VISUAL FUNCTION AND VISUAL DISABILITY IN GLAUCOMA

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Being the result of original research work carried out at the Department of Ophthalmology, Princess Alexandra Eye Pavilion, Edinburgh under the supervision of Professor Peter Aspinall, PhD, Faculty of Environmental Studies, Heriot-Watt University, Edinburgh, and Dr. Colm O'Brien, FRCS, FRCOphth, MD, Ophthalmology Unit, Department of Surgery, University of Edinburgh, Edinburgh.

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"We are not in the business of lowering intraocular pressure. We are not in the business of preventing further disc damage. We are not in the business of stopping field defects."

"We are in the business of keeping a patient functioning visually at a level that does not hamper or impede the highest quality of life possible."

T. Zimmerman, J Glaucoma, 1996

TABLE OF CONTENTS

LIST OF TABLES

SECTION I: BACKGROUND AND LITERATURE REVIEW

SECTION II : PILOT STUDY

SECTION III: MAIN STUDY

LIST OF ILLUSTRATIVE MATERIAL

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ABSTRACT

The aims of this study were a) to identify what constitutes visual disability resulting from glaucoma by means of a questionnaire developed for this purpose, b) to examine visual function in glaucoma using a wide range of psychophysical tests and c) to assess the relationship between objective visual function and patients' perception of their visual disability.

The study was carried out in two phases. Firstly, a pilot questionnaire on visual disability in glaucoma was tested on 63 glaucoma patients. Results suggested that there were four main areas of difficulty in the daily life of glaucoma subjects: outdoor mobility, glare and lighting, household tasks and personal care. A significant correlation between self-reported disability and a measure of visual field loss was shown. The questionnaire was subsequently modified for the purpose of the main study and completed by 49 glaucoma subjects with various degrees of visual field loss and 20 normal controls. A range of psychophysical tests was carried out including automated perimetry, contrast sensitivity, critical flicker frequency, glare sensitivity, stereoacuity, colour perception and dark adaptation.

Using factor analysis, the most frequently reported problems were grouped into the following five categories: central and near vision, peripheral vision, dark adaptation and glare, personal care and household tasks and outdoor mobility. These five factors accounted for 79% of the variability in the patients questionnaire responses. Fifteen questions related to the factors dark adaptation and glare, peripheral vision, outdoor mobility and central and near vision were found to be significantly correlated with the extent of visual field loss ($p=0.0001$, $r=-0.6$) and could discriminate between patients and normals and also between groups with mild and severe visual field loss. Patients with moderate visual field

loss did not experience significantly greater disability than patients with mild visual field loss ($p=0.08$), although there was a trend towards significant difference. A strong relationship was found between the severity of visual field loss and all psychophysical tests ($p<0.01$), except colour vision. When comparing normals and early glaucoma patients, the best results were obtained for dark adaptation ($p=0.013$), glare disability ($p=0.023$) and the contrast sensitivity test ($p=0.039$). When comparing objective visual function and self-reported visual disability, a strong relationship was found between the questionnaire performance index and all psychophysical tests ($p<0.05$), with the exception of colour vision. Glare disability ($p<0.0001$), contrast sensitivity ($p<0.0001$) and dark adaptation ($p=0.007$) appear to be the tests that give the best information about quality of life issues.

Glare disability, dark adaptation and contrast sensitivity appear to be the tests which give the best information about the quality of life in glaucoma. In addition these tests best separated early glaucoma from normal controls and deserve more attention in future research work on glaucoma.

PUBLICATIONS IN PRESS OR ARISING FROM THIS STUDY

1. Patients' Perception of Visual Impairment in Glaucoma I.
   P Nelson, C O'Brien, P Aspinall. Investigative Ophthalmology and Visual Science, Supplement: March 15, 1997, Vol.38, No.4.

2. Patients' Perception of Visual Impairment in Glaucoma: A Pilot Study.
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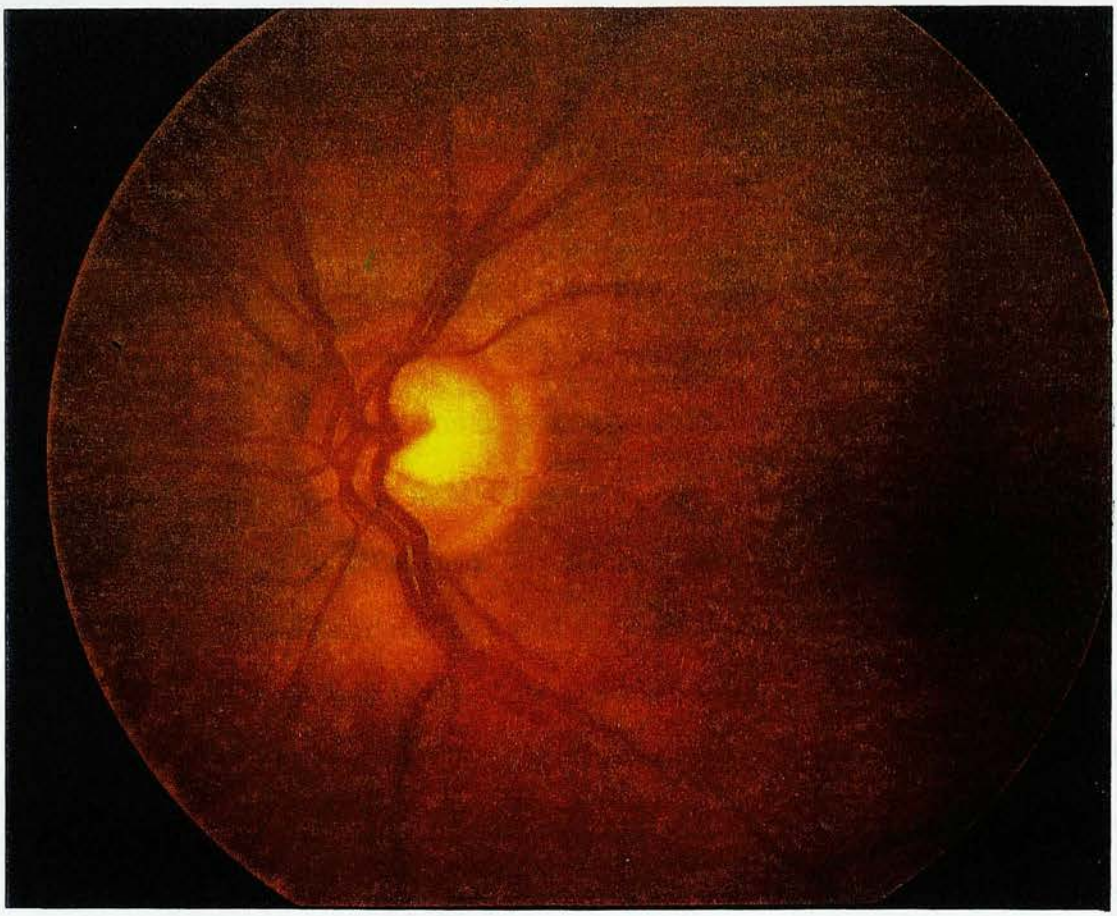


Glaucomatous optic disc.

INTRODUCTION

In a recent paper by Quigley it was pointed out that glaucoma is the second leading cause of visual loss in the world, and the estimated number of people suffering from this eye disease world-wide in the year 2000 will be approximately 67 million (1). About 10% of those with this disease may suffer from bilateral blindness, while the remaining 90% have varying degrees of visual impairment and disability (1). Loss of vision in glaucoma is irreversible and those who have glaucoma have to live with their disease and cope with its consequences.

Outcome assessment has become increasingly important as a critical measure for treatment and management of medical conditions, and Zimmerman (2) and Lee (3) have recently highlighted this issue in glaucoma. Reduced vision, as shown in many studies, is correlated with perceived difficulties in everyday tasks (4-9). Very little is known about the impact of glaucoma on the quality of life of those affected (2). For many patients the ability to remain independent is not crucially influenced, but little knowledge is available on the extent and character of visual disability experienced by patients in their daily life. More scientific information is needed on the evaluation of patient capabilities in performing visual tasks and on the correlation of perceived disabilities with psychophysical testing of visual function.

The aims of this study were a) to identify what constitutes visual disability resulting from glaucoma by means of a questionnaire developed for this purpose, b) to examine those aspects of visual function that seem to be compromised in glaucoma, such as contrast sensitivity, flicker sensitivity, colour vision, dark adaptation, brightness acuity (glare disability), Esterman visual field and

stereoacuity, and c) to assess the relationship between objective visual function and patients' perception of their visual disability.

To meet these overall aims, two studies were carried out. Firstly, a pilot study was undertaken. Its purpose was to identify the most commonly perceived disabilities in the daily life of glaucoma patients by means of a questionnaire, to rank the perceived problems with regard to frequency, to group related visual problems and assess their impact on daily life activities, and to examine the relationship between perceived visual difficulties and the severity of visual field loss, looking in particular at those variables which could discriminate between different grades of visual field loss. A pilot questionnaire was designed for this purpose. A further task was to specify a glaucoma-specific subgroup of questions and to test the validity and reliability of this newly created questionnaire subscale.

Secondly, in the main study, a range of psychophysical tests was carried out and visual disability was measured using the questionnaire developed in the pilot study. The relationship between various aspects of visual function (contrast/flicker sensitivity, colour vision, dark adaptation, glare disability, Esterman visual field and stereoacuity) and patients' perception of visual impairment was examined.

SECTION I

BACKGROUND AND LITERATURE REVIEW

Chapter 1

VISUAL IMPAIRMENT

1.1 Visual Impairment: terminology and definitions

There is a marked lack of consistency in the use of terms to describe people with visual loss. For example Baranga in 1983 (10) listed nineteen different terms which have been used at different times by different professionals. The World Health Organisation (WHO) (11) published the International Classification of Impairments, Disabilities and Handicaps (ICIDH). The definitions it presents are widely used and accepted and it is these definitions that have been adopted for this study. In 1976 Colenbrander (12) worked on the WHO committee and offers the following definitions specific to visual problems.

1.1.1 Visual Disorder

A visual disorder is a disease, injury or congenital anomaly, that is, a deviation from the normal structure of the visual apparatus.

1.1.2 Visual Impairment

A visual disorder is considered to give rise to a visual impairment if it results in an uncorrectable limitation of one or more of the basic visual functions, such as acuity, fields, colour discrimination and so on.

1.1.3 Visual Disability

The impairment may result in a disability, that is, a limitation in performing certain visual tasks. A visual impairment can result in multiple disabilities, such as difficulty in reading, poor mobility, difficulty with personal care etc. A disability does not occur if aids, such as spectacles, are able to compensate for the impairment.

1.1.4 Visual Handicap

A visual handicap is the disadvantage a person experiences as a result of the visual impairment or disability. A disability such as difficulty in reading, for example, could become a handicap if it results in a person's loss of independence or self-esteem. Handicaps are therefore often affected by the environment, the roles an individual is expected to fulfil and the person's own expectations.

It is important to note that these four terms are not interchangeable but represent qualitatively different levels of functioning. Disorders and impairments are essentially medical in origin, disabilities and handicaps are essentially social. People with similar disorders and impairments might respond in very different

ways and therefore have different disabilities and handicaps, both in terms of type and severity.

1.2 Blindness and Partial Sight: registration, history and benefits

The legal definition of blindness in the UK has remained unchanged since it was introduced in 1921 in the Blind Persons' Act. It states that a person is blind when 'he/she is so blind as to be unable to perform any work for which eyesight is essential.'

This act was followed in 1948 by the National Assistance Act which made further provision for a second category know as partial sight. No statutory definition of partial sight was given, although the Ministry of Health subsequently advised that a person who is 'substantially and permanently handicapped by a congenital defect, illness or injury is eligible to be registered as partially sighted.'

These definitions are essentially functional and there is no legal definition of the visual acuity that a person must have in order to be registered in either category. Form BD8 (or form BP1 in Scotland), which the ophthalmologist must complete in order to register a person, offers guidelines which are detailed in the Table 1.

TABLE 1. *Guidelines provided to ophthalmologists on visual acuity (VA) and fields likely to warrant registration as blind or partially sighted:*

Category	*Guidelines**
blind	corrected VA 3/60 or less, or, corrected VA 3/60 but less then 6/60 with a contracted field of vision, or, corrected VA 6/60 but visual field markedly restricted
partially sighted	corrected VA of 3/60 to 6/60 with a full visual field, or, corrected VA of 6/24 with moderate constriction of the field, or, corrected VA of 6/18 or better with a gross visual field defect

* all refer to acuity in the better eye

The ophthalmologist is also advised that they should take into account that a person who has lost their vision recently might find it harder to adapt than a person who lost their sight some time ago and that an older person may not adapt as readily as a younger person. The registration form also states that, because not all cases will fall precisely within the guidelines, the ophthalmologist may use their own judgement with regard to registration.

The register is kept by the Social Services Department of the local county council, with whom the responsibility lies for providing services. Central government is responsible for deciding the financial benefits of registration. At present, people registered as blind are entitled to extra income tax relief, some

financial advantages if they are entitled to other forms of financial support, a small reduction in the cost of a television licence, some car parking concessions and some postal concessions.

People registered as partially sighted are not entitled to any financial benefits but they are entitled to the same help from social services as people on the blind register. The basis for these services lies in the National Assistance Act (1948) which has been reinforced by a series of Acts of Parliament, including the Chronically Sick and Disabled Persons' Act (1970), the Disabled Person's Act (1986) and the National Health Service (NHS) and Community Care Act (1990). In essence, these include provision for daily living skills, communication, mobility training and recreational and social activities.

All local authorities are constrained by limited resources, meaning that there is a shortage of specialist workers and, for operational reasons, there is often an uneven spread of existing staff around the country. In some cases, people may wait many months between the original date of certification and the first visit by a social worker. Bruce et al (13) conducted a survey of around 900 visually impaired people on behalf of the Royal National Institute for the Blind (RNIB) in 1991. They found that 45% of newly registered people claimed not to have been visited by someone from the local Department of Social Services. They conclude that, although some of these people were probably visited, it made such an insignificant impact that they could not remember it.

1.3 Prevalence of Blindness and Partial Sight

Statistical projections suggest that the number of visually impaired people is on the increase (Lowman and Kirchner, 1979) (14). The incidence of visual impairment increases with age and people over the age of sixty-five will soon

represent a much larger proportion of the population. In the UK, the number of people over sixty-five has risen by 9% since 1979 (White, 1994) (15). People aged sixty or more make up 90% of all visually impaired people (Bruce et al, 1991) (13).

One way of measuring prevalence rates of partial sight and blindness is to examine registration figures. There has been a steady increase in the number of people registered as blind and partially sighted over the last few decades and this is caused almost entirely by an increasing number of people aged seventy-five or more on the register (Cullinan, 1987) (16). Of those people who are registered as blind or partially sighted, 69% are aged seventy five or more and 88% are aged sixty or more (Bruce et al, 1991)(13). This is partly because more older people are seeking registration and partly because of the increasing longevity of those already registered.

The total numbers of people registered as blind or partially sighted in the UK (i.e. regardless of age), represents 0.47% of the population although the RNIB suggests that the true proportion of the UK population which is visually impaired is 1.8% (Bruce 1991)(13). Registration figures probably underestimate true prevalence rates partly because not all blind and partially sighted people will choose, or have the opportunity, to register (Cullinan, 1986) (17), partly because many people may be disabled by their vision, but do not meet the criteria for registration (Farrall, 1991) (18) and partly because of the wide differences among ophthalmologists' in the way they interpret the guidelines for registration. Cullinan (1986) (17) also argues that the criteria for blind registration serves older people badly, because it concerns work only and because it omits any idea of near vision.

Gibson et al (1986) (19) surveyed a sample of 529 members of the general population recruited at a local general practice. They found that the blind register was relatively good at reflecting true prevalence rates, but the partially sighted register underestimated the prevalence of actual partial sight present in the

population. In all, those not registered represented 21% of the registrable visually impaired population.

1.4 Principal Diseases Causing Blindness and Partial Sight Amongst Older People

There is a difference between more and less economically well-off countries in relation to the causes of visual loss. In developing countries diseases affecting vision are related to malnutrition and infection. Fortunately, both are preventable and treatable. Visual impairment in technically developed countries is mostly related to age and can be caused by systemic disease or acute or chronic diseases of the eye. Less often, a birth defect is responsible for the impaired eyesight.

The Office of Population Censuses and Surveys (OPCS) provides the following statistics for the principal disorders causing registration for blindness and partial sight amongst older adults in England and Wales (Evans, 1995) (20)(Table 2).

TABLE 2. *Statistics for the principal diseases causing blindness and partial sight amongst older adults in England and Wales (Evans, 1995)*(20).

Disorder	*Partially sighted*	*Blind*
Age related macular degeneration	53%	55%
Glaucoma	11%	13%
Cataract	8%	4%
Diabetic retinopathy	2%	2%
Other	26%	27%
Total	100%	100%

Chapter 2

GLAUCOMA

2.1 Introduction

Quigley has observed that glaucoma is the second leading cause of vision loss in the world and the estimated number of people suffering from this eye disease world-wide in the year 2000 will be 66.8 million (1). The commonest form of this disease in older age is chronic simple glaucoma with a prevalence of 10% at age 80. It is the cause of one in eight registrations for blindness (21).

Loss of sight in glaucoma is the result of progressive damage to the optic nerve, particularly in its upper and lower parts, with a resulting characteristic pattern of visual field loss, superiorly, inferiorly and nasally, with eventual tunnel vision.

Chronic glaucoma is often asymptomatic. Central vision of a patient is usually not affected for many years and very few patients experience pain or notice any specific problems with their vision if the defect is not extensive. In a large proportion of cases the condition is discovered by an optician during a regular eye examination.

2.2 Definition of Glaucoma

Glaucoma is a progressive form of optic neuropathy which is characterised by the following features (22):

- cupping of the optic nerve head
- visual field loss
- the intraocular pressure may be elevated or normal

2.3 Pathogenesis of Glaucoma

There are two possible reasons for developing glaucomatous field loss (22):

- Direct mechanical damage of the optic nerve due to increased intraocular pressure (IOP), which is a result of increased resistance to the outflow of aqueous humour through the trabecular meshwork. Studies of axoplasmic flow show vulnerability of the nerve axon bundles to elevated IOP as they pass through the lamina cibrosa in the optic nerve head (22).

- Damage due to changes in the vascular system when optic nerve fibre bundles are indirectly affected as a result of compromised optic nerve blood circulation. In as many as one in six subjects, IOP is never raised above normal (22).

It seems likely that both mechanisms may play a part in most cases. The damage of the nerve bundles results in a characteristic pattern of visual field loss. Visual loss

is irreversible but early detection is essential as treatment may stop or slow down the rate of further damage.

2.4 Optic Nerve Head

Approximately 1.2 million nerve fibres (axons) distributed across the retina pass through the optic nerve head (optic disc) as they follow to enter the brain. As mentioned earlier, these nerve axon bundles are vulnerable to damage due to elevated intraocular pressure or vascular compromise. The damage can be detected by visualisation of the changes in the shape, appearance and colour of the optic disc and the surrounding blood vessels. The glaucomatous changes and enlargement of the optic cup are referred to as *cupping of the optic disc head* (Figure 1) (22). In eyes with early glaucoma subtle signs of retinal nerve fibre damage can be detected prior to the development of either pathological cupping or clinically detectable visual field defects.

FIGURE 1. *Glaucomatous optic disc.*

2.5 Visual Field Loss

Dropout of the nerve fibres results in a visual field defect. Fortunately in chronic glaucoma the damage often progresses slowly and patients may not experience any problems with their vision for years as good central vision is usually retained until the later stages of the disease. Over the years, patients also may have subconsciously developed techniques to counteract their visual impairment. Clinically the field loss is almost exclusively detected using perimetry (22).

Visual field loss and visual function in glaucoma is of primary importance to this study and will be discussed in later chapters in greater detail.

2.6 Intraocular Pressure (IOP)

The normal IOP varies between 10 mm Hg and 21 mm Hg (mean 16 +- 2.5 mm Hg). Although there is no absolute cut-off point, 21 mm Hg is considered as the upper limit of normal and levels above this are viewed with suspicion (22). However, in some patients glaucomatous damage occurs with IOPs less than 21 mm Hg whilst others remain unscathed, at least in the short term , with IOPs up to 30 mm Hg. Although the actual level of IOP is important in the development of glaucomatous damage, other factors also play a part (see Pathogenesis of glaucoma) (22). The level of IOP is inherited so that first-degree relatives of patients with primary open-angle glaucoma have higher pressures (22).

2.7 Classification of the Glaucomas

The many types of glaucoma are classified as being of the *open-angle* or *angle-closure* type, according to the manner by which aqueous outflow is impaired. Further classification describes the disorder as *primary* or *secondary* depending on the presence or absence of associated factors contributing to the rise in IOP. In some cases the age of the patient at the onset of glaucoma is also taken into consideration and the condition is then described as *congenital, infantile, juvenile* or *adult* onset accordingly (22).

2.8 Medical Treatment

In spite of controversy on the subject of treatment, there is evidence that the lowering of ocular pressure slows down the progression of field loss. Reduction in IOP can be achieved medically or surgically (22). Most patients are started on medical therapy, using a β-adrenergic blocker, which reduces aqueous inflow. Progressive optic nerve damage may result from poor compliance, spikes of raised IOP from intermittent dosing, or failure to reduce IOP far enough. There are side effects resulting from systemic absorption - visual disturbance, increased airways obstruction in asthmatic patients; decreased exercise tolerance; postural hypotension and falls; and occasional psychiatric disturbances, such as confusion, insomnia and depression (23-26).

Surgical therapy by laser trabeculoplasty produces only a 25% fall in IOP; and its effects are of limited duration. Another option is surgical trabeculectomy, often a very successful procedure, although this too has its problems (21).

2.9 Visual Disturbance Due to Treatment

Pilocarpine and Dipivefrin were the most widely used alternatives to beta adrenoceptor blockade therapy in the medical management of open-angle glaucoma. In comparison to the majority of other antiglaucoma medication, these types of drugs have a specific influence on visual performance.

It is generally agreed that the miosis produced by pilocarpine adversely affects the visual field as evaluated by both kinetic (27, 28) and automatic static perimetry (29, 30). This can have important implications where serial fields are used to monitor the effect of therapy in glaucoma. Transitory reductions in visual acuity caused by ciliary spasm following the instillation of pilocarpine have been well documented (23, 24), and may prevent the use of the drug in younger patients.

Dipivefrin, a prodrug of epinephrine, has been reported to cause mydriasis (pupil enlargement) in several long-term clinical trials involving patients with glaucoma and/or ocular hypertension (31, 32), and may affect visual performance.

2.10 Probability of Blindness from Glaucoma when Treated

Preliminary results from retrospective studies indicate the cumulative probability of blindness in at least one eye from open-angle glaucoma is 27% and for both eyes is 8% at 20 year follow up (33).

Chapter 3

VISUAL FUNCTION IN GLAUCOMA

3.1 Measures of Visual Performance in Glaucoma

Psychophysical tests of visual function have been used to detect glaucoma for many years. Conventional perimetry using a white stimulus on a white background has become the essential test in the diagnosis and management of glaucoma, but whether or not it can give a good prediction of functional problems encountered by glaucoma patients is not known.

In recent years a new generation of psychophysical tests has emerged which aims to detect glaucoma at an earlier stage. The development of these tests has been stimulated by evidence that glaucomatous damage in the form of ganglion cell loss could be quite advanced before a defect could be detected by conventional perimetry (34, 35). It is also claimed that it is the large ganglion cells which project predominantly to the magnocellular layers of the lateral geniculate nucleus which are selectively damaged in early glaucoma (M-cells) (36). Motion detection, which is considered a predominantly magnocellular (M-cell) function has been described as abnormal in patients with early glaucoma by Fitzke et al (37), Bullimore et al (38), Trick et al (39) and others. Many studies have also described abnormalities in both spatial contrast sensitivity and temporal flicker contrast sensitivity in glaucoma (40-45). A number of research investigations

indicated that glaucoma patients develop blue/yellow colour defects at an early stage (46-48). This is believed to be because, at the photoreceptor level, the short wavelength sensitive cones (S cones) were damaged earlier than the medium (M) and long (L) wavelength cones. High-pass resolution perimetry has been advocated by other authors as an alternative form of perimetric testing for screening and for follow up of glaucomatous visual field loss (49-52). The findings of Fellman et al suggest that glaucomatous optic nerve damage affects rod thresholds more than cone thresholds (53, 54). Studies by Drum, Quigley, Congdon and others on dark adaptation in glaucoma have also shown that scotopic sensitivity may be impaired (55-57). Dengler-Harnes et al showed that forward light scatter exaggerates existing visual field loss in glaucoma patients and increases glare disability (58). Hoshino and Mizokami found a significant correlation between glare sensitivity measured with the Millar-Nadler glare tester and central visual field damage in patients with early to middle stage glaucoma (59). Research on stereoacuity in glaucoma indicates a profound disruption of stereoacuity which appears to result from disorder in the spatial sampling array at the ganglion-cell level (60, 61). Essock et al found that the mean stereoacuity of glaucoma patients and suspects was significantly worse than the level of stereoacuity expected for normals with the same Snellen acuity level (62).

Although many authors have repeatedly investigated differences between glaucoma patients or patients with ocular hypertension and normal controls and showed decreased function, it is not known whether these deficits in visual function have any effect on the day to day function of patients. Since Ross, Bron and Clarke (41) published their study on visual disability in glaucoma no other study (to our knowledge) has addressed the subject in the same comprehensive manner.

In this study, visual function of glaucoma patients and normal controls was assessed using a number of psychophysical visual function tests including

standard clinical measurements (Snellen visual acuity and white-on-white perimetry) and a battery of research tests of special aspects of visual function that have been shown to be affected in glaucoma. These include contrast sensitivity (CS), critical flicker frequency (CFF), dark adaptation (DA), glare disability (GD), colour vision and stereoacuity.

3.2 Distance Visual Acuity

The measure of distance visual acuity is one of the most universally accepted elements of an eye examination. It is quick and, when conducted under identical conditions, reliable. In glaucoma, it is used traditionally with other clinical indicators such as intraocular pressure levels, perimetric findings and side effects of treatment to monitor and evaluate different treatment methods. Out of these clinical outcome measures, visual acuity testing may be the most important indicator of day-to-day functioning. However, in glaucoma, distance vision usually remains unaffected until the late stages of the disease and many patients may not notice any difference in their central vision for years. With the exception of cases with severe glaucoma any change in visual acuity is usually a result of other age-related conditions such as cataract or macular degeneration. Snellen visual acuity is a measure of patient's visual performance in high contrast conditions on a white background and does not deal with medium to low contrast levels. In patients with glaucoma it also does not inform about what patients can achieve with their residual vision and therefore several authors have pointed out that it is not suitable as the single measure of visual performance in daily life situations (63).

There are several different ways of assessing distance vision. In the UK, it is generally the *Snellen chart* that is used. The mathematical basis for these

charts is that each letter subtends a five minute of arc visual angle when viewed from six metres. Normal vision is defined by the figure 6/6, while the figure 6/18, for example, shows that the person must be at six metres in order to see what a 'normally' sighted person could see from a distance of eighteen metres. If a person is unable to read any of the chart, even at a distance of one metre, there are four further categories to which their visual acuity may be assigned. These categories are known as 'count fingers' (if the person can only see how many fingers the tester holds up at a distance of approximately one metre in front of their eyes), 'hand movements', 'perception of light' and finally 'no perception of light'.

