Chapter 1. Introduction

Motion sickness is an unpleasant condition, which many people experience at some point in their life. The most common forms of motion sickness occur during the course of travel on ships, small boats, cars, aeroplanes and buses. This 'travel sickness' is widely experienced and takes the form of a number of common symptoms, such as yawning, cold sweating, increased salivation, drowsiness, dizziness, headaches, stomach awareness, nausea and vomiting.

Motion sickness during sea travel has been noted for many centuries. In more recent times motion sickness symptoms have been noted even without movement of the person experiencing the sickness. Sickness has been noted during wide screen cinema presentations, when playing computer games, during exposure to a motion simulator (such as a flight simulator) or more recently during virtual reality simulations. Visually-induced motion sickness, sometimes known as 'simulator sickness', can pose real problems in the use and development of motion simulators or virtual reality for training purposes. For example, virtual reality has the potential to be used for training pilots or for use in the medical training of surgeons. When motion sickness occurs it can prevent some individuals from participating in the training, it may limit the length of time for which training can occur, or perhaps more seriously the people undergoing training may develop strategies to help avoid experiencing the symptoms, such as minimising head movements, which may then have an adverse effect on their performance when they move to the real world task (i.e. poor transfer of training).

Visually induced motion sickness has been studied for the past 30 years with the use of optokinetic drums. These are cylinders on which the inner surface is painted with black and white vertical stripes. The drum rotates around stationary, seated subjects who watch the stripes. Motion sickness is common upon exposure to an optokinetic drum. Optokinetic drums are used because they are simple to manufacture, operate and can be altered to discover more about visually-induced motion sickness, such as whether the speed of the visual stimulus influences the symptoms experienced (or whether eye movements, made in response to the moving stripes, influence motion sickness).

Subjects also tend to experience an illusion of motion known as 'vection' when viewing an optokinetic drum. Vection has been studied in its own right as an interesting phenomenon. Vection has often been linked to motion sickness in the literature, as a cause of motion sickness, although it has not been proven statistically (e.g. Hettinger *et al.,* 1990). Eye movements have also been suggested as a possible cause for motion sickness, with higher frequency eye movements hypothesised to increase motion sickness in response to an optokinetic drum (e.g. Ebenholtz *et al.*, 1994).

The aim of this thesis was to investigate visually-induced motion sickness by using an optokinetic drum and a virtual reality display. In each of six experiments reported in this thesis, vection and motion sickness were investigated to see whether they were correlated. Visual acuity data for subjects were recorded in each experiment to discover whether the ability of a subject to see fine detail at high contrast would affect their motion sickness symptoms. Additionally, eye movements were recorded in the 2^{nd}, 4^{th} and 6^{th} experiments in order to investigate correlations between visual acuity, eye movements and motion sickness.

In the first experiment, a virtual reality simulation of an optokinetic drum was compared with a standard optokinetic drum to see whether the results found in virtual reality were comparable with past results from a normal optokinetic drum. The second experiment investigated whether suppressing eye movements could influence motion sickness and vection (the illusion of self-motion). A third experiment investigated whether artificially blurring the stripes could affect motion sickness or vection. A fourth experiment compared motion sickness and vection when only central (foveal) vision was stimulated (with a single moving dot) or when central and peripheral vision were stimulated (with multiple moving dots). A fifth experiment investigated whether motion sickness was different when subjects watched the optokinetic drum with or without their vision correction (e.g. their spectacles or contact lenses). The sixth and final experiment investigated whether there was any difference in the eye movements of subjects when they viewed the optokinetic drum with and without their vision correction.

A review of the literature is presented before the experimental work. The literature review encompasses areas such as visual acuity, contrast sensitivity, eye movements, the vestibulo-ocular reflex, vection and motion sickness. The review concentrates mainly on research which has been conducted using optokinetic drums.