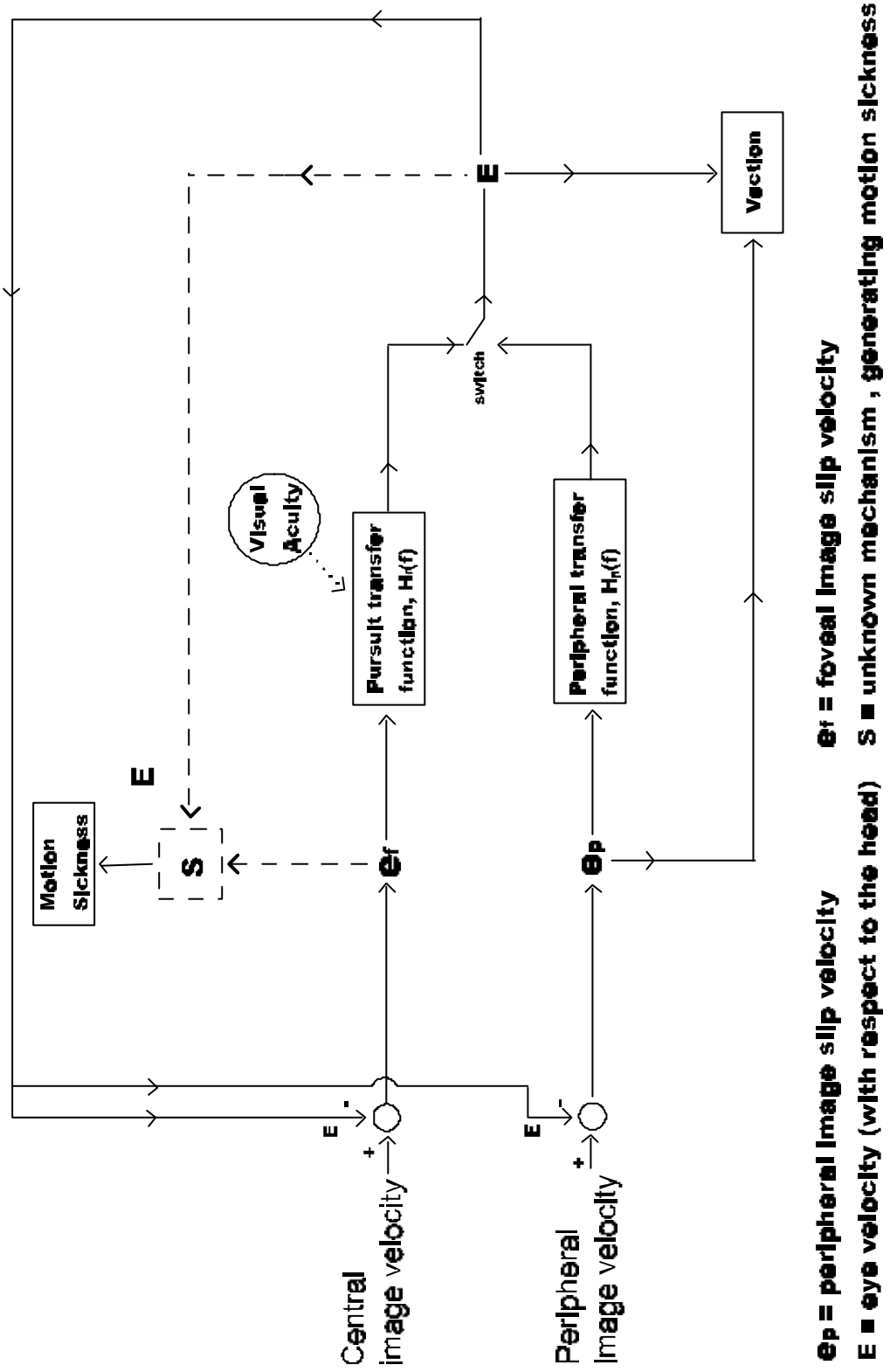

Figure 5.7. Model version 2. The model is identical to that shown in Chapter 4.