The main disadvantage, or shortcoming with the Snellen chart is that there is insufficient detail in the range of letter sizes (i.e. steps between the lines on the chart) commonly needed with visually impaired people and it has been argued that this can be particularly discouraging to people with low vision (64). Another point being criticised is the different number of letters in each line and the ability to learn the order of the letters by memory too quickly.

Distance acuity is also sometimes measured by means of a Bailey-Lovie chart (65). This consists of fourteen rows of letters ranging in size from 6/60 t0 6/3 equivalent. It is designed to be viewed at six metres, but can be converted to shorter viewing distances. Adjacent lines differ in size by a factor of 0.1 log unit. The spaces between lines and letters also follow the same logarithmic basis such that spaces between letters are equal to the width of the letters on that line and the spaces between the lines equal the height of the row of letters beneath that space.

3.3 Visual Field Examination

In the last two decades a large body of evidence has been published on the subject of extensive nerve fibre damage that can exist before defects in the visual field are discovered by conventional perimetry (34). In addition, it was found that pathologic changes in the optic disc and retinal nerve fibre layer can predate field loss (34, 35). Attempts have been made to develop an accurate, rapid test to diagnose glaucoma at the earliest possible stage but none of this research work diminishes the clinical importance of visual field examination using traditional techniques. Perimetric examination remains one of the most important investigations in the clinical management of glaucoma (66).

3.3.1 Perimetry

The visual field is frequently described as being an island of vision surrounded by a sea of darkness. It is not a flat plane but a three-dimensional structure (66).

The outer aspect of the visual field extends approximately 60 degrees nasally, 90 degrees temporally, 50 degrees superiorly and 70 degrees inferiorly. The visual acuity is sharpest at the very top of the island (fovea) and it declines progressively towards the periphery, the nasal slope being steeper than the temporal. The blind spot is located temporally between 10 and 20 degrees (66).

Perimetry is a method of evaluating the visual field. Various methods of attempting this psychophysical function have been developed from simple confrontation testing with hands or targets of various sizes and colours to the sophisticated but still subjective science of automated and computer assisted perimetry. Because of the subjective nature of the patient's responses, efforts have been made to standardise the many aspects of testing in an endeavour to

eliminate as many variables as possible. Despite this, when interpreting a visual field defect, it is still very important to take into account the patient's reliability (66).

Qualitative perimetry. This is a method of detecting a visual field defect and is the first screening phase of glaucoma suspects (22, 66).

Quantitative perimetry (22, 66). After a visual field defect has been detected the next phase is quantitative perimetry by which its severity in terms of size, shape and depth is determined. Subsequent analysis of the visual field defects is used to determine either their stability or progression.

Kinetic perimetry (22, 66). This involves the presentation of a moving stimulus of known luminance or intensity from a non-seeing area to a seeing area until the patient reports that the stimulus has been perceived. The stimulus is moved at a steady speed along a series of meridians and the point of perception is recorded on a chart. By joining these points along different meridians an isopter is plotted for that stimulus size and intensity. Using different stimulus intensities a contour map of the visual field with several different isopters can be plotted. Kinetic perimetry can be performed by simple confrontation, as well as using perimeters such as the tangent screen, Lister perimeter and the Goldmann perimeter.

Static perimetry (22, 66). This is a more difficult concept to perceive but once grasped forms the basis of modern visual field assessment. Static perimetry involves the presentation of stimuli of varying luminance in the same position to obtain a vertical boundary of the visual field. Although it is slower than kinetic perimetry it is much better suited for quantitative testing. Static perimetry can be performed manually with the Goldmann perimeter or with various automated instruments such as Humphrey Visual Field Analyzer (Humphrey Instruments, Inc.; Allergan Humphrey, San Leandro, Ca, USA), Medmont (Medmont Pty. Ltd. Melbourne, Australia) or Octopus perimeters (Interzeng, Bern, Switzerland).

3.4 Contrast Sensitivity

The clinical relevance of visual sensitivity to contrast was first appreciated in the last century (67). Though its use did not become widespread, a practical test of contrast sensitivity was first described in the second volume of the British Journal of Ophthalmology in 1918 (68). A true understanding of the role that contrast plays in the visual discrimination was not achieved until the pioneering studies of Campbell and his colleagues at Cambridge in the mid 1960s (69, 70). They found that we are able to see, at least at contrast threshold and for simple sinusoidal gratings, targets of 'medium' resolution better than those of either low or high resolution – the contrast sensitivity function. This led to the notion that testing contrast sensitivity over a range of target resolutions (spatial frequencies) provides a more comprehensive evaluation of spatial function than does visual acuity.

In glaucoma, instances of disruption in contrast sensitivity function have been demonstrated in patients or glaucoma suspects for static or temporally modulated stimuli in a number of studies (41-45). Essock et al found that both binocular and monocular testing distinguished glaucoma from normals (62). Binocular testing better separated the groups and this test had the highest combined sensitivity and specificity (0.89 and 0.67, respectively) of the battery of psychophysical tests including flicker sensitivity, critical flicker frequency (CFF), contrast sensitivity as measured by Pelli-Robson chart (71), and stereoacuity. Thus, Essock et all concluded that binocular testing of contrast sensitivity appears more effective than monocular testing at detecting functional visual loss in glaucoma patients (62). Ross et al found that contrast sensitivity correlates well with subjective visual disability (41).

Contrast sensitivity has been very successfully measured by the simple to use Pelli-Robson chart (Clement Clarke, Columbus, OH, USA) (9, 72-74). Some studies have shown that the Pelli-Robson chart is more reliable than sinewave grating charts (75). Although the test is limited to providing information only about low to medium spatial frequencies, this is the range that is most closely associated with visual performance in tasks like reading (76), face recognition (77) and mobility (78). In addition, work by Elliot done in 1989-90 has demonstrated that contrast sensitivity at higher spatial frequencies is more highly correlated with visual acuity and thus would be less likely to provide new information (79).

3.5 Flicker Sensitivity. Critical Flicker Frequency

Quigley et al suggested that the retinal ganglion cells whose axons project to the magnocellular layers of the visual pathways suffer preferential loss in early glaucoma (36). These nerve fibres are concerned with the processing of information from stimuli of high temporal contrast , e.g. flicker and movement (80). Flicker perimetry has been shown to detect defects in the visual field of glaucoma sufferers earlier than traditional luminance based systems (81). Kosmin et al suggested that flicker perimetry using critical flicker frequency (CFF) threshold has promise for earlier detection of glaucoma in the middle aged, particularly where there is associated ocular hypertension (82). The use of this technique for both diagnosis and monitoring in older age groups seems to be limited due to a decline in flicker sensitivity with age.

Essock et al (62) found that binocular testing of flicker sensitivity at temporal rates 5 Hz and 34 Hz was more effective at separating glaucoma patients from normal controls than was monocular testing, while the critical flicker frequency (CFF), in contrast to the report by Kosmin et al (82), did not differ

between groups of early glaucoma and normals for either monocular or binocular testing.

Kosmin et al (82) used a prototype flicker perimeter for their study while Essock et al (62) used an instrument developed by Tyler (40). A new research instrument, the Visual Stimulus Generator is available from Cambridge Research Systems Ltd. (Rochester, Kent, England, U.K.) and can be used to generate stimuli to assess various aspects of psychophysical visual function.

3.6 Dark Adaptation

The finding by Quigley and co-workers (34, 35) which showed that the conventionally measured visual field may appear normal in the presence of substantial histologically measured nerve fibre loss, has lead to studies of the effect of adapting field luminance on the earlier detection of glaucomatous field loss. The findings of Fellman et al suggest that glaucomatous optic nerve damage affects rod thresholds more than cone thresholds (53, 54). Studies by Drum, Glovinsky, Quigley, Congdon and others on dark adaptation in glaucoma also have shown that scotopic sensitivity may be impaired (55-57, 83). Stirling and co-workers found abnormal scotopic thresholds in patients with ocular hypertension who represent a glaucoma high risk group (84). Glovinsky et al found abnormal scotopic sensitivity in glaucoma using a newly designed whole-field scotopic retinal sensitivity test with a diagnostic power 0.91 and specificity and sensitivity 91% and 86%, respectively when discriminating glaucomatous from normal eyes (56). Clear evidence that rod thresholds were extensively affected in glaucoma would not only provide a basis for early detection of optic nerve damage but would also explain the presence of disproportional visual disability in low luminance conditions as indicated from the study by Ross et al where the vision

at night appeared to be a separate issue of concern among patients with glaucoma (41).

There are few instruments available which can be used to measure scotopic sensitivity. Glovinsky developed an instrument that was successfully used to study glaucoma patients (56), Stirling et al used a modified Friedman Mark 1 campimeter with test stimuli generated by light-emitting diodes (84), while Congdon used a modified Humphrey perimeter, and the Goldman-Weekers Dark Adaptometer was used in studies on diabetic retinopathy (85, 86).

3.7 Glare Disability

Glare disability has traditionally been an issue in cataract patients and often a crucial parameter to rely on in making the decision about surgery. Bailey highlighted importance of this phenomenon in detecting early vision loss in the elderly (87). Recently a number of studies have shown the presence of this symptom in glaucoma patients.

In 1989 Dengler-Harles et al showed that forward light scatter exaggerates existing visual field loss in glaucoma patients (58). In 1992 Ochsner and Zrenner included some glaucoma patients in their glare sensitivity study, and suggested that changes in the visual acuity - luminance function accompanied with high glare sensitivity are most often due to pathological changes in neuronal circuity of the retina (88). They remark that sensitivity to glare is an unspecific ophthalmologic symptom which can be caused by different anatomical structures, and although it can be related to optical and to cortical structures, it can also be due to defects in the neuronal mechanisms of the retina that control adaptation processes. Van den Berg found that visual acuity correlates rather weakly with the amount of scatter (89). Since the amount of scatter causes a

considerable loss of visual function, the results of his study showed that for glare sensitive patients the standard Snellen visual acuity test gives a rather limited impression of visual handicap. Hoshino and Mizokami found a significant correlation between glare sensitivity measured with the Millar-Nadler glare tester and central visual field damage in patients with early to middle stage glaucoma (59). Others studies have shown that objectively measured glare disability when taken together with other tests (especially contrast sensitivity and visual acuity) made a distinct contribution to the overall characterisation of visual function (9, 73). More research into the problems associated with intraocular light scatter and brightness acuity and sensitivity in glaucoma is needed.

From the small range of instruments that are available to measure glare disability the Brightness Acuity Tester (BAT) by Mentor O & O (Norwell, MA, USA) has several advantages. It is easy to use and reliable and although it has been around for years it is still claimed to be one of the best or the best tool available for glare disability measurements. In a study by Neumann et al of the different instruments including the Miller-Nadler glare tester, the InnoMed true vision analyzer, the VisTech VCT 8000 and the Eye-Con 5, the BAT showed the best performance characteristics (90). The BAT was successfully used in a number of studies by Harper and Halliday (91), Bailey (87), Steen et al (92), and Rubin et al (74).

3.8 Colour Vision

It is widely accepted that colour vision is diminished in glaucoma. A number of research studies have suggested a correlation between colour vision deficits (dyschromatopsia) and increased intraocular pressure in both glaucoma and ocular hypertension (93). Investigations by Pokorny, 1979 (46), Adams, 1982 (47),

Drance 1981 (48), Sample 1993 (94), Graham and Drance 1996 (52) and others show that a blue-yellow deficit is the most common form of colour vision deficits found in patients with glaucoma. This suggests that, at the photoreceptor level, the short wavelength sensitive blue cones (S cones) or their neural connections are in some way more susceptible to damage from increased intraocular pressure than are the red and green cone systems (the medium, M; and long, L wavelength cones).

These colour vision deficits can be found on central colour vision tests, such as the Farnsworth-Munsell 100 hue tests (48, 95, 96) or the Farnsworth D-15 (47) and are often present before peripheral visual field loss is found by standard perimetry.

Short-wavelength automated perimetry (SWAP) uses a blue stimulus on a bright yellow background and in recent years it has been reported by a number of authors as a superior technique for detecting early glaucomatous loss. Scotomas were deeper and larger than they were on conventional perimetry (97-99).

A number of instruments are available to measure colour vision defects in glaucoma. When examining central vision, the Farnsworth-Munsell 100-Hue test and the Farnsworth D-15 (saturated and desaturated) and the L'Anthony D-15 (saturated and desaturated) were found to be useful in glaucoma. Bassi et al found that the desaturated version of the two shorter tests had a better correlation with ' the gold standard' 100-Hue test and advocated its use for assessing the severity of colour vision loss in glaucoma at a fraction of the time it takes to perform the 100-Hue test (100).

Short-wavelength automated perimeters are sophisticated tools mainly used in research studies for peripheral evaluation of colour perception function. Although it's possible future use as a definitive tool for the diagnosis and management of glaucoma has been recently advocated by many authors, it's clinical usefulness is currently limited. Wild et al. found that the increased

interindividual normal variability, exacerbated by the lack of correction for ocular media absorption results in the reduction in sensitivity required to indicate abnormality and this problem is proportionately greater than it is for white-on-white perimetry (101).

3.9 Stereoacuity

Stereopsis is defined as a relative ordering of visual objects in depth, that is, in the third dimension. Relative localisation in the third dimension in depth parallels that of visual objects in the horizontal and vertical dimensions. The ability to perceive relative depth allows one to localise the peripherally seen wires just alluded to in front of or in back of the fixation wire, and it is this ability that permits one to perceive a cube as a solid.

Wheatstone, by his invention of the stereoscope in 1838, was the first to recognise that stereopsis occurs when horizontally disparate retinal elements are simulated simultaneously (102).

A solid object placed in the median plane of the head produces unequal images in the two eyes. Owing to the horizontal separation of the two eyes (the interpupillary distance), for geometric reasons each eye receives a slightly different image. The sensory fusion of the two unequal retinal images results in a three-dimensional percept. Stereopsis is a response to disparate stimulation of the retinal elements. It is the highest form of binocular cooperation that adds a new quality to vision.

The responsiveness to disparate stimulations has its limits. There is a minimal disparity beyond which no stereoscopic effect is produced. This limiting disparity characterises a person's stereoscopic acuity.

Stereoscopic acuity depends on many factors and is influenced greatly by the method used in determining it. There are no standardised clinical stereoscopic acuity tests, and no results of mass examinations. Generally speaking, a threshold of 15 to 30 sec of arc obtained in clinical tests may be regarded as excellent (102).

A relationship exists between visual acuity and stereoscopic acuity. Stereoacuity cannot be greater than the vernier acuity of the stimulated retinal area. Stereoacuity decreases from the centre to the periphery of the retina. Matsubayashi demonstrated that reduction of visual acuity with neutral filters over one eye did not raise the threshold if the acuity was lowered to as low as 0.3. A further decrease in vision to 0.2 greatly increased the threshold. With a decrease in acuity of the covered eye to 0.1, stereopsis was impossible.

If poor stereoacuity is associated with poor Snellen acuity (103), this should influence the patient selection criteria when investigating stereoacuity.

Research on stereoacuity in glaucoma indicates profound disruption of stereoacuity which appears to result from a disorder in the spatial sampling array at the ganglion-cell level, which was reported by Bassi and Galanis (60) and Liebergall et al (61). Essock et al found that the mean stereoacuity of glaucoma patients and suspects was significantly worse than the level of stereoacuity expected for normals with the same Snellen acuity level (62).

In clinical practice, stereoacuity can be measured using simple stereoplates such as the Frisby stereotest by Clement Clarke International, Ltd, or instruments such as Keystone Orthoscope (Keystone view, Meadville, PA, USA).

Chapter 4

VISUAL IMPAIRMENT AND DISABILITY IN GLAUCOMA

4.1 Visual Impairment and Disability in Older Adults

4.1.1 Disability in the Elderly

Men and women aged 65 years and older are a rapidly growing segment of the population. In 1994 this age group represented 16% of the UK population and although this proportion is not expected to increase substantially by the year 2009, as the total population is also increasing, the number of those aged 75-84 years is expected to rise by 7.2% and of those aged 85 and over by 32% (104). In the USA the proportion of the elderly in the population seems to be even higher, it is estimated that over 20% of the USA population will be 65 or over by the year 2000 (9). This demographic shift has important implications for the provision of services as older people receive a higher proportion of health and social care than younger groups. In 1992 those aged 75 and over, comprising 6.8% of the UK population were responsible for 15.6% of hospital stays, as measured by finished consultant episodes (104). Although most elderly people continue to live independently, and many do so alone, one study found that over 40% of people over 65 years of age report difficulty in performing their usual activities (105). A

community-based study in Ohio showed that 20% of people 65 to 75 are functionally dependent (106). Measures of health status and disability in elderly people are required for planning services, monitoring progress, making comparisons with other areas etc. Previously, the emphasis has been on objective measures of disability and ill health. In recent years, there has been growing interest in patients' perception of their own health. The traditional measures of mortality and morbidity, although useful, have limitations: showing changes in mortality requires prolonged periods of observation or large number of events, or both, and changes in morbidity are more expensive to measure and do not take account of the functional impact on a patient's life. Since levels of functioning are important in predicting demand for services, changes in such health related quality of life outcomes might complement mortality and morbidity measures.

A number of studies in various conditions was carried out to determine the level of disability in chronic diseases such as arthritis (107) (108), asthma (109), multiple sclerosis and Parkinson's disease (110) or acute conditions such as stroke (111).

4.1.2 Visual Impairment and Visual Disability in the Elderly

Along with many types of chronic disorders, vision impairment dramatically increases with advancing age. For example, The Baltimore Eye Survey reported unadjusted prevalence of visual impairment (acuity worse than 6/18 in better eye) of 0.6% for whites and 1% for blacks aged 40 to 49 years and 2.1% for whites and 6% for blacks aged 70 to 79 years (112). In the Salisbury Eye Evaluation Project the population of Americans aged between 65 and 84 years was examined. The overall prevalence of visual acuity impairment in blacks was found to be 5.6% versus 3.0% for whites, using the traditional United States definition

(worse than 20/40 to better than 20/200) and 3.3% for blacks versus 1.6% for whites, using the World Health Organisation definition (worse than 20/60 to 20/400) (74).

In addition to the known figures on visual impairment in the population based studies, Wormald et al suggest that there is a considerable amount of undetected ocular disease in the elderly community (113) and a little is known about vision-related quality of life in such groups.

Several population and community based studies have found that deterioration of vision with advancing age interferes with the older adults' ability to carry out activities essential for personal independence. The Massachusetts Health Care Panel Study (5) showed that persons 65 years old with visual impairment by self-report were more likely to have difficulty with daily activities. In the Salisbury Eye Evaluation project a strong correlation was found between visual impairment and any of the Activities of Daily Living or The Instrumental Activities of Daily Living (114). Other studies in Britain (6), USA (9,115,116), Sweden (7), Finland (4) and Italy (117) concluded that visual impairment measured by objective means was associated with a lack of self-sufficiency in the home and difficulty in daily tasks.

4.2 Age-Related Decline in Visual Acuity and Other Visual Functions. Implications for Visual Disability

Because visual acuity is the most commonly used single measure of visual function, many population based studies evaluated only age-related visual acuity loss, for example The Framigham Eye Study (118), The Baltimore Eye Survey (112), or The Beaver Dam Eye Study (119). It has been well documented that other aspects of visual function, including contrast sensitivity, glare sensitivity,

stereopsis, visual search, visual processing speed and visual field may be compromised despite near-normal visual acuity (9, 74, 115, 120, 121). Acuity tests describe the eye's ability to resolve fine detail in high contrast. They are not adequate enough to predict one's ability to see large or small, low contrast patterns like faces or nearby objects and therefore do not correlate with some types of functional disability.

Other visual tests, such as contrast sensitivity tests, provide important additional information about visual function that may decline with pathological changes before decline in visual acuity. Rubin and colleagues reported contrast sensitivity as one of the most important factors for predicting reading difficulties, face recognition, mobility and independent navigation (9, 76). Leat and Woodhouse also showed that contrast sensitivity is important for predicting reading speed (122). Owsley et al found that older observers require higher contrast to recognise "real world" targets such as traffic signs or faces presumably because of their reduced contrast sensitivity at middle to high spatial frequencies (77, 123). Marron and Bailey also indicated relationship between decreased contrast sensitivity and mobility (78). Wood and Troutbeck found significant correlations in relation to contrast sensitivity and driving performance (124).

Similarly, some subjects with excellent visual acuity report functional disability resulting from disability glare. Disability glare refers to the reduced visibility of a target caused by a light source elsewhere in the visual field. Any disorder that increases intraocular light scatter or exaggerates its effect, such as lens opacity or visual field loss, may cause problems produced by disability glare (59, 125). The use of glare tests has received increasing attention because they have been shown to be more sensitive to anterior segment disorders than ordinary acuity tests. Holladay et al found that glare testing of cataract patients can predict the reduction in visual acuity out of doors when facing the sun or in

indirect overhead sunlight (126). For normal elderly observers, glare sensitivity as reported by Pulling et al, is correlated with simulated night-time driving performance (127). Wolbarsht suggest that disability glare may be associated with accident frequency or limitations in night-time driving (128). Steen and colleagues also suggest that glare can in older patients dramatically reduce chromatic discrimination ability by desaturating the component colours (92).

Newitt and co-workers found that stereoacuity is significant risk factor for recurrent falls in the elderly (129). Owsley, Wood and Troutbeck separately showed that the size of the useful field of view is significant in predicting car-crash risk factors in older drivers (124, 130).

4.3 Measures of Visual Impairment and Disability

To help clarify the relation between visual impairment and disability most authors undertake studies with the following objectives:

- to determine whether self-reported disability is associated with visual impairment assessed by objective methods
- to determine whether various components of vision impairment besides reduced acuity contribute to the reduction in functional independence

4.4 Visual Disability Studies in Ophthalmic Patients

The presence of different ophthalmic conditions significantly increases with older age and causes further deterioration of vision that multiplies the effect of decline due to normal ageing process.

Ocular diseases can have a major impact on quality of life because visual impairment potentially affects so many different aspects of function. Therefore, it is critical to compare alternative approaches to managing ocular disease on the basis of their effects on visual disability and quality of life (63, 131-140).

A number of successful studies were carried out among patients with cataract as their visual disability is very difficult to assess on the sole basis of visual acuity (132, 141-143). In addition, the amount of disability related to certain decrease in visual acuity may vary between patients in relation to their occupation and interests.

Retinitis pigmentosa, diabetic retinopathy, age-related macular degeneration and corneal transplantation are other conditions where visual disability was examined using self-reports and was found to be a useful addition to clinical examination (137-139).

4.5 Visual Disability in Glaucoma

Although preventing visual disability that decreases the quality of life should be the determining factor in the treatment of glaucoma (2), little is known about visual disability in people with visual field loss. Zimmerman and colleagues have recently published an editorial paper (2) stressing the need to perform studies on this subject as a recent review of 102 randomised clinical trials published between 1975 and 1991 showed that only three of the studies gave evidence on long term visual field changes and none addressed the question of visual disability (144). There is a need to determine what constitutes visual disability from glaucoma, what it is and how to measure it (2). While glaucoma has been shown to play a relatively small role in causing legal blindness (in U.K.: approx. 13% (20); in USA: monocular blindness 0.8%, legal blindness 0%, in Beaver Dam Eye Study (142)),

Johnson and Keltner, through their study with the California motor vehicle department, showed more traffic violations and accidents in people with visual field defects (120). It would be beneficial if this could be further investigated with particular attention to glaucomatous visual field defects. No studies were published to explain the relationship between clinically present visual field loss and performance in certain tasks. Zimmerman and colleagues writes: "Is a nasal step in one eye visual disability? Bjerrums in both eyes? Field defect within 10 degrees of fixation? Some guidelines speak to this, but these need to be refined specifically for glaucoma. This may not be simply a matter of defining a degree of visual field loss, as there are variations in an individuals ability to 'compensate' for visual field loss. Visual disability is correlated with visual field loss and visual acuity but is not entirely explained or measurable using these parameters. Means must be developed to quantify visual disability from glaucoma, so we can better define our goal of glaucoma detection and treatment" (2), p.153.

4.5.1 Measures of Visual Impairment and Disability in Glaucoma

To help clarify the relation between visual impairment and disability, research work carried out in this area usually consists of the two steps:

- To determine whether self-reported disability is associated with visual impairment assessed by objective clinical methods, i.e. visual field loss.
- To determine whether various components of vision impairment besides reduced acuity contribute to the reduction in functional independence. In glaucoma, this could be contrast and flicker sensitivity, colour vision, dark adaptation, glare disability, motion threshold and stereopsis. All these aspects of visual function have been found to be compromised in glaucoma (see chapter 'Visual Function in Glaucoma').

4.5.2 Relationship Between Self-Reported Disability and Visual Field Loss in Glaucoma

Among the first to notice the need to examine visual disability in glaucoma were Ross, Bron and Clarke who, in 1984, published a study examining the relationship between self-reported visual disability and objective measures of visual function (41). A battery of vision tests was used to quantify visual defect in a group of 50 patients with chronic simple glaucoma. The vision tests were near and distant visual acuity, visual fields, and contrast sensitivity to static and temporally modulated sinusoidal grating patterns. Visual disability was quantified by means of an 84-item questionnaire about the effect of vision on everyday activities. The authors found that near visual acuity, visual field, and contrast sensitivity measures, were the best predictors of the difficulty experienced by patients in performing visually dependent daily activities. Factor analysis was used to process the questionnaire results. Four factors emerged related to navigation out of doors, near vision, navigation at night, vision when cooking as the four main areas of difficulty in the daily life of glaucoma subjects.

Two years later, American ophthalmologists Mills and Drance published a study on the Esterman Disability Rating in glaucoma subjects (145). At that time The Esterman score had been adopted by the American Medical Association as a new standard for rating visual field impairment (146). Contrary to Ross, Bron and Clarke (41) who examined a group of respondents with visual field loss varying from mild to severe, Mills and Drance concentrated on those with severe loss only, as these patients present a challenge to any disability rating system. Many of these subjects had defective visual acuity and visual field, and the abnormalities are asymmetric and noncongruous. Other ocular or systemic disease may further complicate the glaucoma disability. In this study of forty two patients

with severe loss from glaucoma, the patients were assigned an Esterman visual function score according to their performance on a binocular visual field test using an automated perimeter. The visual function score was correlated with patients' responses to questions about perceived visual disability. Among the questions best correlated or predictive of visual field disability scores were activities demanding functional peripheral vision such us bumping into, or tripping over objects or trouble following a line of print/ finding next line (145).

Some authors investigating vision in older adults devoted their attention to particular difficulties related to postural stability. Falls have come to be recognised as a major threat to the health and independence of elderly persons (129). In the USA the dangers of falling are particularly real for the estimated 22% of all elderly Americans who have visual impairment (147). Visual deficits are considered to be important determinants of the risk of falls in the elderly (129, 148). Glyn et. al. (147) who studied falls in elderly patients with glaucoma analysed the determinants of serious falls among 489 ambulatory elders aged 65 years and older who received a comprehensive examination at a glaucoma consultation service. For the previous year, at least one fall requiring medical attention or restricted activity was reported by 9.6% of participants. The greatest single risk factor for falls was the use of nonmiotic topical eye medication. Three other characteristics were also associated with the risk of falls: use of miotic eye medications, visual field impairment of 40% or greater and the use of sedatives, often prescribed to the elderly. The authors concluded that systemic effects of ocular medication may contribute more than the ocular effects such as pupil constriction to the factors that lead to falling.

Recently a number of new studies on the subject of visual disability in glaucoma have emerged. Gutierrez et al (149) carried out a study on glaucoma patients as a part of research work to test the validity and specificity of the National Eye Institute Visual Functioning Questionnaire (NEI VFQ) in various eye

conditions. This questionnaire was developed by Mangione et al in relationship to visual acuity across five diseases as a new vision-specific measure of health-related quality of life (134, 150).

In the study by Gutierrez et al, vision-targeted and generic health status were assessed across five glaucoma treatment categories and a normal reference group (149). The sample consisted of 147 patients and 44 normals. Apart from the NEI VFQ (150), the VF14 (132) questionnaire was also used as a vision-specific measure. The Medical Outcomes Study 36-Item Short Form Questionnaire (151) was used for generic health-related quality of life assessment. Vision-targeted questionnaires were shown to be more sensitive than a generic health-related measure to differences between glaucoma and normal reference participants. Both the VF14 and 7 of 11 subscales of the NEI-VFQ questionnaire were significantly related to a measure of visual field loss ($p>0.05$, $r = -0.28$--0.46), but for the VF14 questionnaire the relationship was not strong enough to significantly discriminate between normals and glaucomas ($p<0.07$). The authors concluded that self-reports of vision-targeted health-related quality of life are sensitive to visual field loss and may be useful in tandem with the clinical examination to fully understand outcomes of treatment for glaucoma (149).

In a study by Parrish et al both the VF14 questionnaire and subscales 'peripheral vision', 'distance activities' and 'vision-specific dependency' of the NEI-VFQ questionnaire did show moderate correlations with visual field loss ($r = -0.55$) (136). Just as in the Gutierrez study (135), the Medical Outcomes Study 36-Item Short Form Questionnaire did not demonstrate more than a weak correlation with visual impairment in the Parrish study (136).

Lastly Sherwood et al examined glaucoma's impact on quality of life and its relation to clinical indicators (63). The Medical Outcomes Study short form questionnaire (MOS-20), Activities of Daily Vision Scale questionnaire (152), visual acuity and visual fields were measured. Significant differences were found in this

study between patients and normals in all but one subscale (pain) of the MOS-20. All subscales of the ADVS (day vision, night vision, far vision, near vision, glare impact, and overall vision) differed significantly between patients and control subjects. A moderate correlation was found between the ADVS subscales and visual field loss ($r=-0.36$--0.59, overall $r=-0.6$, $p<0.01$).

All of these studies showed (by means of a questionnaire) a steady decline in quality of life in glaucoma patients that was correlated with the amount of visual field loss.

4.5.3 Relationship Between Self-Reported Disability and New Psychophysical Measures of Visual Function in Glaucoma

Although studies by Mills and Drance (145), Gutierrez et al (135), Parrish et al (136) and Sherwood et al (63) examined visual disability in relation to visual field loss and visual acuity, the only reported study that performed a variety of other psychophysical tests was the one on the research work by Ross, Bron and Clarke in 1984 (41). They carried out a large number of contrast and flicker sensitivity tests to find out whether these would have better correlation with visual disability (using a questionnaire) than traditional clinical measures.

The results of the study revealed that both contrast and flicker sensitivity were affected in glaucoma and that the results from a specific group of vision tests rather than of a single test offer the best predictive relationship between visual defects and visual disability. The best tests in predicting visual disability, particularly in relation to outdoor mobility seemed to be contrast sensitivity at 2.88 c/deg, visual field and near acuity.

Although glaucoma patients are often symptomless until late on in the course of the disease, this study showed, by means of the questionnaire, a

deterioration in the quality of life in patients which manifested itself in an anxiety element, which appeared to precede the stage where real difficulties were experienced. These early difficulties were found particularly in navigation out of doors where such factors as variation in the weather and the amount of traffic can affect the level of confidence of the patient.

4.6 Influence of General Health, Demographic and Psychological Factors

4.6.1 General Health and Demographic Factors

Age and general health. Older people are more likely to have physical disabilities than younger people. Martin et al. reported on a national survey conducted by the Office of Population Censuses and Surveys (OPCS) (153), which found that the overall rate of disability in the population increased with age. Almost 70% disabled adults were aged sixty or more and nearly 70% were aged 70 or more. Older people were also more likely to have severe disabilities. The number of severely disabled in the population rose steeply at age of seventy and trend was even steeper at age eighty.

In 1987, Cullinan reported on a survey of 15,000 households of older population in the UK (16). He found that, of those who said they had at least some difficulty with their vision, 45% did not identify poor sight as being their major problem. More recently, Bruce et al. (1991) found that 67% of visually impaired adults (total N=600) had another permanent illness or disability (excluding hearing) and 45% said that this illness or disability limited their daily activities (13). The most frequently mentioned illnesses were arthritis (25%), heart condition (18%), legs/mobility (14%) and diabetes (9%). It should be remembered that the

actual rates of disability may be higher than those reported since older people may discount some disabilities that they assume to be a normal consequence of the ageing process.

Mobility in Glaucoma. A number of authors suggested that glaucoma may occur not only as a result of physical damage to retinal nerve fibre layers caused by increased levels of intraocular pressure but also as a secondary condition to pre-existing vascular problems such as high or very low blood pressure, angina and other forms of heart condition, etc.

This is very important to note when studying visual disability in glaucoma patients because a large proportion of them may suffer from breathlessness and therefore some mobility restrictions. Other conditions such as arthritis may further complicate the matter. When creating a visual disability questionnaire, it is advisable to include a section on general health. This section can deal with disability related to other than visual conditions which will allow for adjustment for general health in statistical analysis models.

Sex. It is well known that men and women have different life and health expectancy, women being at an advantage (154). This may explain the difference in severity of glaucoma between men and women as reported by Orgul et al (155).

Financial resources. It has also been hypothesised that the financial resources of the individual might be important in successful adjustment to a visual impairment (156). For example, difficulties encountered with usual daily activities would be decreased for those people who could afford to pay for services such as chiropody, cleaning, cooking, gardening, hairdressing and so on. However, this applies more to other ophthalmic conditions such as age-related macular degeneration or diabetic retinopathy because glaucoma in general is rarely a cause of severe vision impairment (0.8% according to the results of the Beaver Dam Eye Study, (142)). When considering importance of financial resources in relation to availability of medical treatment, countries with national health-care

service systems, such as U.K., are in advantage when comparing to countries with mainly private health-care systems, because availability of health-care is independent of financial resources of an individual.

Level of social support and living circumstances. It has also been hypothesised that social support and living circumstances are important in adjustment to vision loss (156). It might also reflect different levels of life satisfaction. Neugarte et al. found that older people who were single (i.e. unmarried, divorced and widowed) had lower levels of life satisfaction than people who were married (157). There is evidence that the provision of social support by family and friends may be associated among older visually impaired people with decreased depression (158), improved mobility (159), and more successful use of low vision aids (160). However, all these studies were carried out on a sample of low vision patients. Glaucoma is not associated with clinically meaningful decrease in visual acuity (142). The proportion of glaucoma subjects amongst low vision patients is relatively small and a higher standard of quality of life is preserved (142, 161).

4.6.2 Psychological Aspects of Coping with Disability

In 1976 Faye wrote that visual acuity measures 'tend to distract from how well a patient manages' (162). The patient's personality, his unique attitude to life and the way he deals with the circumstances he has to face affect his final behaviour.

One of the relevant issues is the individual's subjective rating of their own eye condition and the difficulties that it causes. Steinberg et al (1994) investigated this possibility among 766 people with cataract who decided to undergo cataract surgery (132). The patients were asked to rate fourteen activities (such as driving, cooking, reading a newspapers etc.) according to how difficult

they were. The five point scale was used, ranging from 'not at all difficult' to 'unable to do'. They were also asked to make two general ratings: (a) how satisfied they were with their vision and (b) how much trouble they were having with their vision. The authors found that the subjective rating of difficulty with activities correlated more strongly with self-rated satisfaction with vision and perceived trouble caused by vision than did the clinic based measures of visual acuity. The correlation between visual acuity and satisfaction with vision was zero. Some people with particular visual acuity were satisfied with their vision while others with the same visual acuity were dissatisfied, regardless of whether that visual acuity was high or low.

Another factor is patients' knowledge of their own eye condition. This may indicate how realistic are their expectations and understanding of their own abilities. In a national survey for the Royal National Institute for the Blind (RNIB) in 1991, Bruce et al. found that people were often vague about the cause of their visual problem and 20% of people aged 75 or more mentioned nothing more specific than "old age" (13). Davis et al. (1995) found that one third of people with ARMD in their study (total N=30) wrongly described or had no idea of the cause (163).

Mental Health, Psychological and Social Factors

Factors associated with vision may not be the only variables that influence one's ability to carry out different visual tasks: psychological and social factors are also likely to play a role. Riffenburgh (1967) noted that visual disability would be affected by acuity, speed of onset of the vision loss and the age at which it occurred. "These things, however, will not determine the response, but will be influences on the reaction of the basic personality of the individual to his visual

loss" ((164), p.127). Some authors have since speculated about the specific nature of these personality factors and these are discussed below.

Dodds suggested that self-efficacy is central to adjustment of visual loss and later visual disability (165, 166). Onset of visual loss deprives the individual of their usual abilities. If a person has a high sense of self-efficacy, then they will try new things and expect to succeed. If they have a low sense of self-efficacy, then they will avoid new things because they expect to fail. The perception of self-efficacy can therefore have an important motivating role as it can encourage or inhibit ability to strive for further successes. Dodds also describes the concept of locus of control stating that people with an internal locus of control are likely to be motivated whereas people with an external locus of control are more likely to be passive (166). Lack of efficacy and control may cause a person to perceive themselves incompetent, induce feelings of anxiety and depression and reduce self-esteem.

A further source of negative self-perceptions occurs when the person is labelled "blind" or "partially sighted". The degree to which the individual accepts their impairment was found significant as a result of previously held attitudes towards blind people (165, 166). Depression may be another factor that will hinder one's ability to make most of the residual vision (166).

Contrary to many other ophthalmic pathologies chronic glaucoma is characterised by slow progression, often over many years. Even in progressing glaucoma, central vision may remain intact until the late stage of the disease. As a result visual disability is experienced to a comparably lesser extent than in many other ocular diseases and may often be restricted to particular situations, such as rapid changes in general lighting conditions, or activities, such as driving. Even then only a minority of glaucoma patients are banned from driving on the basis of their visual loss. The majority of patients can, overall, enjoy a high quality of life style for many years. Recent research reports on patients in glaucoma show that

these subjects do not tend to suffer from clinical depression in comparison to patients with retinal pathologies due to the comparably higher quality of life standard that can be preserved in glaucoma (161).

4.7 Conclusion

It is clear that more research work is necessary if we are to understand visual disability in glaucoma. The few listed studies indicate a number of important issues that need further explanation or scientific evidence support:

- Visual disability may provide useful additional information to the clinical examination results to fully understand outcomes of treatment for glaucoma (2, 135, 149).
- Using visual acuity as the primary criterion of disability may lead to underestimation of visual disability if other objective measures such a contrast sensitivity or subjective perception of a patient are not taken into account (41).
- Self-reports on visual disability are sensitive to visual field loss (41, 135, 145).
- Self-reported visual disability seems to correlate well with near visual acuity, contrast sensitivity, visual fields and the Esterman Disability Score (41, 145).
- Visual field loss may be particularly related to difficulties in navigation out of doors, near vision, navigation at night, vision when cooking, activities demanding functional peripheral vision and falls (bumping into and tripping over objects) (41, 145, 147).
- Systemic effects of glaucoma medication may contribute more than the visual impairment itself to mobility difficulties (147).

More evidence is needed to clarify the relationship between the visual field loss and multidimensional visual function tests such as contrast sensitivity, glare

disability, dark adaptation, stereoacuity and flicker/motion sensitivity and self-reported difficulties in daily activities.

Chapter 5

THE MEASUREMENT OF PATIENT OUTCOMES IN MEDICINE

5.1 The Measurement of Patients Outcomes

5.1.1 What Should Be Measured?

Until recently, the focus of health care assessment has been upon illness and its eradication, most often expressed in terms of a range of measurements which may be referred as 'clinical' or 'biomedical', with mortality, morbidity and service utilisation being the primary measures. This traditional perspective is increasingly being challenged by the view that since health cannot be adequately described solely in terms of a disease-based or biomedical model, it is insufficient that expert beliefs about ideal or optimal scores on technical measures should be the only elements which inform judgements of the quality of health care (167).

5.1.2 Why Measure Outcomes?

The objective of quality assurance is to safeguard and improve the quality of health care and its outcome in terms of health, functional ability, well being and consumer satisfaction (168), while at the same time achieving this target in a pragmatic cost-effective manner. Various schemes have been proposed to evaluate care, the most well known being that of Donabedian who described three approaches to the assessment of the quality of medical care: structure, process and outcome (169).

Structure refers to whether the necessary skills, infrastructure and resources are present to allow the health programme to operate. Thus a screening programme for glaucoma would require, among other things, sufficient resources to be able to carry out tonometry, perimetry and ophthalmic examination, clinical skills to interpret the findings, and a comprehensive register of subjects with increased risk of glaucoma within the target age group. Examination of the process would assess how these resources and skills were being used in practice, the percentage of subjects who had been invited and had attended for screening, and the reporting recall rate might be examined. Finally, assessment of outcome would consider the impact of the programme upon patient's or population's current or future health.

The evaluation of outcomes is more difficult than that of structure and process. The validity of outcome measurement is dependent upon the salience of the chosen measures to the actual goals of health care, including patients' perception of those goals (167).

5.1.3 Definition of Outcome and Theoretical Framework

Donabedian defined outcome as: '"a change in a patient's current and future health status that can be attributed to antecedent health care" (169). He includes within his definition social and psychological aspects, attitudes, knowledge and behavioural change.

Outcome measurement can take place at the levels of the individual, groups with common disorders, hospital or the whole population and also may be carried out for a variety of different reasons such as evaluation of effectiveness and efficiency of health care, health care needs assessment, audit and resource allocation.

Most health care resources in technologically advanced societies are devoted to the treatment of and research into the chronic diseases, where the major therapeutic goals are the maintenance and improvement of functional capacity, palliation, limitation and control rather than cure. Interventions, therefore, are more validly judged in terms of their impact upon patients lives or quality of life, both positive and negative. However, rapid advances in medical techniques and technologies have been accompanied by increasing ambiguity about the appropriate standards and goals of their use (167). For example, Wennberg reports that surgeons frequently disagree about the objectives of their treatments and, he says, often know relatively little about the range of probable outcomes, or about patients preferences (170). Naji and Sheldon argue that in the absence of robust studies of outcome, and concomitant theoretical and pragmatic development, debates about appropriate levels of service for populations and treatment choices will continue to be less then fully informed (167).

5.1.4 Problems of Measuring Patient Outcomes

According to Naji and Sheldon many problems arise when terms such as health status, quality of life, and patient outcomes are widely used without sufficient definition of their meaning (167). Two different authors may use the same term in spite of addressing widely divergent topics. Whereas some outcome measures like for example, visual acuity, are relatively easily defined, others such as 'quality of life' are very poorly defined and so difficult to assess.

At the same time, many authors indicate that there may be some discrepancy between patients' and doctors' satisfaction with the outcomes of health care (171, 172). It has been thought that patients cannot judge the quality of care, and that it is too difficult to measure patient satisfaction. Nevertheless, several authors regard patient satisfaction as an outcome measure which provides an important dimension in the assessment of quality of care (173, 174). The interpersonal aspects, technical quality, accessibility, continuity, acceptability and perceived effectiveness of care are all integral parts of patients satisfaction.

5.2 Questionnaire: An Outcome Measure Instrument

Administration of a questionnaire is fast and relatively effortless way to obtain a large amount of information in a short period of time and therefore quickly became one of the most frequently used methods to evaluate an outcome from the patient's point of view whether it is perception of their disease, its influence on their life or a measure of satisfaction with the care provided. However, to be valued as a reliable source of information it has to meet certain criteria. It is

always advisable to use previously developed 'gold standard' instruments whose validity, reliability and other characteristics were successfully published.

5.2.1 Question Design

Although the design process of every new questionnaire is unique, it is advisable to accept some general recommendations. Oppenheim (175) suggests that the following issues are relevant when designing a new instrument:

- *Question generation sources.* It is helpful to use previously developed instruments with similar research targets and facet theory on question accumulation (176). Personal experience of an expert in the investigated research area is invaluable.
- *Question wording.* It is necessary to formulate questions bearing in mind the demand for clarity and non-ambiguity. It is recommended not to use two negatives in one sentence or create double questions. Emotive language and unusual terms should be avoided.
- *Barriers to the truth.* There are certain limitations in asking a question. Restrictions can be unreasonable demands on memory (questions on insignificant details in the past), impolite or irrational questions. Awareness, inadmissibility and self-incrimination could be further barriers to the truth to bear in mind.
- *Context effects.* It is important to bear in mind the context effect within the question and within the questionnaire. For example, questions on a water feature in children's playground can be understood as a source of drinking water, or alternatively, as a pond with water lilies depending whether question is addressing aesthetic or practical features of the playground. If the question

has a double meaning and a researcher is interested in one only, it is necessary to specify the context.

- *Discriminatory questions.* It is wise to avoid any possible offence using correct wording and restrict to factual questions rather than questions that may imply any form of discrimination for any involved group.
- *Response types.* Questions can be open ended or closed. Open ended questions are recommended for pilot studies as they are more informative. Closed questions are recommended for further examination following the pilot study as they are easier to analyse across large samples.
- *Levels of measurement and anticipation of data analysis.* It is often useful to have some idea about the necessary statistical analysis. Much information may be lost if the questionnaire is designed in a style that is not possible to transform into a data file suitable for analysis.
- *Number of response categories.* Most authors agree on the necessity of midpoint and three, five or seven answer point scale according to the purpose of the questionnaire.
- *Unipolar scales.* The answer scale is recommended to be unipolar, i.e. answers to a question on satisfaction should be between 'not satisfied'...'satisfied' rather than 'dissatisfied ... satisfied' as verbal opposite of the original measure often does not represent psychological opposite in meaning.
- *Acquiescence set.* Some subjects tend to answer positively only, therefore it is advisable to change the polarity of questions, to alter positive and negative questions if possible.

5.2.2 Questionnaire Scale Design

Scale design is the design of a set of questions which (when summed) give a measure of an attribute, attitude etc. Two characteristics of scale are necessary to bear in mind:

validity

reliability

The subject of validity, reliability and other performance characteristics of a questionnaire will be discussed in detail in a further chapter.

5.2.3 Questionnaire Design

- *Covering letter.* It is advisable to present any questionnaire with a covering letter assuring the subject of anonymity, confidentiality, data protection, the purpose of the questionnaire and aims and objectives of the research work. However the last point should be very brief without giving any real clue to the purpose of investigation as this may influence the attitude in which the subject answers the questions.
- *Visual presentation.* This is particularly important when the instrument is presented to the elderly or a visually impaired population. It is advisable to use easy to read density, font size and style. The layout of questions should be clear and easy to follow.
- *Placement of responses categories.* This will avoid answers in an open ended manner and lead to consistency for data input as well as for participant.
- *Length.* The shorter the questionnaire, the more response is expected and the more precise answers.

- *Sequencing of questions.* The recommended order is: status, doing, knowing, attitudes and intentions. Sensitive questions are advised to be placed at the end and a few easy questions at the beginning.

5.2.4 Summary

The above points are guidelines only: there is no recipe book approach to questionnaire design. The main purpose of a questionnaire is to get useful information from a participant. It should therefore be unambiguous, easy to understand, not irritating or difficult to complete, it should convey credibility and usefulness. Piloting of a questionnaire is advisable if there is not a 'gold standard' instrument available to be used instead of a new one.

5.3 Questionnaire Review Criteria

It was mentioned earlier that a questionnaire can be accepted as a valuable source of information only if it meets certain criteria related to its performance as a measure. These are validity, reliability, responsiveness, interpretability and burden.

5.3.1 Validity

Validity indicates the extent to which a test or technique measures what it is supposed to measure, and thus indicates the range of appropriate inferences that can be drawn (167). It is often expressed using correlation coefficients. Although

there are different ways of classifying validity, most authors identify the following main types (167, 177)

Face validity considers the extent to which the test and its components appear to be relevant to its purpose. This is normally based upon subjective judgements derived from expert 'review'. Although it may seem to be a rather superficial concept, the importance of face validity should not be underestimated.

Content validity considers the extent to which components of the instrument represent a reasonable sample of the content domain to be measured. In the case of measuring visual disability as a result of peripheral visual field loss, the question would be whether the entire domain of issues relating to peripheral vision loss was included in the scale. How well balanced are questions relating to indoor and outdoor mobility, driving and other relevant issues? Wide sampling of items helps to achieve acceptable content validity. Methods commonly used to obtain evidence about content-related validity include use of lay and expert panel judgements of the clarity, comprehensives and redundancy of items and scales of a questionnaire (177).

Criterion validity considers the extent to which scores on the measure correlate with some other instrument or assessment which has already been shown to be a valid and accurate measure of the same or closely related construct. A strong relationship between the two tests is evidence of validity provided that the criterion, i.e. the 'gold standard' test was set up independently and that both the new test and the criterion are reliable. Correlation rarely exceed 0.5 (175, 178). In the area of health status assessment, criterion validity often cannot be tested because of the absence of widely accepted criterion measures.

Construct validity is used when there may not be appropriate criterion measures against which to test a new measure. It shows how well the test meets expectations of theoretical assumptions about the underlying attribute. Using the previous example in subjects with loss of peripheral vision it would be expected

that those with advanced loss would have more difficulties walking on steps or stairs and possibly a higher occurrence of falls.

5.3.2 Reliability

Reliability covers two aspects of test design: the homogeneity of scale items and the reproducibility of the instrument (167, 177). The principal definition of reliability is the degree to which an instrument is free from random error.

Internal consistency. Coefficient (Cronbach's alpha) provides an estimate of reliability based on all possible correlations between each question with the set of questions.

Test-retest reproducibility is the degree to which an instrument yields stable scores over time among respondents who are assumed not to have changed on the domains being assessed. The influence of test administration on the second administration may overestimate reliability. Conversely, variations in health, learning, reaction, or regression to the mean may yield test-retest data underestimating reliability. Despite these cautions, information on test-retest reproducibility data is important for the evaluation of the questionnaire.

Interviewer reproducibility is examined if the questionnaire is administered by an interviewer. The correlations between two or more interviewers are examined.

The length of a test can affect the reliability, it is usually increased with additional items (provided that they are appropriate to the test). The size of the sample on which reliability figures are calculated should be above 30.

5.3.3 Responsiveness

Responsiveness refers to an instrument's ability to detect change, often defined as the minimal change considered to be important by the persons with the health condition or their health-care providers. The criterion of responsiveness requires asking whether the measure can detect differences in outcomes that are important, even if those differences are small (167, 177).

Common methods of evaluating responsiveness include comparing scale scores before and after an intervention that is expected to affect the construct, and comparing changes in scale scores with changes in other related measures that are assumed to move in the same direction as the target measure.

Medical Outcomes Trust recommends assessment of responsiveness involving estimation of the effect size. Effect size is an estimate of the magnitude of change in health status. Effect size translates the before-and-after changes into a standard unit of measurement. Different methods may be used to calculate effect size (177).

5.3.4 Interpretability

Interpretability is defined as the degree to which one can assign qualitative meaning to an instruments quantitative scores (177).

5.3.5 Burden

Respondent burden is defined as the time, energy, and other demands placed on those to whom the instrument is administered. Administrative burden is defined as the demands placed on those who administer the instrument (177).

5.4 Types of questionnaires

5.4.1 Generic versus Specific Measures

Generic measures are those which have been designed to be applicable to a wide variety of conditions, treatments, populations or contexts. Most common of these instruments are health-profiles. These are single instruments which aim to provide assessments of multiple dimensions of people's lives and yield a set of scores for each of those dimensions; or a single summary score, in which case the measure may be referred to as an 'index' (167). A health index aggregates the dimensions of interest to produce a global score. This technique has been favoured by some authors investigating visual disability (135), however some serious reservations have been expressed about the practice of collapsing dimensions into a single number (179, 180). Some well known and widely used examples of generic health measures are the Index of Activities of Daily Living (181), the Nottingham Health Profile (182), the Sickness Impact Profile (183), the Quality of Well-Being Scale (184) and the Medical Outcomes Study Instrument (151).

There are a number of potential advantages associated with the use of generic measures. They have often been subject to much more examination and refinement than is usual within medical measurement. The constructs which they

claim to measure, such as health status and quality of life should be relevant to most, if not all, conditions so that their use offers the possibility of meaningful comparisons, especially if measures which yield index scores are included.

The limitations of generic measures lie predominantly in the fact that the provision of some overall picture may be obtained at the expense of assessing a dominant symptom or factor which may be of major importance to patients and amenable to intervention by elements of process.

In contrast, one may be interested in outcomes that are more discrete, proximate and more intimately related to aspects of the process of care under investigation. The outcomes and their measures may be specific to the disease, population or some other factor, and each is measured individually and independently. In many cases specific measures may be more relevant to patients and doctors and can therefore serve as a means of stimulation to respond to the given health-care for patients. They may be required for a measurement of small but significant changes associated with particular interventions, and for identifying important concerns of patients with particular conditions.

The main disadvantage of specific measures is that they are not, by definition, comprehensive and cannot easily be used for comparisons across conditions or populations. A restricted approach may therefore fail to assess the impact of disease and treatment upon wider aspects of patients' lives.

5.5 Outcome Measures in Medicine

The need to provide some outcomes in health care was obvious some decades ago. Rheumatologists have been pioneers in the development and use of clinical measures for outcome assessment (185). The Lansbury Index developed in 1958 and the Empire Rheumatism Gold Trial performed in 1960 (185) both used

sophisticated pseudo-placebo-controlled trial designs and standardised prespecified clinical outcome measures to establish the clinical usefulness of a drug whose benefit did not become evident until it was administered for several months. Since these studies, other studies have established the clinical and statistical groundwork for rheumatoid arthritis outcome measures. In 1980, the Health Assessment Questionnaire and the Arthritis Impact Measurement Scales were added (185). Research work on quality of life of patients suffering from arthritis was accompanied with studies investigating costs of different forms of treatment. Direct costs of rheumatoid arthritis were found to be high but indirect costs to society caused by decreased work capacity were even higher due to considerable morbidity and functional impairment (186, 187). Comparison in outcome when performing total hip arthroplasty and drug therapy has been evaluated (188). When analysis of the economic impact and quality of life impact of drug treatments was performed, the influence of the side effect of treatment was also taken into account as associated allergic reactions and gastrointestinal events could significantly decrease quality of life of patients and considerably add to the economic burden of society (189). Comparison of outcomes in inpatient and outpatient rehabilitation in arthritis was also examined (107). In addition, outcomes of functional status and patient satisfaction when care was provided by primary care physicians and specialist were compared with positive outcome and less disability for care provided by specialists (108).

In asthma, quality of life assessments show that this disease also has a significant socio-economic impact, not only on the patients themselves, but on the whole family (190). A significant amount of research work on outcome measures was done to determine functional status, patient health-related quality of life and patient satisfaction. At the same time the relationship between these and clinical measures was investigated and finally studies on the cost-effectiveness of treatment were carried out. Quality-of-life benefits were examined in different

treatment strategies using specific asthma instruments, the Living With Asthma Questionnaire and Asthma Quality of Life Questionnaires (in (191)). These disease-specific quality of life questionnaires were assessed as reliable instruments in reflecting disease severity but also in detecting changes in quality of life produced by different asthma treatments (in (109, 191)). On the basis of studies on outcome, international guidelines have been introduced to improve asthma management (190). The resulting improvements in control of asthma are expected to reduce the number of hospitalisations associated with asthma. A positive correlation between total costs of asthma and the degree of severity was found by a German research team (192). As prevention is the best treatment strategy in any disease, a national education and prevention programme was established in the USA (193) where asthma affects up to 15 million people (194).

A number of generic health measures were designed to allow examination of functional status across various conditions. These reliable instruments became a form of 'gold standard' in outcome research and the most widely used are the Index of Activities of Daily Living (181), the Nottingham Health Profile (182), the Sickness Impact Profile (183), the Quality of Well-Being Scale (184) and the Medical Outcomes Study Instrument (151).

5.6 Outcome Measures in Ophthalmology

In ophthalmology, good examples of the use of outcome measures are the studies on outcomes in diabetic retinopathy. Prior to the availability of laser photocoagulation, little treatment was available for proliferative diabetic retinopathy. The natural history of the problem was therefore well documented. When the laser became available, scientific methods were applied to compare laser treatment with no treatment (195, 196). Results showed decreased morbidity and

the positive economic benefits of early detection and treatment (197). Subsequent epidemiological studies provided a profile of the disease so that a rational approach and method of screening could be undertaken (198, 199).

Similarly, a number of studies has been carried out on cataract patients (132, 141, 143, 152, 200, 201). According to the data from 1993, cataract surgery is one of the most frequently performed surgical procedures in Medicare beneficiaries in the USA, with more than 1.1 million procedures performed annually and more than $2 billion in Medicare costs (200). It was important to prove the cost-effectiveness of the procedure. Although the success of cataract surgery was generally measured in terms of improved Snellen visual acuity, it was suspected that the patient's subjective assessment of visual function and/or quality of life may be a more important measure. Research projects started attempting to develop techniques and visual disability questionnaires to measure outcomes of the surgery in one and both eyes (132, 141, 152, 200). The findings of this research work both in the USA (Javitt et al, 1993 (200)) and in the UK (Laidlaw et al, 1998 (202)) clearly supported the policy recommendation that cataract surgery in both eyes remained the appropriate treatment for patients with bilateral, cataract-induced visual impairment on the grounds of major benefits in the resulting quality of life.

5.7 Outcome Measures in Glaucoma

"It is evident that the outcomes information which will be required by the health care revolution is not currently available in glaucoma."

Zimmermann, J Glaucoma,1996 (2).

In 1996 the authors Zimmerman, Karunaratne and Fechtner challenged the current guidelines for the treatment of glaucoma with the statement: "We are not in the business of lowering intraocular pressure. We are not in the business of preventing further disc damage. We are not in the business of stopping field defects. We are in the business of keeping a patient functioning visually at a level that does not hamper or impede the highest quality of life possible. In addition, we should accomplish the above in the most effective and economical manner. How can we meet these challenges?" ((2), p.151).

In contrast to the case of diabetic retinopathy, treatment for glaucoma has been available for more than 100 years and little is known about the natural history of the untreated disease. In contrast to the case of cataract, subjective visual disability in glaucoma was not documented either. Zimmerman and colleagues argue that the cost of 20 years of medical care for one glaucoma patient in the USA translates into about $20, 000 for the patient and/or society to cover the necessary outpatient visits, visual field tests, optic disc photography, and medical therapy (2). In the UK, Spencer, Sparrow et al reported an average cost of £30-50 per appointment in a shared care scheme aimed at monitoring glaucoma patients by community optometrists (203).

Zimmerman et al stressed the need to carry out studies that would in a scientific manner provide some outcome measures that could answer questions on who, when and how should be treated, how much treatment should be given, whether all the individuals should receive the same treatment and what is best for the individual and for society (2). Refocusing and refining the goals of glaucoma treatment is seen as inevitable (2).

5.7.1 Outcome Measures in Glaucoma: New Goals

Outcome research focuses on the impact of medical interventions on patients' functional status and health-related quality of life. The results can be used in numerous ways:

Evaluation , planning and assessing needs of health care:

- Evaluation of medical care, assessing needs and determining the allocation of resources (2, 183, 204).

  Examination of the quality of health care is important for decision making in clinical practice and for management of the health care system. Evaluation is not only oriented toward the patient but also begins to provide a sense of the importance and value of restoring or preserving a given level of visual function (204).

Clinical decision making:

- To provide a measure of perceived health status and visual disability. (183). Research work on developing a questionnaire specific for patients suffering from glaucoma has only recently been started and only a small number of studies and abstracts have been published (149, 205). There is a need to find out more about the degree of disability that patients perceive in certain stages of the disease and the role of treatment in increasing the disability and lowering the quality of life. Gutierrez et al found that among persons with mild to moderate field loss, glaucoma-specific syndromes as blurred and hazy vision negatively affect vision-targeted health-related quality of life more than the field loss (149). These findings emphasise the importance of considering and monitoring symptoms to maximise health-related quality for persons in glaucoma by a wisely chosen treatment strategy.
- Defining the line between over and under-treatment (204). From what was stated earlier, it is clear that there are some questions to be answered in relation to management of glaucoma. Gutierrez and Mangione et al found that in the mild to moderate stages of the disease, patients experience more discomfort or disability in relation to glaucoma-specific symptoms (ocular discomfort, burning, itching, smarting, blurring of vision etc.) rather than the field loss itself (149). Caputo and Katz have also suggested, that it is sometimes difficult to determine whether treatment has more detrimental effects on quality of life than the disease itself, because of the adverse effects of beta blockers, miotics, carbonic anhydrase inhibitors and surgical treatment (133). Zimmerman et al points out that although the technological advances have made it possible to detect glaucomatous visual field loss and optic nerve damage at an earlier stage that have ever been possible, little work has been

done on visual disability (2). At the same time they feel that preventing visual disability that decreases the quality of life should be the determining factor in the treatment of glaucoma. Do medical interventions stop visual disability from glaucoma without over-treatment? A recent review identified only 16 of 102 randomised clinical trials published between 1975 and 1991 had adequate data to compare medical treatment versus placebo or no treatment (144). The results showed a statistically significant reduction in mean intraocular pressure, but only three of the studies gave evidence on long term visual field changes. None addressed the question of visual disability. The difference in prevalence and the response to the treatment was found between different populations, for example open-angle glaucoma is four times more prevalent in African-American population (206) and the prevalence of blindness from glaucoma is several times higher (112). Is this a result of the natural history of the disease or of its management (207)?

- Monitoring patients progress in relation to functional decrement and/or treatment compliance. While visual acuity and visual fields remain an important component of the evaluation for treatment strategy, recent findings in ophthalmology suggest that it is the decrement in a patient's functional status that is the critical factor - and that the functional decrement is to be evaluated from the patient's own subjective, individual point of view (204). Compliance and the side effects of treatment may be difficult to evaluate without the patient expressing his difficulties and experiences. Every patient is different and treatment may vary according to patient's personal preferences in relation to his quality of life. Some patients tolerate pilocarpine well, others may experience dramatic decrease in their quality of life because blurred vision restricts them from driving. Diggory and Franks report that many elderly patients, without a history of bronchospasm and apparently using topical timolol without complaint, experience significant impairment of

lung function tests (25) with the possible effect of decreased mobility. Monitoring of any changes in the patient's functional status and health-related quality of life can affect the choice of topical medication and otherwise influence the treatment.

Standardisation of policies on preventing/minimising visual disability.

- Lack of knowledge about visual disability in daily activities of glaucoma sufferers results in the absence of the support services that are provided for patients with age-related macular degeneration. Mills and Drance (145) reported increased difficulty in obstacle avoidance, tripping over objects, walking on steps and stairs and uneven ground in glaucoma. Therefore subjects with glaucoma are at higher risk of falls which are one of major accidental causes of death in the elderly (129, 145). Dengler-Harles et al found that forward light scatter exaggerates existing glaucomatous loss (58). The practical question arises of what could possibly be done for the patients in their homes or in the way that public buildings are designed?
- Home improvements. There are a number of strategies targeted to decreasing glare in the environment by careful choice of contrast conditions in certain areas (208). For example, a pair of light coloured curtains on a north-facing window will significantly decrease glare perception that is present when windows are surrounded by dark colours. Increased levels of brightness and markings on stairs may prevent falls.
- Architectural and environmental changes. Similar to the situation in homes some changes can be made in public areas to increase safety and comfort of the visually impaired (208). General rules on glare prevention can be applied as well as marking on steps and increased lighting in critical areas. A number of

authors reported on way-finding difficulties of the visually impaired in large public buildings (hospitals, shopping areas, community dwellings) (209-211). As an extreme example of encountered difficulties, anecdotal evidence suggests some partially sighted residents will not travel 30 m to the TV room for fear of not finding their way back. This may result in severe restriction of social life and mobility and contribute to depression and a decrease in general health status. More research work is needed on this subject.

Standardisation of criteria for driving.

- Currently set driving standards for the visually impaired are questioned (212, 213). Controversy exist between authors investigating driving in glaucoma and low vision. Johnson et al examined relationship between frequency of road crashes and incidence of visual field loss in 20, 000 eyes with chronic open-angle glaucoma. The study concluded that subject with visual field loss had higher incidence of road crashes than normal controls (120). Other authors claim that visually impaired people are usually aware of their visual deficit which results in self-imposed restriction in driving at night or in areas of potential hazard (214).

Financial decision-making.

- Financing decisions and cost-effectiveness in health care (2, 141, 204). A positive example were the studies on binocular cataract surgery outcomes. When the health-care reformation in the USA started at the beginning of the nineties with its era of cost containment, it may have been attractive for

insurers to provide disincentives to second eye surgery on the notion that the major improvement in vision and quality of life follows cataract surgery in the first eye. The data from the study by Javitt et al that followed in 1993 contradicted that notion (200). The study covered a broad range of medical, functional, and social outcomes and found a benefit associated with restoring binocular vision in the population. The findings supported the policy recommendation that cataract surgery in both eyes was the appropriate treatment with benefits to the patient and to society (200).

- Protecting patients' needs in cost-effectiveness programmes (2, 141, 204). The recent example from USA in Oregon of the low priority, and therefore, non allocation of Medicare funding for laser therapy of central retinal vein occlusion has shown that decisions, which may be considered unfavourable, are made when relevant scientific information is lacking to prove the cost/benefit and cost/effectiveness of the management of the disease that is for the best of the patient (2).

SECTION II

PATIENT'S PERCEPTION OF VISUAL IMPAIRMENT IN GLAUCOMA

A Pilot Study

Chapter 6

PATIENT'S PERCEPTION OF VISUAL IMPAIRMENT IN GLAUCOMA

A Pilot Study

6.1 Introduction

When this study commenced in 1995, there was little by way of published papers on visual disability in glaucoma. The subject has not been covered since the studies by Ross in 1984 (41) and Mills and Drance in 1986 (145) were published. None of the questionnaires available, such us the Activities of Daily Living Scale (152) or the Visual Functioning-14 Questionnaire (132), were tested on glaucoma patients. There was a large spectrum of issues that needed to be addressed as no information was available on the range of day to day problems encountered by patients and its relevance to clinical measures. A decision was made to carry out two studies in this project. In the first part, the pilot study, we would deal with patient's perceptions of visual impairment in glaucoma and related the findings to a measure of visual field loss. In the second part, the main study, the relationship between visual disability and visual function in its various aspects would be examined.

The aims of the pilot study were to identify the most commonly perceived disabilities in the daily life of glaucoma patients by means of a questionnaire, to rank the perceived problems with regard to frequency, to group related visual problems and assess their impact on daily life activities, and to examine the relationship between perceived visual difficulties and the severity of visual field loss, looking in particular at those variables which could discriminate between different grades of visual field loss. A pilot questionnaire was developed for the purpose of this study. A further task was to identify a glaucoma-specific subgroup of questions and to test the validity and reliability of this newly created questionnaire subscale.

6.2 Subjects

6.2.1 Visual Disability Questionnaire

Sixty-three patients attending the glaucoma review clinic within a three month period were enrolled in the study. There were 31 males and 32 females in the sample. The mean age of the sample was 70 years (standard deviation: 14 years) ranging from 45 to 90. Snellen visual acuity varied between 6/4 and 6/36, with the mean value of 6/6. Patients with clinically significant cataract, macular degeneration or any other ophthalmic condition were excluded from the study. Glaucoma was diagnosed on the basis of glaucomatous disc cupping and reproducible visual field damage in one or both eyes. Eighty percent of the subjects suffered from primary open angle glaucoma (intraocular pressure >21mmHg), and the remaining 20% were patients with other types of chronic glaucoma (normal pressure, angle closure, pseudoexfoliative). All 63 patients completed the questionnaire.

6.2.2 Relating Subjective Visual Disability to a Measure of Severity of Binocular Visual Field Loss

Although the questionnaire was anonymous, a subsample of 39 patients spontaneously agreed to give us their name and to allow us to gather further information on their visual field loss. A further analysis of the data in relation to the severity of visual field loss was performed on these patients. The patients in this subsample suffered from different degrees of visual field loss. Twenty three males and 16 females were included in this analysis, with a mean age 71 years (SD 10 years) ranging from 45 to 90. Only patients with Snellen visual acuity less or equal to 6/12 in the better eye were included in the study (mean VA 6/6). Only two patients had vision in the fellow eye worse than 6/12. The central 24 degrees of visual fields (threshold and suprathreshold strategies) were plotted using automated perimetry and the central visual fields were classified (by Mr. Colm O'Brien) into three groups of severity as mild, moderate or severe (details in Methods).

6.3 Methods

6.3.1 Visual Disability Questionnaire

A pilot questionnaire was used to record self-reported disability in glaucoma patients. The process of developing this questionnaire benefited from previous studies on visual disability in glaucoma (41, 145) and other ocular conditions (9, 132, 152, 201, 215) as well as from the clinical experience of a glaucoma specialist (Mr. Colm O'Brien).

All patients were interviewed by the same person (Mrs. Patricia Nelson) before they were given the questionnaire. Note of patients' age, sex, Snellen visual acuity and diagnosis was made. Patients with clinically significant cataract, macular degeneration or any other ophthalmic condition were excluded from the study. The task of the interviewer was to make sure that every participant understood the nature of the study and how to answer the questions on a five point scale ranging from "no difficulty at all" to "severe difficulty". It was also made clear that patients had to answer questions in relation to their vision alone. An extra option was given in the questionnaire in case the patient did not carry out a particular task for other than visual reasons. After the short interview, patients were asked to complete the questionnaire themselves during the time they were waiting in the clinic. The questions were formulated in plain English and easy to understand.

The questionnaire comprised of a total of 62 questions (Appendix I). These covered 47 different activities of daily living (ADL) in ten main areas of daily life: mobility indoors and outdoors, housework, reading, watching television (TV), social life, leisure activities, travelling, ability to enjoy scenery and driving.

Confidence in Performing Routine Daily Tasks. As the questionnaire took 20 to 30 minutes to complete, only a subgroup of 35 patients were administered a further group of 19 questions dealing with the subject of patients' confidence rather then disability in performing certain tasks. These patients were asked how confident they felt to carry out daily tasks such as cooking, crossing the road, walking on steps etc. The purpose was to find out whether patients experience increased anxiety and lack of confidence in their daily life resulting from their visual difficulties.

6.3.2 Relating Subjective Visual Disability to a Measure of Severity of Binocular Visual Field Loss

The central 30 degrees of visual fields (threshold and suprathreshold strategies) were plotted with the Humphrey Visual Field Analyser (Humphrey Instruments, Inc.; Allergan Humphrey, San Leandro, Ca, USA) or the Medmont Automated Perimeter (Medmont Pty. Ltd. Melbourne, Australia). The central visual fields were classified (by Mr. Colm O'Brien) into three groups of severity as mild (unilateral loss with less than half of the visual field lost), moderate (unilateral loss with more than half of the visual field lost, or, bilateral loss with less than half of the visual field lost in each eye) or severe (bilateral loss, more than a half of the visual field lost in either eye). Using this qualitative subdivision, 10 patients had mild field loss, 15 had moderate damage and 14 severe visual field loss. The groups were compared for differences in relation to age, gender or visual acuity using chi-square test and Kruskal-Wallis ANOVA. No statistically significant difference was found in relation to any of these categories in the three groups of visual field loss.

6.4 Statistical Analysis

6.4.1 Visual Disability Questionnaire

Factor analysis using the Varimax rotation of the Principal Component Analysis provided by SPSS statistical software package (SPSS for Windows; Version 6.0, SPSS, Chicago, IL) was used to process the results of the questionnaire. It is a data reduction technique, in which an initial set of intercorrelations between

variables is given a simplified structure by the formation of groups from the initial set (216). A small number of new groups or patterns emerged called factors which account for most of the variation in patients' responses.

6.4.2 Relating Subjective Visual Disability to a Measure of Severity of Binocular Visual Field Loss

Using SPSS, a Kruskal-Wallis one way analysis of variance (ANOVA) was performed on the three groups (mild, moderate and severe field loss) followed by the Mann-Whitney U test for two independent samples. As the direction of significant difference was predicted a priori, i.e. with progressing field loss increased visual disability was expected, a one-tail test was used for analysis of the data. A probability value of $p<0.05$ was considered as a critical level for significant results.

Validity and reliability of the glaucoma-specific subset of questions. Those activities which best separated the groups with different levels of visual field were used to create a glaucoma-specific subset of questions. The validity of this newly created subset of questions was evaluated using Spearman correlation coefficient between the computed average score for those questions and the severity of the visual field loss. Reliability analysis of the subset of glaucoma-specific questions was carried out using Cronbach's α as a measure of internal consistency (SPSS for Windows; Version 6.0, SPSS, Chicago, IL).

6.5 Results

6.5.1 Visual Disability Questionnaire

The frequency of reported difficulties is presented in Table 3. A high percentage of glaucoma patients complained about problems with common, everyday activities. Of particular note was the percentage of patients who experienced problems with glare (70%) and adaptation to different levels of lighting (54%) followed by difficulties when walking on steps or kerbs (49%), reading activities (43%), shopping (42%), crossing the road (36%), using the bus or train (26%), visiting friends and restaurants (20%), etc. Most vehicle drivers also complained of increased difficulty with glare when driving towards the sun or oncoming headlights (72%). A small number of patients (approximately 10%) mentioned that because of problems with glare they had to stop driving at night or during winter months. Among other examples of reported visual disability were driving at night time (52%), the ability to see the control panel in the car at night (33%), the ability to see traffic signs during day time (15%) and reversing (15%).

TABLE 3. *Frequency of self-reported difficulties.*

Percentage	Patients who failed to answer or did not perform activity for non-visual reasons	Activities
70%	2%	Glare
54%	5%	Adaptation to different levels of lighting
49%	2%	Walking on steps or kerbs
43%	6%	Reading newspapers
42%	3%	Shopping
40%	30%	Needlework
36%	2%	Crossing the road
32%	2%	Recognising faces and expressions
26%	3%	Using bus or train
26%	4%	Watching television
25%	6%	Indoor mobility
20%	6%	Visiting friends or restaurants
17%	7%	Housework & cooking
17%	5%	Enjoyment of scenery

Factor Analysis. While the frequency of reported difficulties gives information about their occurrence (i.e. presence or absence of problems), factor analysis deals with interrelationships within the data. It reveals therefore the key groups of questions which underpin the problems reported by the patients.

Factor analysis identified nine new groups of questions (factors). Taken together, the first four factors accounted for most of the variability in patients' responses (72%) and are summarised under the following general headings: outdoor mobility / navigation, lighting & glare and activities demanding functional peripheral vision, household tasks and personal care. The technique simplified the 62 questions in the questionnaire into the four main groups and arranged them in descending order in which they accounted for the variability in patients responses. To test the stability of this structure, a second factor analysis was performed with a smaller set of 18 questions. The activities with high ($r>0.7$) and moderate ($r>0.5$) correlations on the first five factors were included in this part of analysis. An identical factor structure was obtained with this secondary analysis.

The frequency of occurrence of difficulties related to these four groups can be found in Table 4. The greatest frequency was observed in the second factor, *lighting & glare and activities demanding functional peripheral vision* (Table 4).

TABLE 4. *Frequency of occurrence of the main groups of difficulties experienced by patients suffering from glaucoma.*

FACTOR NAMES	FREQUENCIES
Glare and lighting	70%
Outdoor mobility day and night	32-56%
Household tasks	17%
Personal care	8-12%

Frequency of occurrence shows the number of patients experiencing difficulty with the listed groups of activities.

Questions that correlated best on the four factors are listed in Table 5. For the first factor, highly correlated activities were observed relating to *outdoor mobility/ navigation* such as walking outside in the street during the day or at night, crossing the road, moving in traffic and also activities related to judging distances. The second factor (*lighting & glare and activities demanding functional peripheral vision)* indicated difficulty with disability glare and adaptation to different levels of lighting either indoors or outdoors. Activities demanding functional peripheral vision such as tripping over when walking, bumping into objects or failing to see people or objects in the periphery also correlated mostly on this factor, even though the correlation was not as strong as for glare disability and lighting. Ability to judge distances correlated evenly on the first two factors. The third factor (*household tasks)* clearly defined problems with typical household activities indoors and in the garden. *Personal care* tasks like dressing, washing and bathing correlated on the fourth factor.

TABLE 5. *Factor structure of the data. Intercorrelation coefficients of different daily activities on the first four factors that accounted for most of the variance in the patients responses.*

DAILY ACTIVITIES	FACTOR 1 Outdoor mobility	FACTOR 2 Glare and Lighting and PV Activities	FACTOR 3 Household tasks	FACTOR 4 Personal care
Outdoor mobility in general	.70	.	.	.
Crossing the road	.77	.	.	.
Seeing moving vehicles	.78	.	.	.
Walking outdoors after dark	.75	.	.	.
Ability to see outdoors after dark	.71	.	.	.
Judging distances	.57	.	.	.
Glare in general	.	.70	.	.
Adaptation to different levels of lighting	.	.75	.	.
Bumping into objects	.	.62	.	.
Seeing in periphery	.	.63	.	.
Tripping over objects	.	.59	.	.
Cooking	.	.	.79	.
Housework	.	.	.73	.
Gardening	.	.	.63	.
Dressing	.	.	.	.85
Washing	.	.	.	.83
Colour vision	.	.	.	.82

PV Peripheral Vision

6.5.2 Relating Subjective Visual Disability to a Measure of Severity of Binocular Visual Field Defect

Further analysis of the data was carried out on a subgroup of 39 patients as described above. Kruskal-Wallis ANOVA and Mann-Whitney tests were performed on the three groups of patients with different levels of visual field loss (mild, moderate and severe) (Table 6).

TABLE 6. *Group differences in visual disability questionnaire responses with regard to the severity of binocular visual field loss .*

	ANOVA Kruskal-Wallis	*Mann-Whitney U Test*		
Activities	*All groups (p-value)*	*Mild vs. Moderate (p-value)*	*Moderate vs. Severe (p-value)*	*Mild vs. Severe (p-value)*
ADL in general	0.07*	**0.04**	.	**0.01**
ADL performed in dim lighting	**0.04**	**0.03**	0.15*	0.07*
Adjusting to bright lighting	**0.055**	.	**0.02**	0.14*
Tripping over	**0.04**	0.09*	0.16*	**0.01**
Going from bright to dark room or vice versa	0.15*	.	0.16*	**0.05**
Confidence in going out in the street	**0.01**	.	**0.03**	**0.02**

ADL Activities of Daily Living. (* Indicates trend towards significance. Significance may be achieved with a larger sample size.)

Using the ANOVA assessment significant differences across all groups were found in patients confidence when going out in the street (p=0.01) and in tripping over when walking (p=0.04). Glare disability when adjusting to high levels of lighting had a borderline probability value (p=0.055) (Table 6). These variables are related to the first and second factor of the factor structure *('outdoor mobility', 'glare & lighting and activities demanding functional peripheral vision').* Also, in the responses to the general question on perceived "difficulty in activities of daily living (ADL) performed in dim lighting" there was a significant difference between the groups (p=0.04).

The ANOVA was followed by Mann-Whitney U test for two independent samples (Table 6). With increasing severity of binocular visual field loss, the number of significant differences between the groups increased. The only significant difference found between mild and moderate visual field loss groups was in two general questions on "activities of daily living performed in dim lighting" (p=0.03) and "activities of daily living in general" (p=0.04). There were no differences in any of the specific daily tasks among these two groups of patients. When comparing the groups with moderate and severe field loss the best predictors were a confidence question on "going out in the street "(p=0.01) and glare disability (p=0.02). Significant differences were found between groups with mild and severe visual field loss in the questions on performance in ADL in general (p=0.01), tripping over objects (0.01), confidence when going out in the street (p=0.02) and adaptation when going from dark to light room or vice versa (p=0.05).

Finally the groups with mild and moderate loss were combined and compared with the group with severe loss (Table 7). The Mann-Whitney U test showed significant differences between these two groups in adjusting to bright lighting (p=0.02), a general question on difficulty with glare (p=0.02) and

tripping over objects (p=0.04). Adaptation when going from a bright to a dark room or vice versa had a borderline probability value (p=0.055). All these questions were related to the second factor of the factor structure.

TABLE 7. *Comparison of the combined group of mild & moderate field loss with the severe binocular visual field loss group (Mann-Whitney U test).*

Activities	p-value
Adjusting to high levels of lighting	0.02
Disability glare in general	0.02
Tripping over	0.04
Going from bright to dark room or vice versa	0.055

6.6 Validity and Reliability of the Questionnaire Subscales

Validity. This questionnaire was based on several examples in the literature from a range of ophthalmic conditions including glaucoma. The purpose was to find questions which would show a relationship with a measure of severity of visual field loss. The validity of the questionnaire could therefore be tested only in relation to possible glaucoma-specific subgroup consisting of the questions found to be able to discriminate or contribute to the discrimination between the three groups with varying degrees of visual field loss. The validity of the specific questions was demonstrated in their relationship with a measure of visual field loss, Tables 6 and 7. Most of these questions were related to the factor 'glare & lighting and activities demanding functional peripheral vision'. The average score

(mean value) for these questions has also been computed and correlated with the measure of severity of binocular visual field loss. The Spearman coefficient was used for evaluation of this relationship with the resulting value of r=0.37 ($p<0.05$).

Reliability. The Cronbach's α showed high internal consistency for all the subscales of the questionnaire as suggested by the factor analysis: outdoor mobility (0.96), disability glare & lighting and activities demanding functional peripheral vision (0.93), household tasks (0.92), personal care (0.97). Internal consistency of a possible glaucoma-specific subgroup of questions related to factor 'glare & lighting and actions demanding functional peripheral vision' was also found to be high (0.96).

6.7 Discussion

6.7.1 Visual Disability Questionnaire

This study has identified outdoor mobility, glare and lighting, household tasks and personal care as the main groups of problems encountered by glaucoma patients. This factor structure confirmed the previous findings of Ross et al. (Table 8) (41). Both the sample in the study of Ross and the sample in this study were comparable in their size and considered the same age group. Both studies examined subjects with varying degrees of the visual field loss and used a similar technique to analyse the data.

TABLE 8. *Comparison of the factor structure reported by Ross et al 1984* (41) *with the factor structure resulting from this study.*

Present study	Ross et al
Outdoor mobility	Navigation outdoors
Disability glare & lighting	Navigation at night
Household tasks	Vision when cooking
Personal tasks	-
Near vision	Near vision

The first factor described by Ross as *navigation outdoors* (41) is identical with the group of experienced disabilities that correlated on the factor *outdoor mobility* in our study. Problems with *navigation at night* (41) indicating difficulty with adaptation to different levels of *lighting* were confirmed in this study, in relation to the second factor. The questions related to *glare disability and activities demanding functional peripheral vision*, like tripping over and bumping into objects or ability to see objects coming from the side also correlated on this factor. Naturally, one would expect a correlation of activities demanding functional peripheral vision on the outdoor mobility factor. This was partially the case as the correlation of these activities was spread across the first two factors, but predominant on the second one. It is difficult to explain at this stage why the relationship of these activities with glare problems seems to be stronger than with outdoor mobility difficulties.

Vision when cooking (41) was one of the activities that correlated on the factor with the general heading of *household tasks* in this study. *Near vision* (41) corresponds with the fifth factor in the present study. This factor did not

significantly increase the proportion of variance in the patients' responses and therefore was not described in detail. In relation to the use of factor analysis, it is necessary to note that because the sample size in this study was smaller than the usually recommended ratio of 2:1 (number of subjects : number of questions), or 20 times the number of factors (216), a secondary analysis was performed to test the stability of the factor structure. A smaller set of 18 questions which correlated strongly ($r>0.7$) or moderately ($r>0.5$) on the first five factors were entered into the secondary analysis and an identical factor structure was obtained.

A loss of confidence in performing certain tasks was observed by the glaucoma patients in this study before real problems with visual disability were apparent, an observation also reported by Ross (41). These difficulties were particularly related to outdoor mobility (going out in the street, visiting friends), where a change in weather conditions and the amount of traffic can cause some anxiety and affect the level of confidence of a patient.

6.7.2 Relating Subjective Visual Disability to a Measure of Severity of Binocular Visual Field Defect

The results of this study indicate that subjective data can discriminate between patients with mild/moderate and advanced binocular visual field loss as defined in this study (see Subjects). The best discriminators seems to be the second factor given by the factor structure in this study, i.e. disability glare, adaptation to different levels of lighting and activities demanding functional peripheral vision. However, these subjective discriminators do not seem to be sensitive enough to detect differences between mild and moderate binocular field loss as defined in this study. Although patients with moderate damage may have some idea of increased difficulties with daily life activities in general, no difference is found

between the two groups when performing any particular task. This suggests that patients may progress from the mild to the moderate stage of the visual field damage (as defined herein) without noticing it in their daily routine. Normal subjects were not considered in this study as the purpose was to examine visual disability between groups with varying degrees of visual field loss.

Disability glare and lighting have separated mild / moderate from severe visual field loss in this study (Table 7). In every day situations, glare disability is observed when driving at night against oncoming car's headlights or during sunny winter days, entering dark rooms, and when indoors with mirrored areas facing lighting sources. Although the results of this study in regard to disability glare and lighting cannot be directly compared to any other study, the work by Sherwood et al in a very recent publication indicates that glaucoma patients experience glare and have difficulty with night vision when compared to normals (63). In 1989 Dengler-Harles et al (58) showed that forward light scatter exaggerates existing visual field loss in glaucoma patients. In 1992 Ochsner and Zrenner included some glaucoma patients in their glare sensitivity study (88), and suggested that changes in the visual acuity - luminance function accompanied with high glare sensitivity are most often due to pathological changes in neuronal circuity of the retina. They remark that sensitivity to glare is an unspecific ophthalmologic symptom which can be caused by different anatomical structures, and although it can be related to optical and to cortical structures, it can also be due to defects in the neuronal mechanisms of the retina that control adaptation processes (88). Van den Berg found that visual acuity correlates rather weakly with the amount of scatter (89). Since the amount of scatter causes a considerable loss of visual function, the results of his study showed that for glare sensitive patients the standard Snellen visual acuity test gives a rather limited impression of visual handicap. Hoshino and Mizokami found a significant correlation between glare sensitivity measured with the Millar-Nadler glare tester

and central visual field damage in patients with early to middle stage glaucoma (59). Others studies have shown that objectively measured glare disability when taken together with other tests (especially contrast sensitivity and visual acuity) made a distinct contribution to the overall characterisation of visual function (9). The issue of dark adaptation in glaucoma was addressed by Glovinsky, Quigley and Drum et al who found abnormal scotopic sensitivity in glaucoma patients when compared to normals (56). More research into the problems associated with intraocular light scatter, brightness acuity and sensitivity and scotopic sensitivity in glaucoma is needed.

Our patients also had problems with vision in activities demanding functional peripheral vision, particularly when walking. With advancing glaucoma damage the number of subjective discriminators seems to increase (Table 6). These results reaffirm the conclusions of Mills and Drance (145) who used the Esterman binocular test as an objective measure of visual function and compared the performance scores to the self-reported disability in patients with severe visual field damage. They found a significant correlation between the Esterman test and responses to a short visual disability questionnaire, particularly in activities demanding peripheral vision, i.e. questions on tripping over, bumping into people or objects and following the line of print or finding the next line (145). A number of groups have recently demonstrated visual disability in glaucoma patients using a questionnaire. A study by Gutierrez et al showed that a steady decline characterised the relationship between visual field loss and health-related quality of life (135). Sherwood and Parrish found a correlation between increasing field loss and a reduction in activities of daily living (63, 136).

Some other signs of deterioration in the quality of life of a given patient were found in this study by a loss in confidence when performing certain activities, especially outdoor mobility tasks (going out in the street). Anxiety and

loss of confidence seem to precede the stage of actual problems in performing the tasks.

As mentioned earlier the selection of questionnaire items in this study was based on several examples in the literature from a range of ophthalmic conditions including glaucoma. The summary measure of a single value used by some authors (135) as a performance measure across a number of questions was therefore inappropriate in this situation because of the basis on which the questions were chosen.

The validity of the glaucoma-specific subgroups of questions was shown by the significant correlation with severity of visual field loss (Table 6). This correlation was similar to the value published by Gutierrez et al (135) in glaucoma patients. A high level of internal consistency was found in the questionnaire structure and the glaucoma-specific subgroup of questions.

The influence of different forms of treatment (medical, laser, surgery) and in particular pupil diameter was not addressed in this study. Pilocarpine is known to cause a diffuse depression in the hill of vision due to pupil miosis (29, 30). Pupil enlargement may be associated with increased glare disability (217). Topical beta blockers can cause systemic side-effects which may influence general well being and have a bearing on subjective responses (25). A recent study by Wang aimed at developing a research instrument for measuring the effect of glaucoma and its treatment on quality of life and functional status (218), concluded that the Glaucoma Disability Index, a 31 item questionnaire showed high internal consistency and construct validity and is intended to be used to evaluate quality of life related to treatment. Sherwood et al found that glaucoma medication correlated with self-reported glare disability and night vision problems (63). All of the aspects relating to treatment and side-effects of therapy need further investigation (219). In our ongoing study we are also looking at the relationship

between other psychophysical tests of visual function and self-reported visual impairment in glaucoma.

6.8 Conclusion

This study has shown that from a large set of questions on daily living activities, the responses of glaucoma patients can best be described by four different areas. These are *outdoor mobility / navigation, glare & lighting and activities demanding functional peripheral vision, household tasks* and *personal care.* The results of this study also indicate that subjective data can discriminate between patients with mild/moderate and advanced binocular visual field loss, as defined in this study (see Methods). The signs of a reduction in quality of life were experienced in difficulty with adapting to glare and different levels of lighting and in activities demanding functional peripheral vision, particularly when walking (tripping over objects). A loss of confidence was apparent in patients when going out in the street, before the actual disability problems were noted. The validity of the glaucoma-specific subgroup of questions was shown by a significant correlation with the severity of visual field loss. A high level of internal consistency was found in the questionnaire structure.

There is a clear need to find out more about visual disability in glaucoma. The results so far are challenging, particularly as experienced difficulties are a crucial outcome measure and quality of life indicator. As many reports indicate (2, 63, 135, 218) this aspect of care is essential to the treatment and management of the glaucoma patient. Further studies are needed if we are to address the questions and problems of visual disability in glaucoma.

Chapter 7

REVIEW OF THE PILOT STUDY

7.1 Conclusions for the Main Study

The first phase of this research project, the pilot study, fulfilled its purpose in focusing our attention on the three main aspects of daily activities that were found to have strong relationship with a measure of severity of visual field loss: *outdoor mobility/navigation, glare & lighting* and *activities demanding functional peripheral vision.* Understandably, these would be investigated in the main study in greater detail not only by means of a questionnaire but also by means of objective measures of visual function.

7.2 Questionnaire for the Main Study

When creating a new questionnaire for the second phase of this research project, the main study, the following steps were taken:

- Questions that had significant relationship with a measure of visual field loss or contributed to it were included.

- Questions that highly ($r>0.7$) and moderately (approx. $r=0.5$) correlated on the five factors (including the factor *near vision*) that emerged in the pilot analysis were included.
- Activities that were correlated with each other above the value $r>0.7$ were analysed and only the one with better performance was included.
- A section on general health, mental health (the MOS-36 short-form health survey (220)) and psychological aspects (the Nottinhgam Adjustment Scale (221), shortened version) that could influence one's visual disability were included following the recommendations of Cotton, Hill and Aspinall (215). These authors carried out an extensive study to investigate influence of demographic and psychosocial characteristics of older adults in relation to their visual impairment. Included were measures: *general health* (the Short Form-36 Health Survey (151)), *psychosocial measures* such us the Nottingham Adjustment Scale (221) (a measure of psychological factors such as anxiety, depression, self-esteem, personal satisfaction, attitudes, acceptance etc.) and the Life Satisfaction Index (222, 223), *demographic variables* (finance, living circumstances and social support), a section on psychological factor *hardiness* and also a section on *religious motivation*. It was not possible to include all the factors that play important role in coping with visual impairment and in the resulting level of disability in the present study. However, the recommendations of Cotton, Hill and Aspinall (217) were followed to include the most important measures, i.e. the psychosocial characteristics: anxiety, depression, acceptance, personal satisfaction and attitudes. As a result, 10 questions were added (2 for each measure) to the final questionnaire in the main study.
- An up-to-date literature search was carried out and a number of additional questions on social life and spare time activities were included (224). It was

shown that the ability to carry on with usual social life activities and hobbies plays a very important role in preserving one's quality of life level.

The questionnaire designed for the main study comprised of a total of 58 questions (Appendix II). Visual disability was assessed in the following areas: personal care and domestic tasks; glare and dark adaptation; navigation and mobility; navigation at night; near vision; and social contact and leisure activities. In addition, as already mentioned above, some questions were included addressing general, health, mental health, and psychosocial measures. The questions were to be answered on a five point scale ranging from "no difficulty at all" to "severe difficulty". It was also made clear that patients had to answer questions on visual disability in relation to their vision alone. An extra option was given in the questionnaire in case the patient did not carry out a particular task for other than visual reasons. The experience from the pilot study showed that questions were formulated in plain English and easy to understand.

SECTION III

RELATIONSHIP BETWEEN BINOCULAR VISUAL FUNCTION AND VISUAL DISABILITY IN GLAUCOMA

Chapter 8

RELATIONSHIP BETWEEN BINOCULAR VISUAL FUNCTION AND VISUAL DISABILITY IN GLAUCOMA

The Main Study

8.1 Introduction

The purpose of the pilot study was to broadly examine patients' perception of visual impairment in glaucoma and to find out whether self-reported disability was correlated with a measure of visual field loss. The purpose of the main study was confirm this relationship and in addition investigate the correlation between self-reported visual disability and various aspects of visual function. The research work therefore consisted of two parts:

- Visual performance testing in a number of visual functions that were found to be compromised in glaucoma. The Esterman binocular visual field test was carried out and also additional measures of contrast sensitivity, flicker sensitivity, colour vision, dark adaptation, glare disability, and stereoacuity testing.

- A questionnaire was used to record self-reported visual disability in glaucoma patients. The questionnaire was successfully piloted prior to the main study on a sample of 65 patients and was designed to cover various aspects of everyday life. Visual disability was assessed in the following areas: personal care and domestic tasks; glare and dark adaptation; navigation and mobility; navigation at night; near vision, and social contact and leisure activities. In addition some questions were included addressing general health, mental health, and also feelings and attitudes that could be related to social and emotional aspects of the disease.

8.2 Subjects

A sample of 47 glaucoma patients and 20 normal control subjects who met eligibility criteria were enrolled from the glaucoma clinic at the Princess Alexandra Eye Pavilion of Royal Infirmary of Edinburgh, Scotland between July 1996 and October 1997(Table 9).

There were 22 males and 25 females in the patient group. The mean age of this sample was 68 years (standard deviation: 7.4 years) ranging from 53 to 81 years with onset of glaucoma after 40 years of age and of at least one year duration. Snellen visual acuity varied between 6/4 and 6/12, with the mean value of 6/6. Glaucoma was diagnosed on the basis of glaucomatous disc cupping and reproducible visual field damage in one or both eyes. Fifty nine percent of the subjects (29 patients) suffered from primary open angle glaucoma (intraocular pressure >21mmHg), 37 % (18 subjects) suffered from normal tension glaucoma and 4 % were patients with other types of chronic glaucoma (angle closure, pseudoexfoliative).

TABLE 9. *Characteristics of patients and normal controls. Kruskal-Wallis One-way Anova and Chi-square test.*

Characteristics	Mild VF loss	Moderate VF loss	Severe VF loss	Normal controls	Difference among groups
Age	67.72 (SD 7.45)	67.21 (SD 7.61)	71.70 (SD 6.97)	66.50 (SD 4.35)	p>0.05
Sex Male / Female	8/10	9/10	5/5	6/14	p>0.05
Snellen VA	6/6	6/6	6/6	6/6	p>0.05
MD	-7.34 dB (SD 4.65)	-14.29 dB (SD 5.03)	-27.61 dB (SD 6.40)	-0.15 dB (SD 1.79)	p<0.0001
CPSD	7.28 dB (SD 3.19)	12.77 dB (SD 2.93)	12.24 dB (SD 2.85)	1.85 dB (SD 1.27)	p<0.0001
Pupil size (mean rank)	4.1 mm (SD 1.7) 34.19	3.7 mm (SD 1.0) 29.76	3.8 mm (SD 1.7) 29.85	4.4 mm (SD 1.1) 39.92	p>0.05
General health (mean rank)	38.86	32.63	42.72	25.35	p>0.05
Mental health (mean rank)	33.58	36.13	39.00	28.45	p>0.05
Psychosocial measures (mean rank)	32.17	32.34	46.22	30.08	p>0.05
Pilocarpine medication (mean rank)	N=6 23.33	N=6 22.92	N=5 27.75	-	p>0.05 (comparing patients groups)

Only patients with stable visual fields were eligible to participate in the study. The central visual fields were classified (by Mr. Colm O'Brien) into three groups of severity as mild (unilateral loss with less than half of the visual field lost), moderate (unilateral loss with more than half of the visual field lost, or, bilateral loss with less than half of the visual field lost in each eye) or severe (bilateral loss, more than a half of the visual field lost in either eye). Using this qualitative subdivision, 18 patients had mild field loss (MD=-7.3dB, SD 4.65; CPSD=7.28, SD 3.19), 19 had moderate damage (MD=-14.2dB, SD 5.03; CPSD=12.77, SD 2.93) and 10 severe visual field loss (MD=-27.6dB, SD 6.4; CPSD=12.24, SD 2.85), Table 9. Patients with clinically significant cataract, macular degeneration or any other ophthalmic condition were excluded from the study. Patients with a history of incisional eye surgery within three months before recruitment were excluded from the study (Table 9).

Six men and 14 women were enrolled in the normal control group (Table 9). These subjects were either members of the hospital volunteer staff, or spouses and friends of our patients. The mean age of this sample was 67 years (standard deviation: 4.4 years) ranging from 57 to 74 years. Snellen visual acuity varied between 6/4 and 6/12, with the mean value of 6/6. Subjects in the reference group were examined and had no underlying vision problem except for correctable refractive error.

Both the patients and the normal controls had their central 24 degrees of visual field plotted using the Humphrey 24-2 threshold strategy program (Humphrey Visual Field Analyzer, Humphrey Instruments, Inc; Allergan Humphrey, San Leandro, CA, USA). To minimise the possible influence of minor, clinically nonsignificant cataract in this age sample, the cut-off point for Snellen visual acuity was chosen at 6/12 for both groups. Refractive error was corrected for any of the tests and only respondents with refractive error smaller than 4

dioptres and a stigmatism of less than 2 dioptres were included in the study. Pupil size was recorded in all subjects. General health and mental health were measured using a shortened form of the MOS-20 (220), based on the recommendations of Cotton, Hill and Aspinall (215). These authors, as it was previously mentioned in the review of the pilot study, carried out an extensive study considering the influence of psychosocial and demographic variables on visual impairment. Based on their recommendations, the factors with the strongest influence were included in this study: 10 questions addressing psychosocial variables (questions originated from the Nottingham Adjustment Scale (221), based on the recommendations of Cotton, Hill and Aspinall (215)). The type of local ophthalmic medication was also noted (Pilocarpine or other). All respondents had to understand and speak fluently in English to respond to the questionnaire.

The four groups (three patient groups and normal control group) were not significantly different in relation to age, sex, Snellen visual acuity, pupil size, general health, mental health or psychosocial measures (Table 9). There was no statistically significant difference among patient groups in relation to local ophthalmic medication (Pilocarpine or other) (Table 9).

8.3 Methods

8.3.1 Visual Disability Questionnaire

A newly created questionnaire was used to record self-reported disability in glaucoma patients. The process of developing this questionnaire benefited from previous studies on visual disability in glaucoma (41, 145) and other ocular conditions (9, 132, 152, 201, 215) as well as from the clinical experience of a glaucoma specialist (Mr. Colm O'Brien). The questionnaire was piloted prior to the main study on a sample of 65 glaucoma subjects with various degrees of visual field loss. The process of developing the questionnaire and examining its performance characteristics were described in detail in the section dealing with the pilot study. Just to remind the reader, a significant correlation with the measure of severity of visual field loss was found thus demonstrating the validity of the questionnaire. The reliability of the questionnaire subscales as measured using Cronbach's α was very high at minimum $\alpha = 0.92$.

The questionnaire used in the main study comprised of a total of 58 questions. Visual disability was assessed in the following areas: personal care and domestic tasks; glare and dark adaptation; navigation and mobility; navigation at night; near vision, social contact and leisure activities. In addition questions were included addressing general health, mental health (shortened form of the MOS-20 (220), based on the recommendations of Cotton, Hill and Aspinall (215)) and psychosocial measures (shortened form of the Nottingham Adjustment Scale (221), based on the recommendations of Cotton, Hill and Aspinall (215)). The questions were to be answered on a five point scale ranging from "no difficulty at all" to "severe difficulty". It was also made clear that patients had to answer questions on visual disability in relation to their vision alone. An extra option was given in the questionnaire in case the patient did not carry out a particular task for other than visual reasons. The experience from the pilot study showed that questions were formulated in plain English and easy to understand. The patients

administered the questionnaire themselves for two reasons. Firstly, the patient was about to undergo a battery of psychophysical tests for a period of two hours and any extra time could increase the fatigue effect. Secondly, when consulting a psychologist with experience in questionnaire surveys (Prof. Peter Aspinall), a self-administered questionnaire was recommended because experience has shown that patients reacting to hospital staff tend to try to answer in a more positive manner than they would in their home environment and underevaluate the real extent of their difficulties.

8.3.2 Assessment of Visual Function

All patients and normal controls underwent a series of visual function tests by the same person (Mrs. Patricia Nelson) with the exception of visual field plots and Snellen VA test in some patients who had had these tests done previously as a part of their clinical examination. When it was necessary, subjects had their vision corrected using clear monofocal glasses. The order of the test administration was randomised and a trial run was performed to ensure that subjects understood the nature of the test. The experimental protocol took on average two hours. Subjects were given at least one break during the experiment. Normal controls or patients who had not had their visual fields plotted on the Humphrey Visual Field Analyser before were given this test on a separate day prior to the experiment. A note was taken of pupil diameters in mm (estimating by eye, under the same lighting conditions for all subjects) and ophthalmic medication. The tests were performed in a time-frame that was aimed to avoid the time-frame of a daily ophthalmic medication regime as some drops containing Pilocarpine or Propine could in some cases affect visual performance.

Distance Visual Acuity

Visual acuity was measured using the Snellen chart (details see chapter 'Visual Function in Glaucoma'). In comparison to the pilot study, where visual acuity was requested to be 6/12 or better in the better eye, only subjects with visual acuity 6/12 or better in *each* eye were included in the main study. This decision was made following further literature search on correlation between monocular and binocular visual performance (225).

Visual Field Examination

The Humphrey Visual Field Analyzer (Humphrey Instruments, Inc; Allergan Humphrey, San Leandro, CA, USA), an automated static perimeter was used in this study to plot visual fields in all patients and normal controls. Two programs were used and a trial run was given before either of them:

Humphrey 24-2 threshold strategy monocular test plotted the central 24 degrees of visual field in both eyes. This test is clinically used for quantitative assessment and progression of visual field damage separately in each eye. Apart from statistical evaluation this test offers a grayscale picture of visual fields. In all subjects the right eye was done as first in this study. This test was used when grouping the patients into the three groups of severity of visual field loss as described in Subjects. The resulting Mean Deviation (MD), a measure of a generalised loss, and Corrected Pattern Standard Deviation (CPSD), a measure of localised loss, were recorded in dB units. This test was carried out on a separate day prior to experiment because it is time consuming (approximately 15 min per eye) and requires high concentration.

Esterman binocular field test. This test is one of the tests used clinically for examination of driving abilities according to DVLA recommendations. It is a qualitative test using suprathreshold strategy. It provides information on

functionality of the binocular field of vision. The test plots the central 150 degrees of binocular visual field. The result is recorded in % on the test performance. A subject is allowed to drive if the visual field defect does not affect the central 20 degrees of binocular visual field. The test takes approximately 5 minutes.

Contrast Sensitivity (CS)

Pelli-Robson Letter Sensitivity Chart. The chart is placed at 1 m from the patient and illuminated to approximately 100 cd/m2 in accordance with recommended standards for vision testing (National Academy of Sciences - National Research Council, 1980). The Pelli-Robson chart consists of eight rows of six uppercase Sloan letters. The letters are arranged in triplets, two triplets per row. The letters are of constant size (6/190 Snellen equivalent), but triplets decrease in contrast by 0.15 log units. The test is administered like an ordinary acuity test. The patient names the letters and the test continues until two or more errors are made in a triplet. Blank responses are not allowed so the test is truly forced-choice. Contrast threshold is determined by the last group in which at least two of the three letters are correctly identified and noted in log CS units. The test was performed both binocularly and also monocularly on each eye, right eye first.

Some studies have shown that the Pelli-Robson chart is more reliable than sinewave grating charts (75). Although the test is limited to providing information only about low to medium spatial frequencies, this is the range that is most closely associated with visual performance in tasks like reading (226), face recognition (77), and mobility (78). In addition, the work of Elliot done in 1989-90 has demonstrated that contrast sensitivity at higher spatial frequencies is more highly correlated with visual acuity and thus would be less likely to provide new information (79).

Visual Stimulus Generator (Cambridge Research Systems, Ltd., Rochester, England). This is a highly sophisticated research instrument designed to investigate contrast sensitivity. The instrument is fully automated. The software (Psycho for windows, Cambridge Research Systems, Ltd.) enables a scientist to design a test with the target that can alter in contrast, spatial and/or flicker frequency. In the visual disability study we used a test with a single disc shape target placed in the middle of the screen. Spatial frequency of 3 c/deg was chosen for the target as human vision reaches its maximum detection/resolution at this level (45). The target was viewed from the distance of 2 metres. One alternative forced-choice psychophysical technique was used during the test and the result of the test was the threshold level in log CS units recorded after seven reversals. Contrast decreased and increased in 2 dB steps. A trial run was given prior to this test.

Critical Flicker Frequency (CFF)

The Visual Stimulus Generator was used to perform this test. We used a single disc-shaped stimulus placed in the centre of the screen flickering at low contrast (30%). When the test started, the stimulus was flicking at the clearly visible frequency of 27 Hz. During the test the frequency of flicker increased till the subject was not able to see the target. The one alternative forced-choice technique was used and a result of the test was the threshold level in Hz recorded after seven reversals. Flicker increased and decreased in 2 dB steps. A trial run was given before this test.

Brightness Acuity Test

The effect of glare on visual acuity and contrast sensitivity was investigated using the Brightness Acuity Tester (BAT) by Mentor O&O, Inc., USA. In the

present study the glare test was performed using the Pelli-Robson contrast sensitivity chart. The BAT is a hand-held tool used monocularly. The patient views the chart through the hole of the illuminated hemisphere. The result is taken as log CS of the last triplet that a subject is able to read. The test takes approximately 15 minutes when performed with two of the three glare conditions as provided by the manufacturer (moderate 200 ftL and high 400 ftL). We combined monocular results using probability summation of monocular fields recommended by Nelson-Quigg and Johnson et al (225) in their study on predicting binocular visual sensitivity of glaucoma patients using monocular data:

Binocular Sensitivity = Square Root (Square(Sensitivity R eye)+Square(Sensitivity L eye))

Dark Adaptation

Dark adaptation was tested using the Goldmann Weekers Dark Adaptometer. The 30 minute procedure was shortened to 20 minutes using a 2 min pre-adaptation period at low luminance level. The decision was taken after a pilot experiment was carried out comparing the results of the standard test procedure (5 min pre-adaptation at 5000 cd/m2, 30 min dark adaptation) with a shorter test where the subject was pre-adapted at low luminance (2 min pre-adaptation at 100 cd/m2, 20 min dark adaptation). The decision to use the shortened test was based on a paper which found that after 15 minutes of dark adaptation, anomalies were obvious in glaucoma subjects giving significantly different results from normal controls (84).

The psychophysical method of limits was used in this test. After the pre-adaptation period, the patient's sensitivity of light perception was recorded. The luminance of the light source was increased and decreased and patient's response when he noticed the light for the first time or stopped seeing it completely was recorded. This procedure was repeated approximately every 2 minutes for 20

minutes. A dark adaptation curve was plotted. Note of the final dark adaptation threshold was taken for statistical analysis.

Stereopsis

The Frisby stereotest was used for the study purposes. The test set consists of three plates of different thickness made of clear plastic. Four identical squares with a pattern are printed on each plate. In one of the squares a small central part of the pattern is printed on the back side of the plate rather than on its front. The patient is supposed to see depth of the picture, i.e. thickness of the plate given by prints on each side in one of the squares, and asked to point to the square with the depth picture in it. By altering the thickness of the plates and changing the viewing distance a final result can be computed. The test takes approximately 5 minutes.

Colour Test

The Farnsworth desaturated D-15 colour test was used as the measure of colour vision. It is a shortened version of the well known Farnsworth-Munsell 100 Hue Test. It is intended for screening purpose, rather than for the in-depth study of a colour vision defect. Each set of discs contains a reference or 'pilot' cap, holding Munsell notation 10 B 5/4 and fifteen numbered disc which make up an incomplete colour circle. Each disc is partially safeguarded from being touched, and therefore spoilt, by mounting in a plastic cap. Subjects taking the test were asked not to touch the coloured surface. The performance on this test can be influenced by lighting conditions and therefore we used a light source recommended by the manufacturer of the Huematic-100 Colour Vision Test, Clement Clarke International Ltd. The patient was asked to arrange 15 colour caps into a line starting from a given colour. The presence of a significant defect

can be detected. In our study, the presence of any defect was recorded as 'positive' (1) and the perfect arrangement was recorded as 'negative' (0).

8.4 Statistical Analysis

Statistical analysis was carried out using SAS statistical software package (SAS Institute Inc., Cary, NC, USA) and SPSS statistical software package (SPSS for Windows; Version 6.0, Chicago, IL, USA).

For the purpose of the statistical analysis, the results were adjusted for the influence of age, sex and physical disability. It was already mentioned earlier that the four groups (three patient groups and normal control group) did not differ in terms of age, sex, Snellen visual acuity, pupil size, general health, mental health and psychosocial measures, and that there was no difference between the three patient groups in local ophthalmic medication (Pilocarpine or other). Where necessary, monocular data (Mean Deviation perimetric values, Pelli-Robson contrast sensitivity and glare disability results, Snellen visual acuity) were transformed using a formula recommended by Johnson and Nelson-Quigg et al (225):

Binocular Sensitivity = Square Root (Square(Sensitivity R eye)+Square(Sensitivity L eye))

Visual Disability Questionnaire

Factor analysis using the Varimax rotation of the Principal Component Analysis was used to process the results of the questionnaire (216).

Visual Disability Questionnaire in Relation to the Severity of Visual Field Loss

The Fisher's Exact two-tail test (SAS) was used to determine the relationship (227).

Summary Performance Measure for Visual Disability Questionnaire

As there were no missing values in the set of answers a summary performance measure was calculated by adding the scores on the 15 questions that were found to be significantly related with the severity of visual field loss.

Severity of visual field loss. A General linear models procedure (Type III SS test) and Least square means procedure (227) was performed on the four groups with various degrees of visual field loss.

Visual Function Tests in Relation to the Severity of Visual Field Loss in Glaucoma

The General linear models procedure (Type III SS test) and Least square means procedure (227) was performed on the four groups with various degrees of visual field loss (227).

Visual Disability Questionnaire and Measures of Visual Function

Fisher's Exact two-tail test was used to determine the relationship (227).

Summary Performance Measure for Visual Disability Questionnaire. Relationship with Visual Function Tests

Analysis of variance of the General linear models procedure was carried out to investigate the relationship between a summary performance value and each of the visual function tests (227).

Chapter 9

RESULTS

9.1 Visual Disability Questionnaire

9.1.1 Factor Analysis

Factor analysis, as was mentioned earlier, deals with the interrelationships within the data. It reveals the key groups of questions which underpin the problems reported by subjects.

Factor analysis identified five new groups of questions (factors). Taken together, these factors accounted for most of the variability in patients' responses (79%) and are summarised under the following general headings: central and near vision, peripheral vision (or actions demanding functional peripheral vision), dark adaptation and glare, personal care / household tasks and outdoor mobility. The technique simplified 36 questions in the questionnaire into five main groups.

Questions that correlated best on the five factors of the factors structure are listed in Table 10.

TABLE 10. *Factor structure of the data.*

DAILY ACTIVITIES	FACTOR 1 Central & near vision	FACTOR 2 Peripheral vision	FACTOR 3 Dark adaptation & glare	FACTOR 4 Personal care and household tasks	FACTOR 5 Outdoor mobility
Reading TV text	.86	.	.	.	.
Watching TV	.79	.	.	.	.
Bingo	.78	.	.	.	.
Following a line of print	.75	.	.	.	.
Reading letters	.74	.	.	.	.
Reading hymn numbers in the church	.72	.	.	.	.
	.70	.	.	.	.
Shopping	.69	.	.	.	.
Recognising faces	.65	.	.	.	.
Seeing bus numbers	.64	.	.	.	.
Bumping into objects	.	.82	.	.	.
Steps / stairs	.	.76	.	.	.
Seeing in periphery	.	.68	.	.	.
Indoor mobility	.	.68	.	.	.
Visiting friends & restaurants	.	.66	.	.	.
Judging distance of foot from step	.	.64	.	.	.
Tripping over	.	.63	.	.	.
Walking on uneven ground	.	.55	.	.	.
Adjusting to dim lights	.	.	.81	.	.
Going from light to dark	.	.	.78	.	.
Glare	.	.	.77	.	.
Seeing at night	.	.	.74	.	.
Walking in the dark	.	.	.68	.	.
Finding dropped objects	.	.	.64	.	.
Colour perception	.	.	.40	.	.
Pouring tea	.	.	.	.78	.
Garden	.	.	.	.75	.
Cooking	.	.	.	.74	.
Dressing	.	.	.	.61	.
Needlework	.	.	.	.60	.
Walking on the street	.	.	.	.	.77
Crossing the road	.	.	.	.	.72
Using a bus	.	.	.	.	.57

For the first factor, highly correlated activities were observed relating to *central and near vision* such as reading TV text, watching TV, watching bingo, following a line of print, reading letters, hymn numbers in the church or reading newspapers, shopping, recognising faces and seeing bus numbers. The second factor *peripheral vision* indicated difficulty with activities demanding functional peripheral vision such as bumping into objects, walking on steps or stairs, seeing in the periphery, moving in unfamiliar places while visiting friends and moving around in restaurants, judging distance of foot from step, tripping over objects and walking on uneven ground. Difficulties related to *dark adaptation and glare* such as adjusting to dim lights, going from light to dark or vice versa, disability glare, seeing at night, walking in the dark, finding dropped objects (this is an activity which is crucially dependent on sufficient lighting). Colour perception difficulties also correlated on this factor. A number of peripheral vision questions (Factor 2) had correlations which spread also across Factor 3; these are not presented in the Table 10 because the correlations were lower than the threshold of inclusion in the table. This is an indication that these two factors may integrate into a "glaucoma specific factor". The fourth factor *Personal care and household tasks* clearly defined problems with typical household and personal activities: pouring tea, working in the garden, cooking, dressing, needlework. *Outdoor mobility* tasks like walking on the street, crossing the road and using a bus correlated on the fifth factor.

9.1.2 Visual Disability Questionnaire in Relation to a Measure of Severity of Visual Field Loss

Fisher's Exact Test (2-tail), SAS was used to perform this analysis. Fifteen questions were found to be significant predictors of visual field loss (Table 11). Six of these questions correlated on Factor 3 (dark adaptation and glare) of the questionnaire factor structure, six questions correlated on Factor 2 (actions demanding functional peripheral vision), two questions correlated on Factor 1 (central and near vision) and one question correlated on Factor 5 (outdoor mobility) (Tables 10, 11). The best predictors seem to be the questions on the following activities / abilities: walking after dark ($p<0.001$), seeing at night ($p<0.001$), seeing objects coming from the side ($p<0.001$), adjusting to dim light ($p=0.001$), walking on uneven ground ($p=0.001$), disability glare ($p=0.002$), going from light to dark room or vice versa ($p=0.002$), recognising faces ($p=0.002$), tripping over objects ($p=0.004$), finding dropped objects ($p=0.005$), judging distance of foot to step ($p=0.005$), crossing the road ($p=0.006$), walking on steps / stairs ($p=0.009$), reading newspapers ($p=0.01$), bumping into objects (0.02).

TABLE 11. *Glaucoma Visual Disability questionnaire in relation to a measure of severity of visual field loss. Fisher's Exact Test (2-tail).*

Daily Activity	Severity of VF loss p-value	Factor No.	Factor Description
Walking after dark	<0.0001	3	Dark adaptation & glare
Seeing at night	<0.0001	3	Dark adaptation & glare
Seeing objects coming from the side	<0.0001	2	Peripheral vision
Adjusting to dim light	0.001	3	Dark adaptation & glare
Walking on uneven ground	0.001	2	Peripheral vision
Glare	0.002	3	Dark adaptation & glare
Going from light to dark room or vice versa (13)	0.002	3	Dark adaptation & glare
Recognising faces (30)	0.002	1	Central & near vision
Tripping over objects(17)	0.004	2	Peripheral vision
Finding dropped objects (10)	0.005	3	Dark adaptation & glare
Judging distance of foot to step (20)	0.005	2	Peripheral vision
Crossing the road (22)	0.006	5	Outdoor mobility
Walking on steps/stairs (16)	0.009	2	Peripheral vision
Reading newspapers (27)	0.011	1	Central & near vision
Bumping into objects (18)	0.015	2	Peripheral vision

9.1.3 Summary Performance Measure for Visual Disability Questionnaire. Relationship with Severity of Visual Field Loss

As there were no missing values in the set of answers a summary performance measure (or: questionnaire index) was calculated by simply adding the scores on the 15 questions that were found to be significantly correlated with the severity of visual field loss (Table 11).

Severity of visual field loss. This summary measure was compared to perimetric Mean Deviation (MD) value (binocular transformation, details in 'Statistical Analysis') as well as to the measure of severity of visual field loss as defined in Methods. General linear models procedure was used to analyse the data. The relationship was significant for both measures, using Type III SS test ($p<0.0001$). Correlation with perimetric MD value was significant ($p<0.0001$, $r=-0.6$). Within the patient group, group differences were noted between mild and severe visual field loss ($p=0.008$), but not between the groups with mild and moderate ($p=0.08$) or moderate and severe ($p=0.16$) visual field loss (Table 12); however there was an evidence of difference between these groups and when increasing group numbers this difference could lead to significant results. There was a strong difference between normal subjects and all of the three patient groups ($p<0.01$).

The *reliability* of the questionnaire subscale selected for the questionnaire performance index (Table 11) was tested using Cronbach's α. This value was found to be high at Cronbach's $\alpha = 0.92$.

TABLE 12. *Relationship between severity of visual field loss and visual disability questionnaire performance measure. Overall p-value<0.0001. (General linear models procedure, Least square means analysis).*

	Questionnaire Score (SD)	Normal VF p-value	Mild VF loss p-value	Moderate VF loss p-value
Normal VF	15.7 (1.0)	.	.	.
Mild VF loss	20.1 (1.0)	**0.0021**	.	.
Moderate VF loss	22.5 (0.9)	**0.0001**	0.0818*	.
Severe VF loss	24.9 (1.4)	**0.0001**	**0.0080**	0.1640*

VF: visual field. Results adjusted for the influence of age, sex, physical disability, pupil size and local ophthalmic medication. (* Indicates trend towards significance. Significance may be achieved with a larger sample size.)

9.1.4 Sensitivity / Specificity Ratios for the Questionnaire Performance Index. Unadjusted Values.

Sensitivity and specificity ratios for the questionnaire performance index, as seen in Table 13, Figures 2-5, were based on the original visual disability index values, i.e. raw data (no adjustment for other factors, see paragraphs below). When separating patients from normals the ratio was 77/82 %. When separating early glaucoma from normals, this ratio decreased to 65/82%. The questionnaire index separated normals from patients with moderate visual field loss with a high sensitivity/specificity ratio 79/100% and this increased when separating normals from patients with severe visual field loss to 100/82 %.

Table 13. *Sensitivity/Specificity ratio of the questionnaire performance index.*

	Normal controls
All patients	77/82 %
Mild VF loss	65/82 %
Moderate VF loss	79/100 %
Severe VF loss	100/82 %

Figure 2. *Sensitivity / Specificity relationship. Questionnaire Performance Index (data prior to adjustment): Comparing normal control and patient groups.*

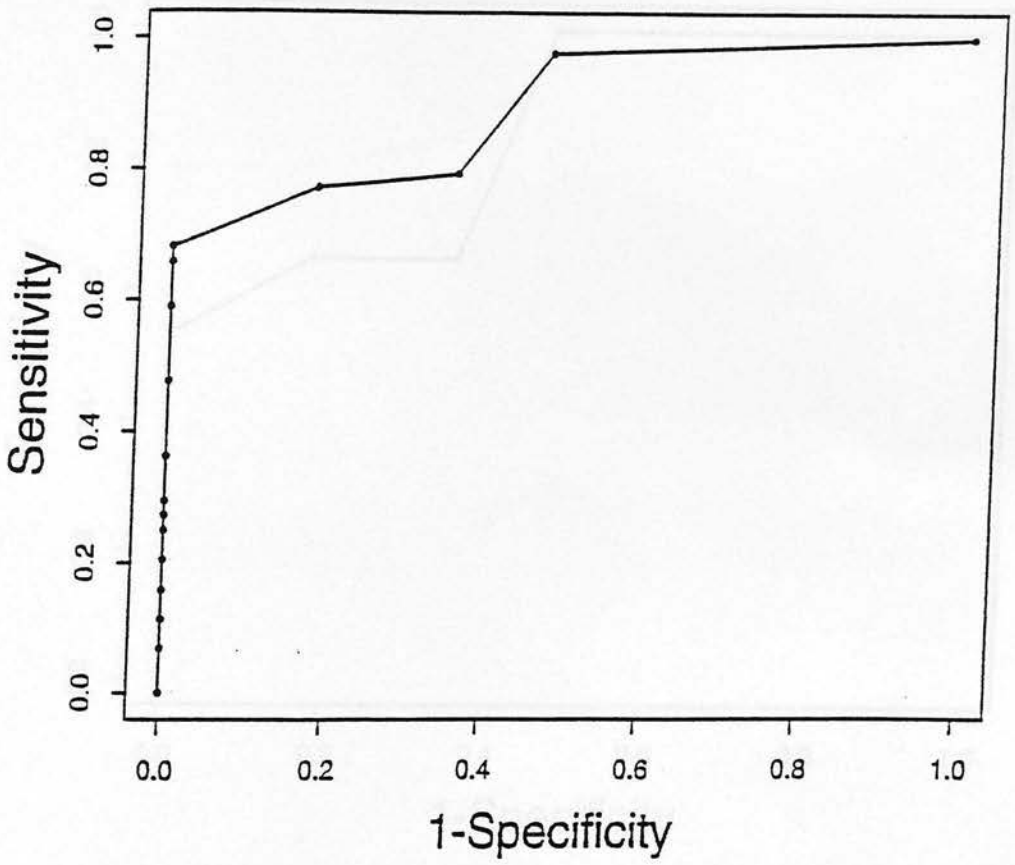


Figure 3. *Sensitivity / Specificity relationship. Questionnaire Performance Index (data prior to adjustment): Comparing normal controls and patients with mild visual field loss.*

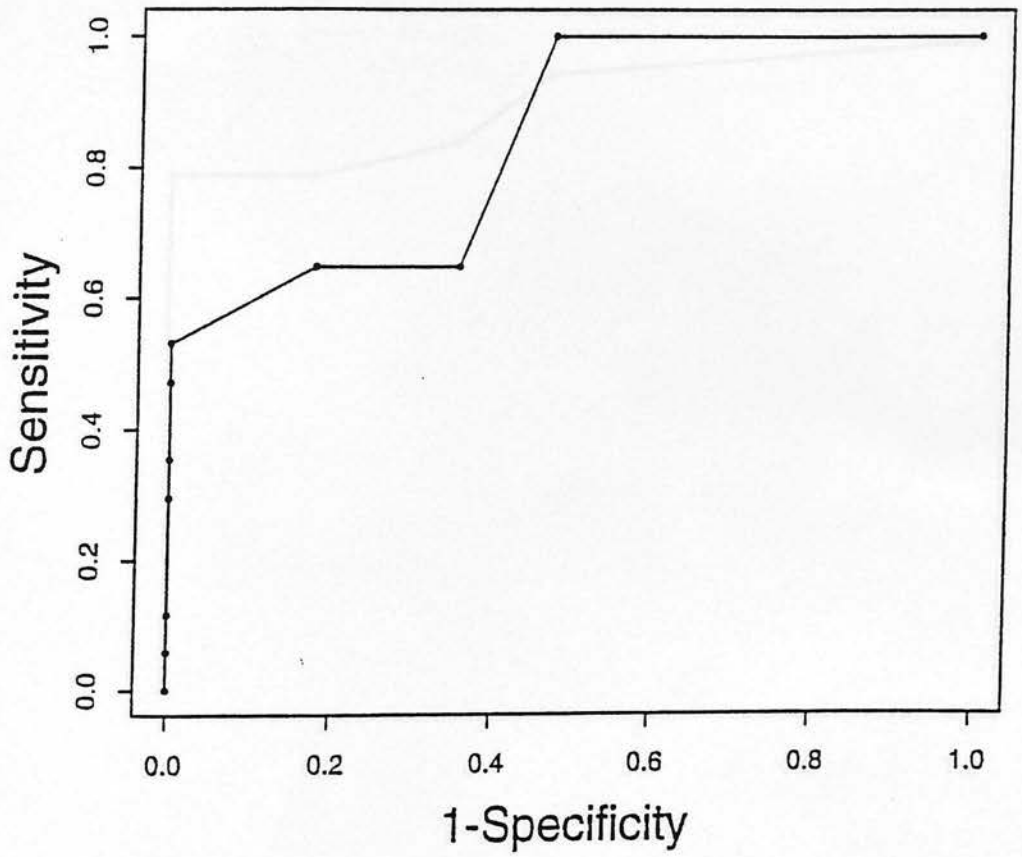


Figure 4. *Sensitivity / Specificity relationship. Questionnaire Performance Index (data prior to adjustment): Comparing normal controls and patients with moderate visual field loss.*

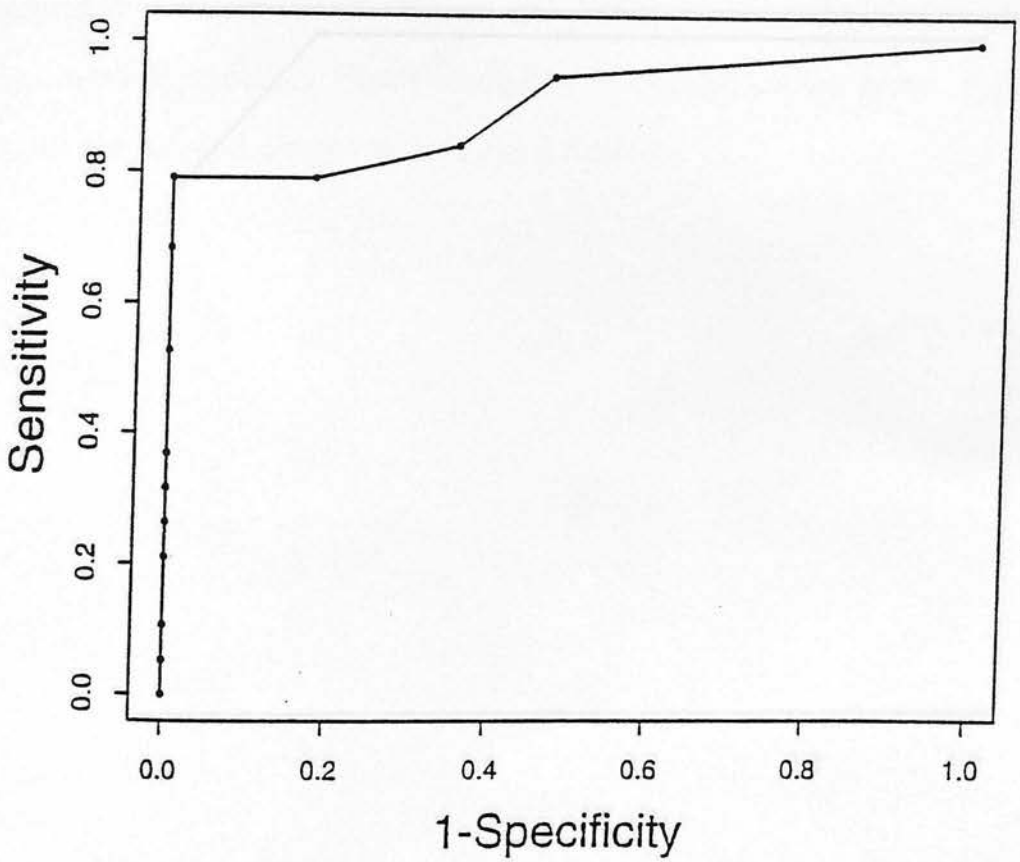
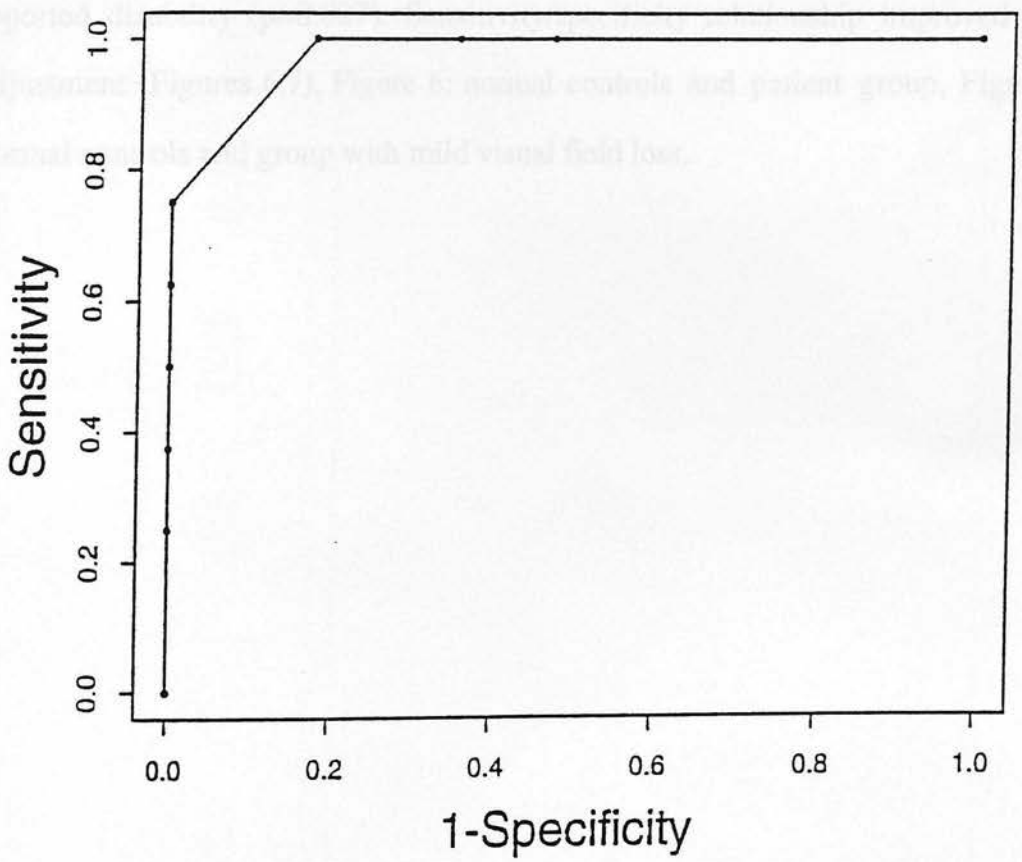


Figure 5. *Sensitivity / Specificity relationship. Questionnaire Performance Index (data prior to adjustment): Comparing normal controls and patients with severe visual field loss.*



9.1.5 Sensitivity / Specificity Ratios for Questionnaire Performance Index: Data Adjusted for the Influence of Age, Sex, Physical disability, Pupil Size and Ophthalmic Medication (Pilocarpine or other)

An attempt was made to adjust this relationship for the set of variables including age, sex, physical disability, pupil size and local ophthalmic medication (Pilocarpine or other) as stated in Subjects section. Pupil size emerged as a single parameter with significant impact on the summary (index) measure of self-reported disability ($p=0.027$). Sensitivity/specificity relationship improved after adjustment (Figures 6,7). Figure 6: normal controls and patient group, Figure 7: normal controls and group with mild visual field loss.

Figure 6. *Sensitivity / Specificity relationship. Questionnaire Performance Index (adjusted data): Comparing normal control and patient groups.*

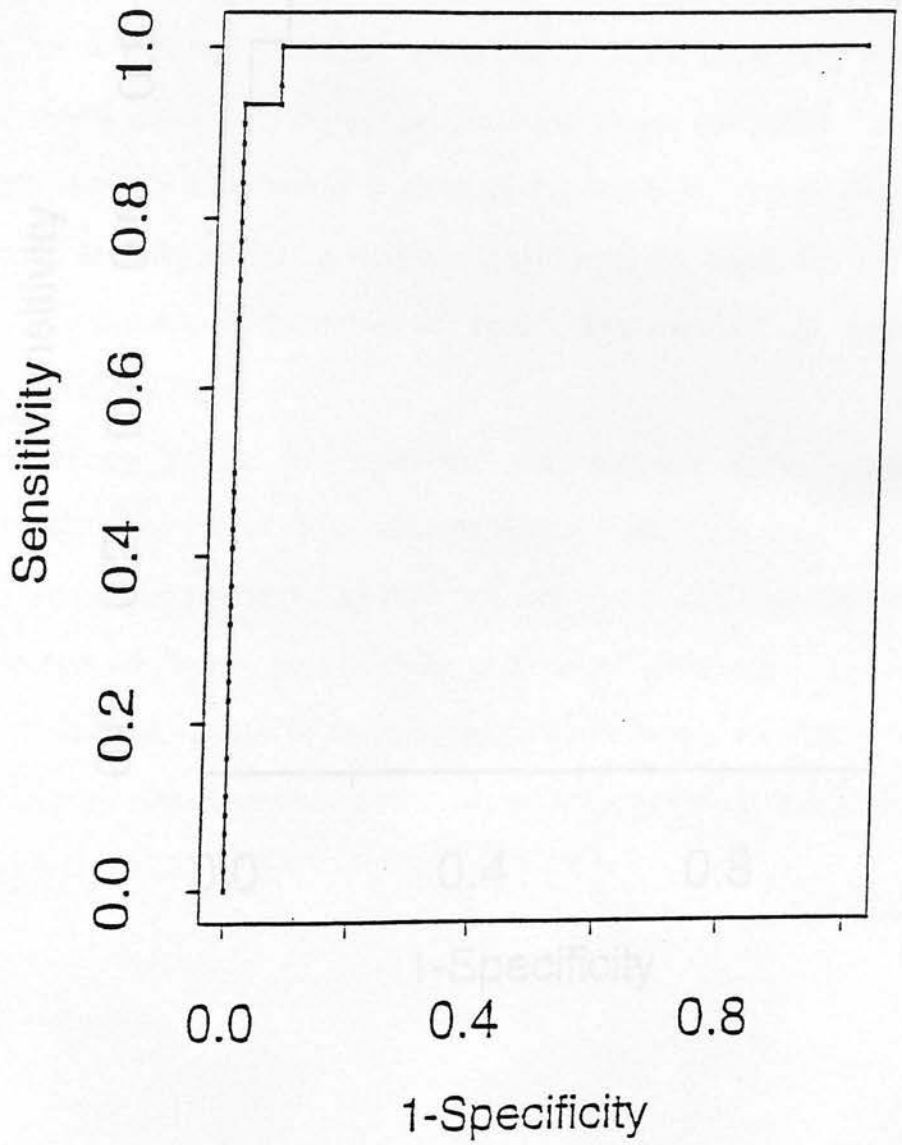
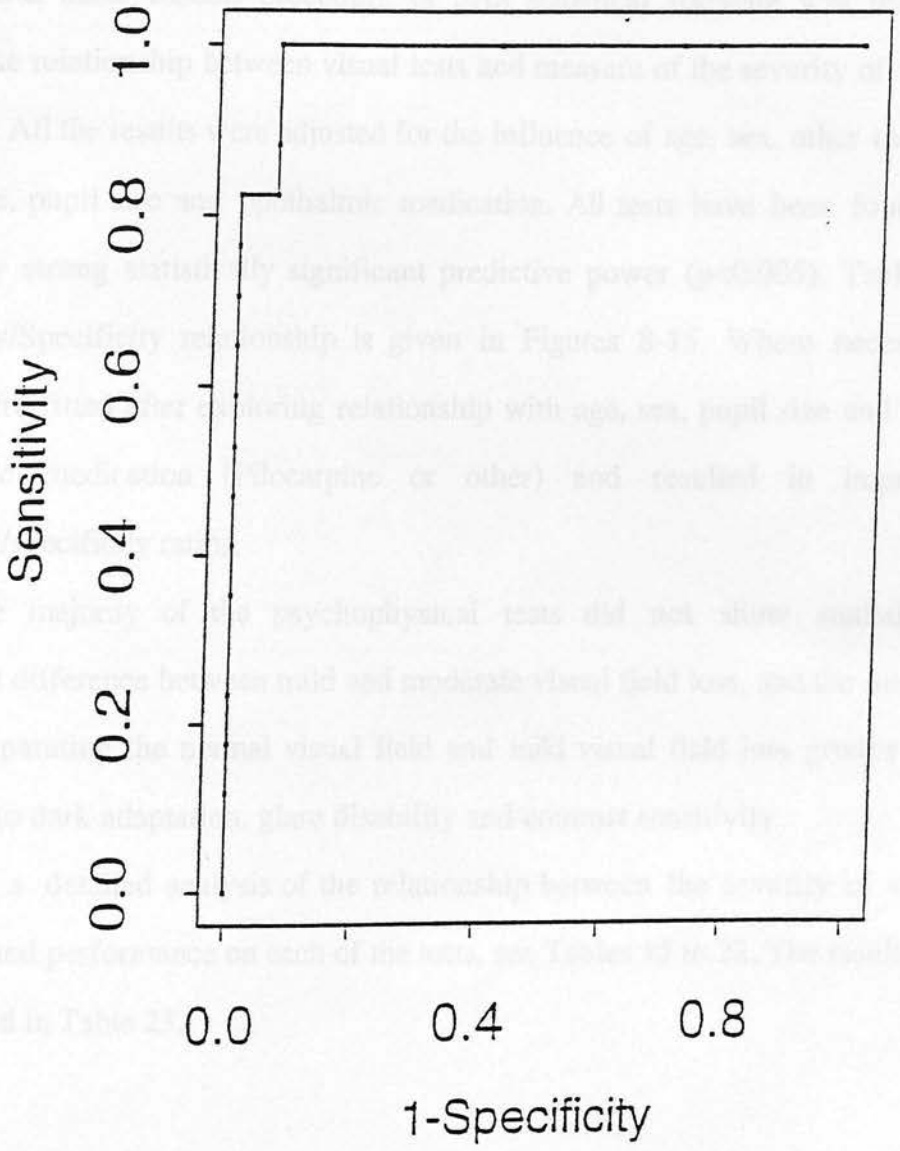


Figure 7. *Sensitivity / Specificity relationship. Questionnaire Performance Index (adjusted data): Comparing normal control and patients with mild visual field loss.*



9.2 Visual Function Tests in Relation to a Measure of Severity of Visual Field Loss in Four Groups with Various Degrees of Visual Field Loss

The General linear models procedure of SAS statistical software was used to analyse the relationship between visual tests and measure of the severity of visual field loss. All the results were adjusted for the influence of age, sex, other medical conditions, pupil size and ophthalmic medication. All tests have been found to have very strong statistically significant predictive power ($p<0.005$), Table 14. Sensitivity/Specificity relationship is given in Figures 8-15. Where necessary, values were fitted after exploring relationship with age, sex, pupil size and local ophthalmic medication (Pilocarpine or other) and resulted in improved sensitivity/specificity ratios.

The majority of the psychophysical tests did not show statistically significant difference between mild and moderate visual field loss, and the number of tests separating the normal visual field and mild visual field loss groups was restricted to dark adaptation, glare disability and contrast sensitivity.

For a detailed analysis of the relationship between the severity of visual field loss and performance on each of the tests, see Tables 15 to 22. The results are summarised in Table 23.

TABLE 14. *Psychophysical tests in comparison to the severity of visual field loss. General linear models procedure. Type III SS test.*

Psychophysical test	p-value	Significance p-value < 0.05 * p-value < 0.01 **
Snellen VA	0.564	
Esterman binocular VF	<0.0001	**
Stereoacuity	<0.0001	**
CFF	0.005	**
CS VSG	0.001	**
Pelli-Robson CS	<0.0001	**
Glare BAT medium	<0.0001	**
Glare BAT high	<0.0001	**
Dark adaptation	<0.0001	**

Figure 8. *Sensitivity/specificity relationship. Esterman binocular visual field test: Comparing patients and normal controls. Original data.*

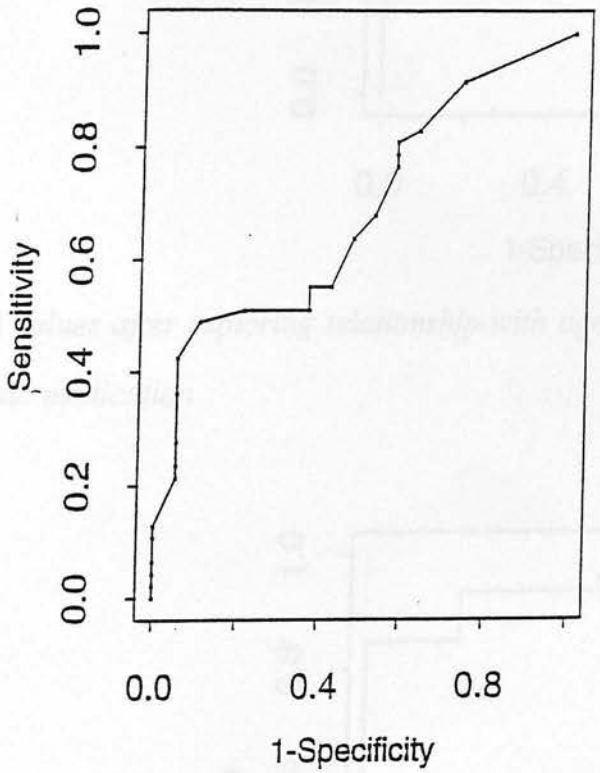
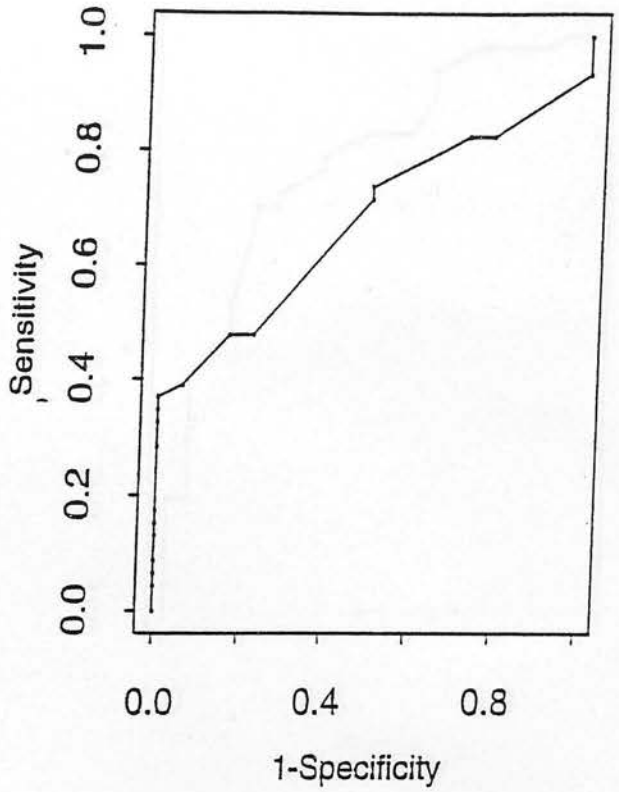


Figure 9. *Sensitivity/Specificity relationship. Stereoacuity: Comparing patients and normal controls.*

A) Original data.



B) Fitted values after exploring relationship with age, sex, pupil size and local ophthalmic medication

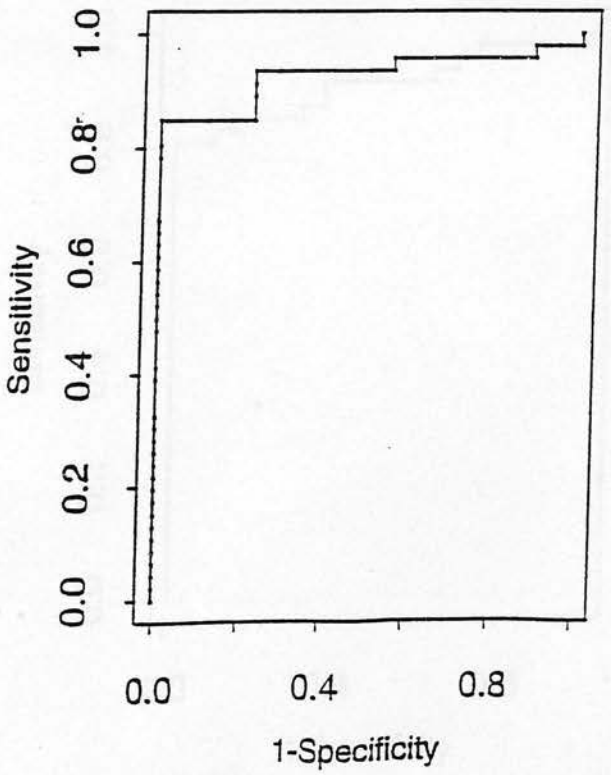
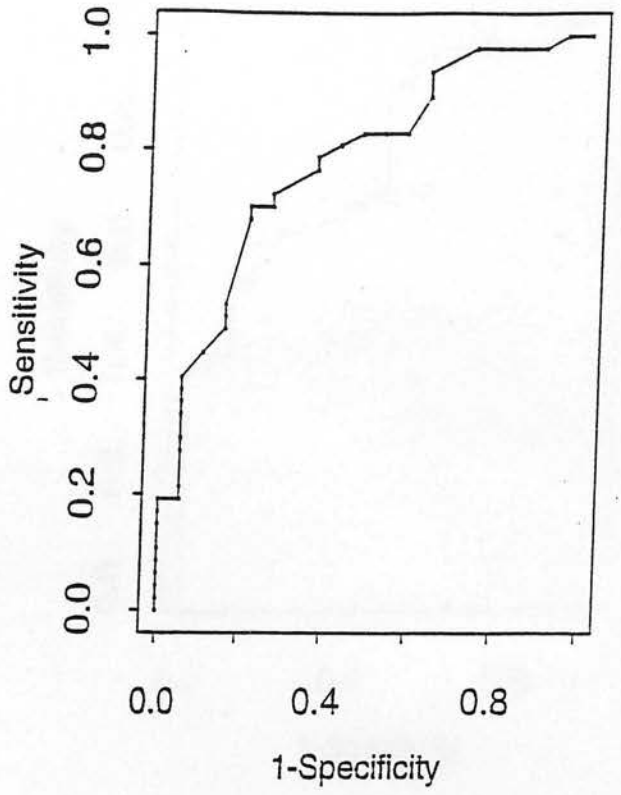


Figure 10. *Sensitivity/Specificity relationship. Critical flicker frequency: Comparing patients and normal controls.*

A) Original data.



B) Fitted values after exploring relationship with age, sex, pupil size and local ophthalmic medication

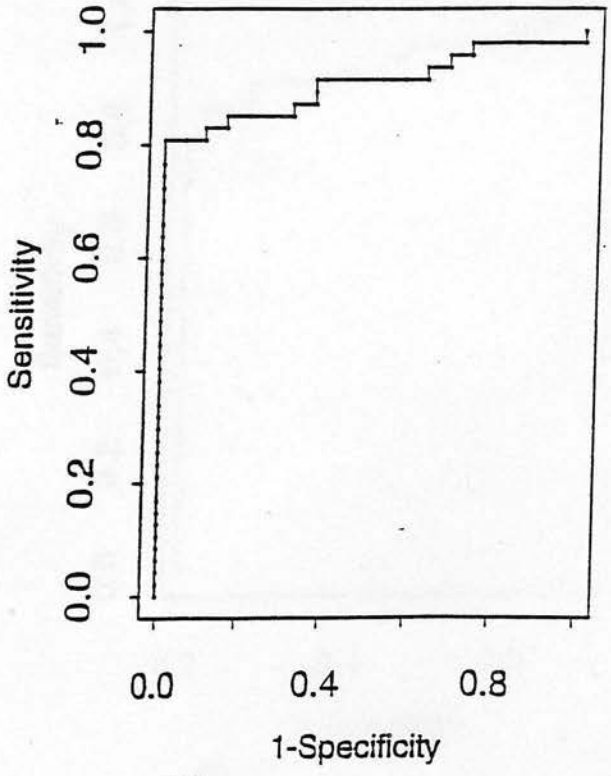
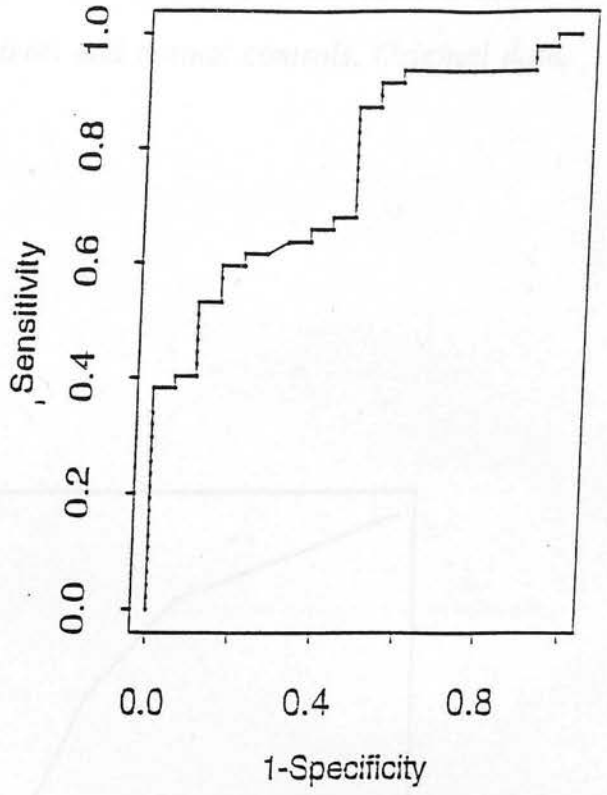


Figure 11. *Sensitivity/Specificity relationship. Contrast sensitivity using Visual Stimulus Generator: Comparing patients and normal controls.*

A) Original data.



B) Fitted values after exploring relationship with age, sex, pupil size and local ophthalmic medication

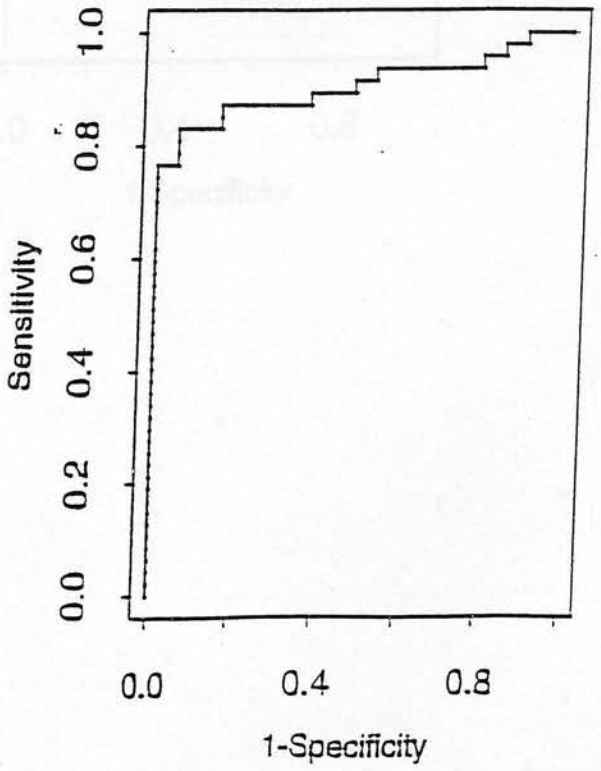


Figure 12. *Sensitivity/Specificity relationship. Pelli-Robson contrast sensitivity: Comparing patients and normal controls. Original data.*

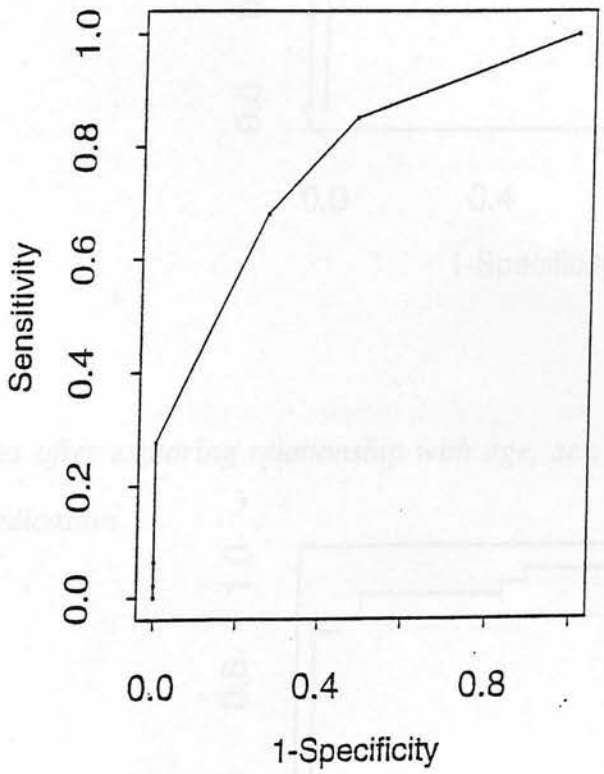
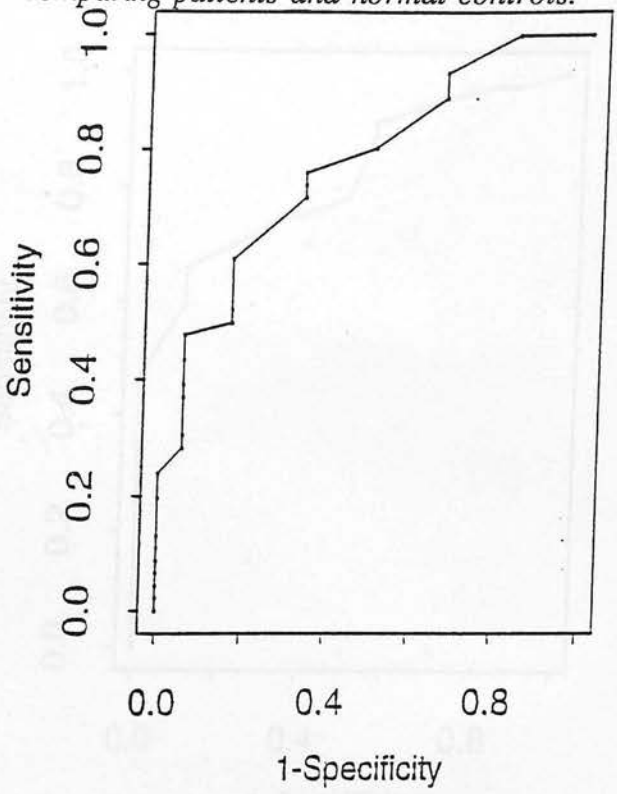


Figure 13. *Sensitivity/Specificity relationship. Brightness Acuity Tester glare disability (medium glare): Comparing patients and normal controls.*

A) Original data.



B) Fitted values after exploring relationship with age, sex, pupil size and local ophthalmic medication

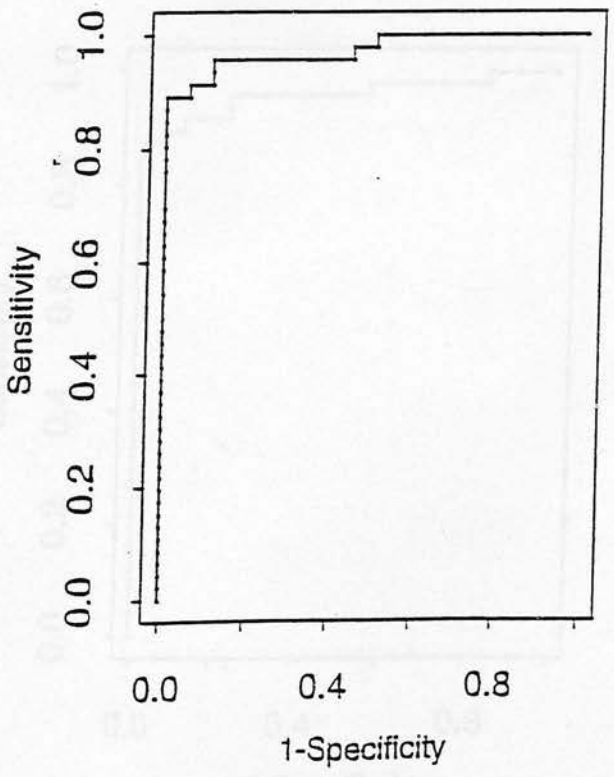
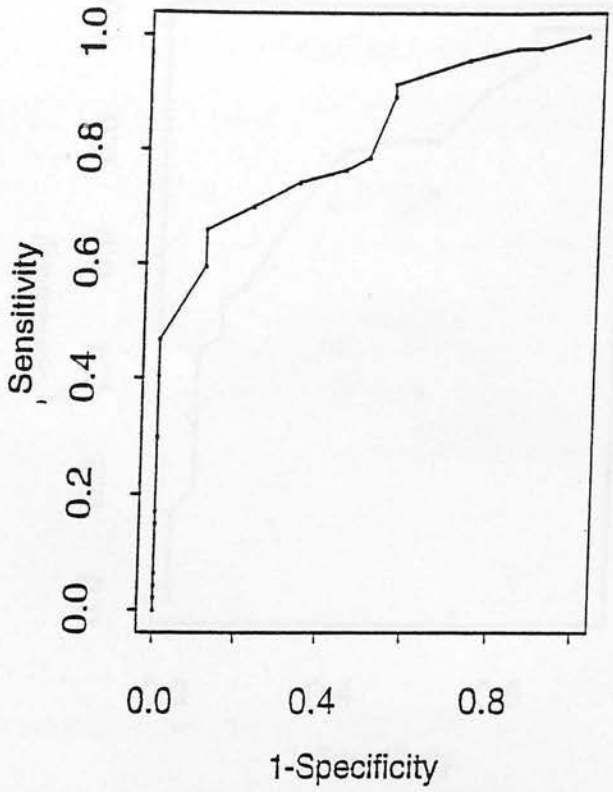


Figure 14. *Sensitivity/Specificity relationship. Brightness Acuity Tester glare disability (high glare): Comparing patients and normal controls.*

A) Original data.



B) Fitted values after exploring relationship with age, sex, pupil size and local ophthalmic medication

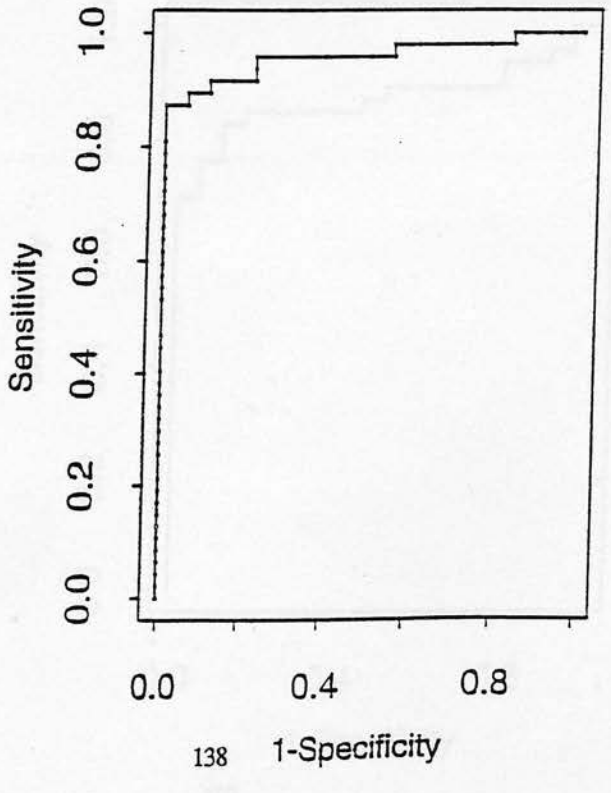
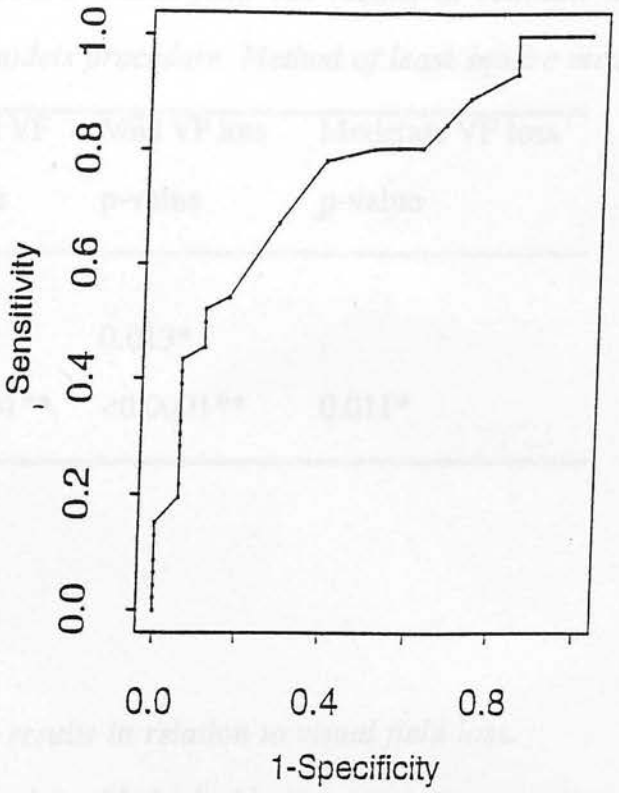


Figure 15. *Sensitivity/Specificity relationship. Dark adaptation: Comparing patients and normal controls.*

A) Original data.



B) Fitted values after exploring relationship with age, sex, pupil size and local ophthalmic medication

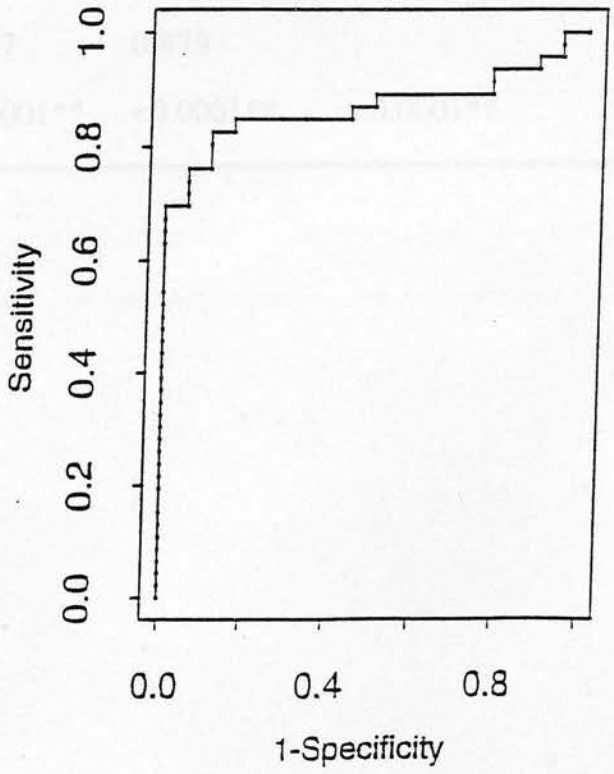


TABLE 15. *Esterman binocular visual field test results in relation to visual field loss. General linear models procedure. Method of least square means.*

	Normal VF	Mild VF loss	Moderate VF loss
	p-value	p-value	p-value
Mild VF loss	0.971	.	
Moderate VF loss	0.013*	0.013*	.
Severe VF loss	<0.0001**	<0.0001**	0.011*

*p<0.05 **p<0.01

TABLE 16. *Stereopsis test results in relation to visual field loss. General linear models procedure. Method of least square means.*

	Normal VF	Mild VF loss	Moderate VF loss
	p-value	p-value	p-value
Mild VF loss	0.598	.	
Moderate VF loss	0.497	0.879	.
Severe VF loss	<0.0001**	<0.0001**	<0.0001**

*p<0.05 **p<0.01

TABLE 17. *CFF test results in comparison to visual field loss. General linear models procedure. Method of least square means.*

	Normal VF p-value	Mild VF loss p-value	Moderate VF loss p-value
Mild VF loss	0.058	.	
Moderate VF loss	0.002**	0.215	.
Severe VF loss	<0.0001**	0.009**	0.082

*p<0.05 **p<0.01

TABLE 18. *Contrast sensitivity (Visual Stimulus Generator) in comparison to visual field loss. General linear models procedure. Method of least square means.*

	Normal VF p-value	Mild VF loss p-value	Moderate VF loss p-value
Mild VF loss	0.028*	.	
Moderate VF loss	0.013*	0.785	.
Severe VF loss	<0.0001**	0.003**	0.006**

*p<0.05 **p<0.01

TABLE 19. *Pelli-Robson CS test results in comparison to visual field loss. General linear models procedure. Method of least square means.*

	Normal VF p-value	Mild VF loss p-value	Moderate VF loss p-value
Mild VF loss	0.039*	.	
Moderate VF loss	0.001**	0.241	.
Severe VF loss	<0.0001**	0.001**	0.014*

*p<0.05 **p<0.01

TABLE 20. *Glare BAT test results (MEDIUM) in comparison to visual field loss. General linear models procedure. Method of least square means.*

	Normal VF p-value	Mild VF loss p-value	Moderate VF loss p-value
Mild VF loss	0.008**	.	
Moderate VF loss	0.018*	0.722	.
Severe VF loss	<0.0001**	0.019*	0.009**

*p<0.05 **p<0.01

TABLE 21. *Glare BAT test results (HIGH) in comparison to visual field loss. General linear models procedure. Method of least square means.*

	Normal VF p-value	Mild VF loss p-value	Moderate VF loss p-value
Mild VF loss	0.023*	.	
Moderate VF loss	0.029*	0.900	.
Severe VF loss	<0.0001**	0.010**	0.008**

*p<0.05 **p<0.01

TABLE 22. *Dark adaptation test results in comparison to visual field loss. General linear models procedure. Method of least square means.*

	Normal VF p-value	Mild VF loss p-value	Moderate VF loss p-value
Mild VF loss	0.013*	.	
Moderate VF loss	0.001**	0.354	.
Severe VF loss	<0.0001**	0.008**	0.047*

*p<0.05 **p<0.01

Table 23. *Psychophysical tests in relation to severity of visual field loss. Specific groups.*

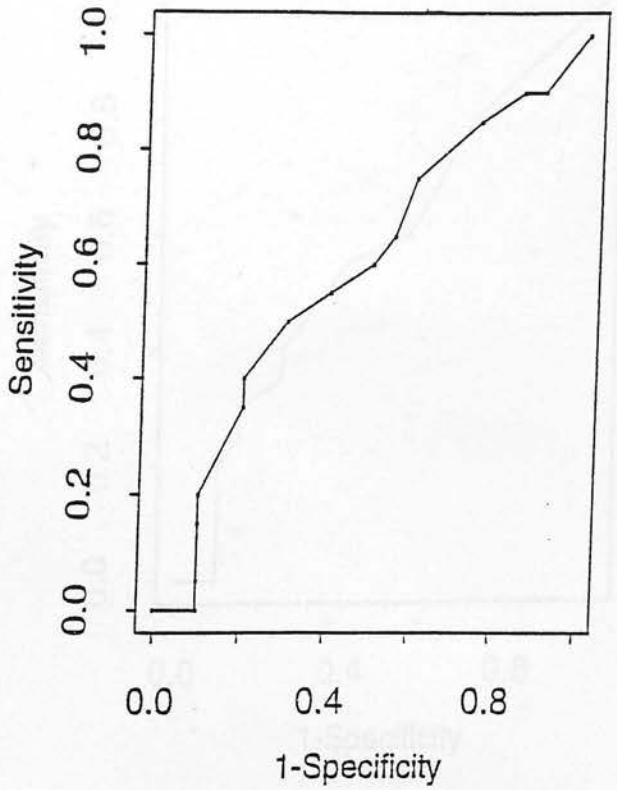
Psychophysical tests	Normals vs. Mild loss (p-value)	Normals vs. Mod. loss (p-value)	Mild loss vs. Mod. loss (p-value)	Mod. loss vs. Severe loss (p-value)
Esterman VF test	0.971	**0.013**	**0.013**	**0.011**
Stereopsis	0.598	0.497	0.879	**0.000**
CFF	0.058	**0.002**	0.215	0.082
CS (VSG)	**0.028**	**0.013**	0.785	**0.006**
Pelli-Robson CS	**0.039**	**0.001**	0.241	**0.014**
Glare disability	**0.023**	**0.029**	0.900	**0.008**
Dark adaptation	**0.013**	**0.001**	0.354	**0.047**

Comparing normals subjects and patients with mild visual field loss. When separating normals from mild glaucoma, a group of tests emerged including dark adaptation, glare disability and contrast sensitivity giving significant results when separating these two groups. The best results were obtained for dark adaptation (p=0.013) and glare disability (p=0.023), followed by contrast sensitivity using the Visual Stimulus Generator (p=0.028) and the Pelli-Robson chart (p=0.039) (Table 23). Sensitivity/Specificity ratios (Figures 16-19), were adjusted, where necessary, for influence of age, sex, pupil size and ophthalmic medication (Pilocarpine or other), which resulted in improved ratios.

No significant results were found in our study between normals and early glaucoma for critical flicker frequency, stereopsis and Esterman visual field tests (p>0.05) (Table 23).

Figure 16. *Sensitivity/Specificity relationship. Dark adaptation: Comparing patients with mild visual field loss and normal controls.*

A) Original data.



B) Fitted values after exploring relationship with age, sex, pupil size and local ophthalmic medication

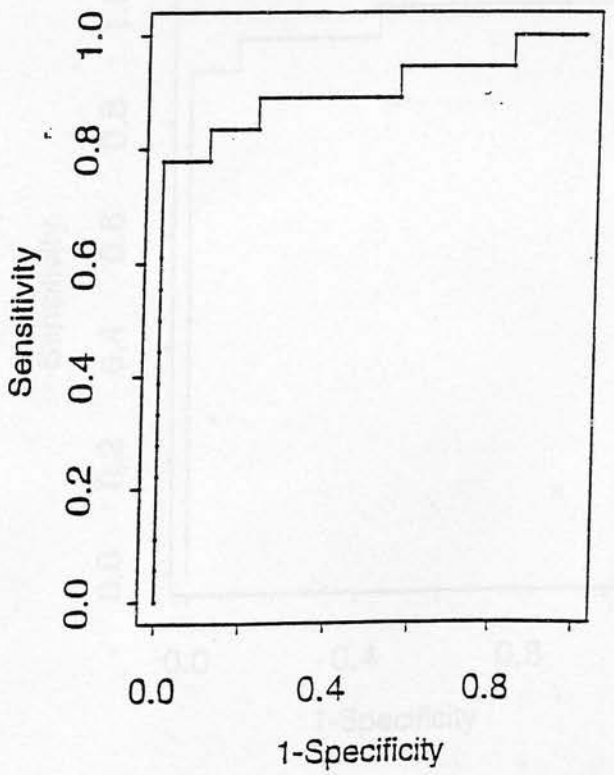
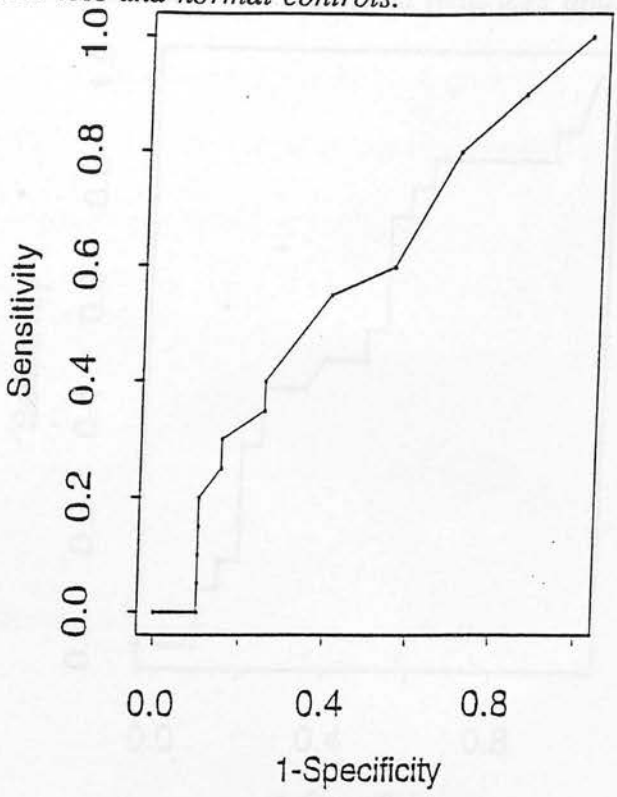


Figure 17. *Sensitivity/Specificity relationship: Glare disability. Comparing patients with mild visual field loss and normal controls.*

A) Original data.



B) Fitted values after exploring relationship with age, sex, pupil size and local ophthalmic medication

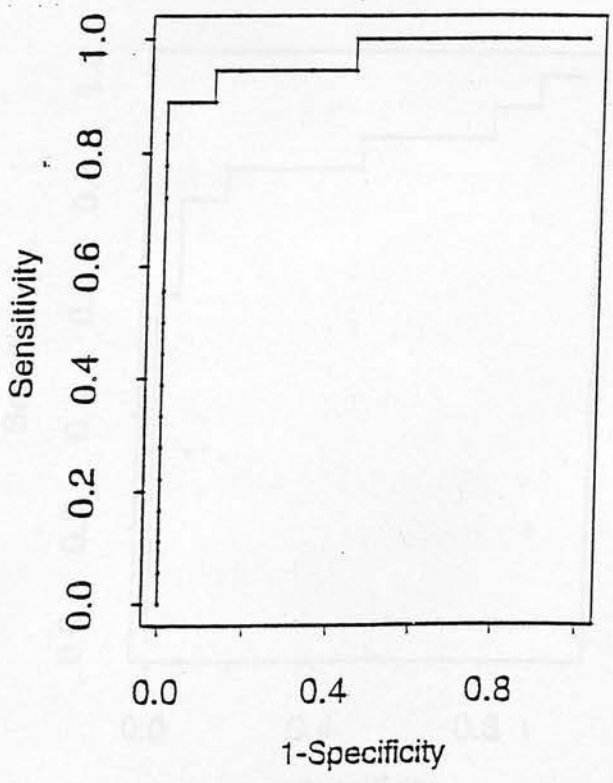
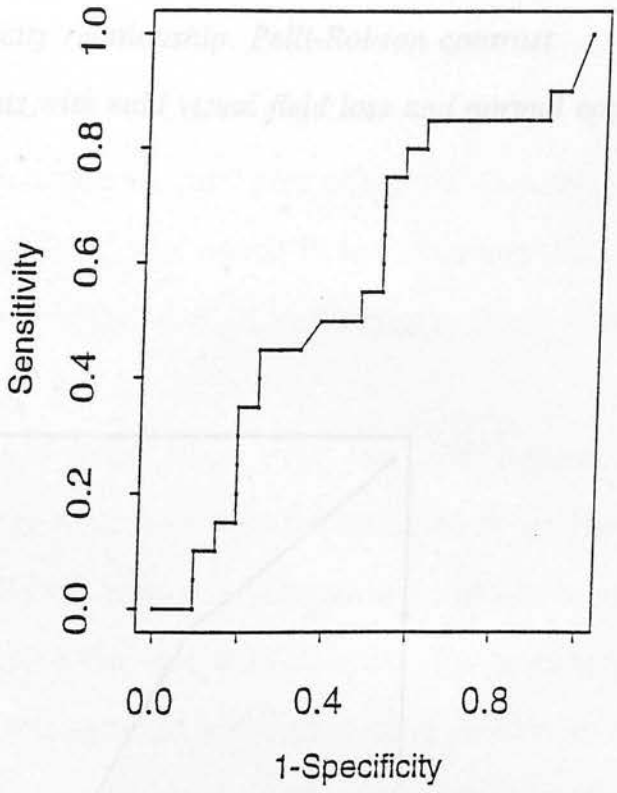


Figure 18. *Sensitivity/Specificity relationship. Contrast sensitivity using Visual Stimulus Generator: Comparing patients with mild visual field loss and normal controls.*

A) Original data.



B) Fitted values after exploring relationship with age, sex, pupil size and local ophthalmic medication

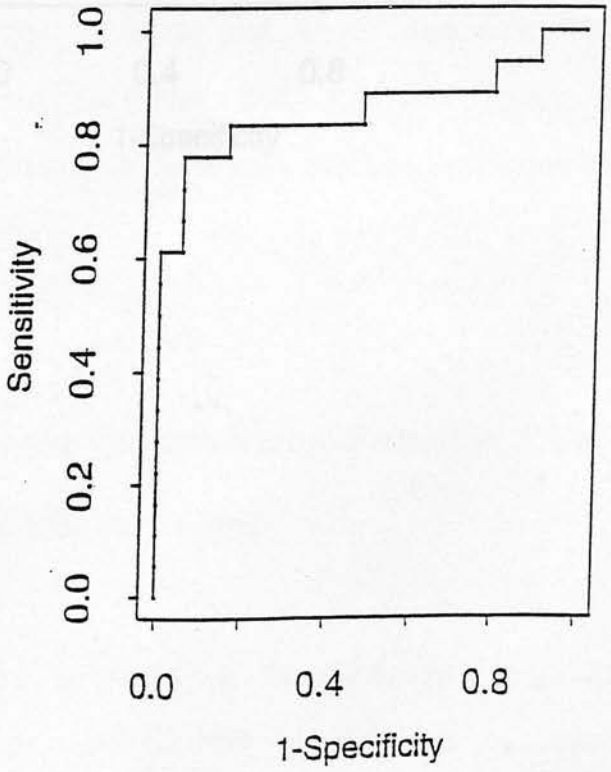
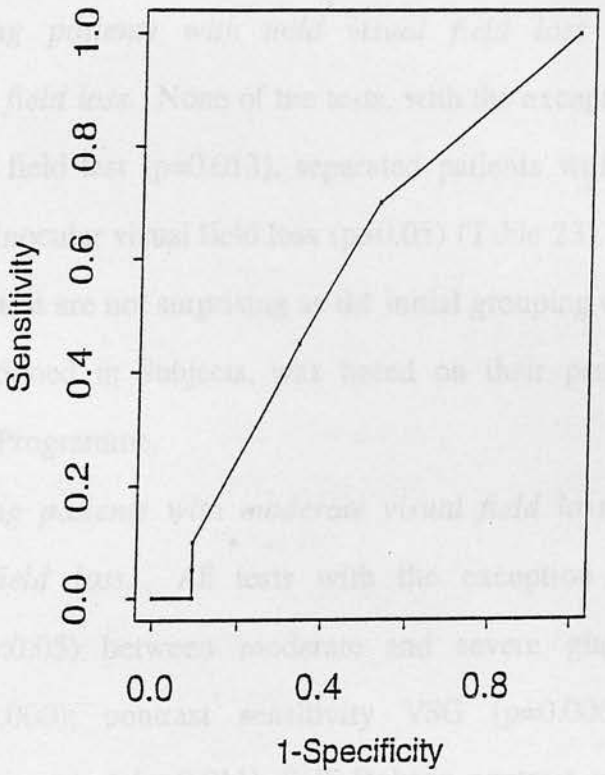


Figure 19. *Sensitivity/Specificity relationship. Pelli-Robson contrast sensitivity: Comparing patients with mild visual field loss and normal controls. Original data.*



Comparing normal subjects and patients with moderate visual field loss. Stereopsis was the only test in our study that did not discriminate normals from patients with moderate binocular visual field loss ($p>0.05$) (Table 23). The best performance was shown on the following tests: dark adaptation ($p=0.001$), Pelli-Robson contrast sensitivity ($p=0.001$) and critical flicker frequency ($p=0.002$), followed by contrast sensitivity VSG ($p=0.013$), Esterman visual field test ($p=0.013$) and glare disability ($p=0.029$).

Comparing patients with mild visual field loss and patients with moderate visual field loss. None of the tests, with the exception of the Esterman binocular visual field test ($p=0.013$), separated patients with mild from patients with moderate binocular visual field loss ($p>0.05$) (Table 23). The positive results of the Esterman test are not surprising as the initial grouping of patients into three groups, as mentioned in Subjects, was based on their perimetric results from Humphrey 24-2 Programme.

Comparing patients with moderate visual field loss and patients with severe visual field loss. All tests with the exception of CFF separated significantly ($p<0.05$) between moderate and severe glaucoma (Table 23): stereopsis ($p=0.000$), contrast sensitivity VSG ($p=0.006$), glare disability ($p=0.008$), Esterman test ($p=0.011$), Pelli-Robson contrast sensitivity ($p=0.014$) and dark adaptation ($p=0.047$).

9.3 Relationship between Various Visual Function Tests and Specific Daily Life Activities.

Fisher's Exact Test was used to investigate the relationship between visual function tests and items of the visual disability questionnaire in our sample of

patients and normals. Dark adaptation, binocular Esterman visual field test and binocular CFF were the tests that were significantly associated with a number of activities (Table 24).

TABLE 24. *Relationship between visual function tests and some daily activities / abilities.*

Activity	Visual Function Test	p-value	Significance
Indoor mobility	dark adaptation	.084	
Findings things	Esterman	.015	*
that one's dropped	Ross CS SD	.019	*
Glare	CFF	.091	
	Ross CS	.093	
Adjusting to dim light	Esterman	.049	*
	CFF	.005	**
	Ross CS SD	.090	
	dark adaptation	.035	*
Going from light to dark	dark adaptation	.067	
Colour	Esterman	.035	*
Walking on uneven ground	stereopsis	.070	
Walking on steps or stairs	Esterman	.080	
Tripping over objects	Esterman	.019	*
	CFF	.049	*
	Pelli-Robson	.073	
	dark adaptation	.045	*
Bumping into objects	CFF	.057	
	dark adaptation	.006	**
Seeing in periphery		.017	*
	CFF	.024	*
	Pelli-Robson	.073	
	dark adaptation	.007	**

*p<0.05 **p<0.01

TABLE 24. *Relationship between visual function tests and some daily activities / abilities (continued from the previous page).*

Activity	Visual Function Test	p-value	Significance
Judging distance of	Esterman	.050	*
foot from steps or stairs	CFF	.068	
	dark adaptation	.030	*
Walking on the street	VA	.030	*
	dark adaptation	.005	**
Crossing the road	Esterman	.030	*
	CFF	.006	**
	dark adaptation	.041	*
Walk in after dark	Esterman	.078	
	CFF	.057	
	dark adaptation	.005	**
Seeing at night	Esterman	.069	
	CFF	.043	*
	dark adaptation	.009	**
Reading newspapers	Ross CS SD	.055	
	Pelli-Robson	.035	*
Following a line of print	Esterman	.045	*
	Pelli-Robson	.035	*
Recognising faces	Esterman	.003	**

*p<0.05 **p<0.01

Dark adaptation correlated strongly with the questions (Table 25): walking on the street (p=0.005), walking after dark (p=0.005), bumping into objects (0.007), seeing in periphery (0.007), seeing at night (p=0.009); and mildly with the questions: judging distance of foot from a step (p=0.030), adjusting to dim light (p=0.035), difficulty walking on steps (p=0.0380), crossing the road (p=0.041) and tripping over objects (p=0.045).

TABLE 25. *DARK ADAPTATION*

Relationship with questionnaire items. Fisher's Exact Test.

Task / Activity	p-value	Significance
Walking on the street	0.005	**
Walking after dark	0.005	**
Bumping into objects	0.007	**
Seeing in periphery	0.007	**
Seeing at night	0.009	**
Judging distance of foot from a step	0.030	*
Adjusting to dim light	0.035	*
Difficulty walking on steps	0.038	*
Crossing the road	0.041	*
Tripping over objects	0.045	*
Going from light to dark	0.067	
Glare	0.070	
Indoor mobility	0.084	

*p<0.05 **p<0.01

Binocular Esterman visual field tests correlated strongly with the following problems (Table 26): recognising faces (p=0.0031), falls (0.0042), finding dropped objects(p=0.015), seeing in the periphery (p=0.017), tripping over objects (0.019); and less strongly with the problems: crossing the road (p=0.030), colour

perception (0.035), following a line of print (p=0.045), adjusting to dim light (p=0.049) and judging distance of the foot from a step (p=0.050).

TABLE 26. *BINOCULAR ESTERMAN VISUAL FIELD TEST*

Relationship with questionnaire items. Fisher's Exact Test.

Task / Activity	p-value	Significance
Recognising faces	0.003	**
Falls	0.004	**
Findings things that one's dropped	0.015	*
Seeing in periphery	0.017	*
Tripping over objects	0.019	*
Crossing the road	0.030	*
Colour	0.035	*
Following the line of print		*
Adjusting to dim light	0.049	*
Judging distance of foot from a step	0.050	*
Seeing at night	0.069	
Walking after dark	0.078	
Walking on steps or stairs	0.080	

*p<0.05 **p<0.01

In Table 27, CFF correlated highly with having difficulties in: falls (p=0.003), crossing the road (p=0.004), adjusting to dim lights (p=0.005), glare (p=0.002); and mildly with the difficulties in: seeing in periphery (p=0.024), seeing at night (p=0.043) and tripping over objects (p=0.049).

TABLE 27. *CRITICAL FLICKER FREQUENCY*

Relationship with questionnaire items. Fisher's Exact Test.

Activity / Task	p-value	Significance
Falls	0.003	**
Crossing the road	0.004	**
Adjusting to dim lights	0.005	**
Glare	0.020	*
Seeing in periphery	0.024	*
Seeing at night	0.043	*
Tripping over objects	0.049	*
Steps	0.056	
Bumping into objects	0.057	
Walking after dark	0.057	
Judging distance from foot to step	0.068	
Glare	0.091	

*p<0.05 **p<0.01

The contrast sensitivity test, using VSG, correlated highly with difficulties resulting in falling (p=0.011). In Table 28, the Pelli-Robson contrast sensitivity test correlated mildly with difficulties when reading newspapers (p=0.035), following a line of print (p=0.035) and going from light to dark or vice versa (p=0.035) (Table 29).

TABLE 28. *CONTRAST SENSITIVITY Visual Stimulus Generator Relationship with questionnaire items. Fisher's Exact Test.*

Activity / Task	p-value	Significance
Falls	0.011	**
Glare	0.093	

*p<0.05 **p<0.01

TABLE 29. *PELLI-ROBSON CONTRAST SENSITIVITY. Relationship with questionnaire items. Fisher's Exact Test.*

Activity / Task	p-value	Significance
Reading newspapers	0.035	*
Following the line of print	0.035	*
Going from light to dark or vice versa	0.035	*
Tripping over objects	0.073	
Seeing in periphery	0.073	
Glare	0.096	

*p<0.05 **p<0.01

9.4 Summary Performance Measure for Visual Disability Questionnaire. Relationship with Visual Function Tests

The summary measure (calculated was a summed score on the basis of performance on 15 questions in the Table 11) correlated well with a number of psychophysical tests (Table 30): Pelli-Robson contrast sensitivity (p=0.000), medium glare brightness (p=0.000), Esterman binocular visual field test (p=0.001), high glare brightness (p=0.003), dark adaptation (p=0.007), critical flicker frequency (p=0.014), contrast sensitivity using the Visual Stimulus |Generator (p=0.016) and stereopsis (p=0.044).

TABLE 30. *Relationship between the summary performance measure for visual disability questionnaire and the visual function tests.*

Test	p-value	Significance
Mean deviation	<0.0001	**
Snellen VA	0.201	
Esterman VF	0.001	**
Stereopsis	0.044	*
CFF	0.014	**
CS VSG	0.016	**
Pelli-Robson CS	<0.0001	**
Glare medium brightness	<0.0001	**
Glare high brightness	0.003	**
Dark adaptation	0.007	**

*p<0.05 **p<0.01

9.5 Influence of Age, Sex, Physical Disability, Pupil size and Ophthalmic Medication (Pilocarpine or other)

It was not a primary purpose of this study to investigate the relationship between visual function/disability and factors such as age, sex, physical disability, and ophthalmic medication (we compared patients who took Pilocarpine against the rest of the sample). However some comparisons were made, and very interesting results were obtained which, to our knowledge, have not been reported in other studies before and are in short summarised here.

Esterman binocular visual field test. No association with any of the above factors.

Stereopsis. Association with pupil size (p=0.038) and ophthalmic medication (p=0.003). A larger pupil size was associated with better performance. In the group with severe visual field loss those patients who were on Pilocarpine performed better than those who did not take Pilocarpine.

Critical flicker frequency. An age related decline was present (p=0.002). Those patients who were on Pilocarpine had on overall lower CFF results than the rest of the group. Relationship with sex parameter was also significant (p=0.010). Women performed worse than men.

Contrast sensitivity VSG. Significant influence of age (p=0.004) and ophthalmic medication (p=0.014). A different relationship between age and contrast sensitivity depending on whether patients took or did not take Pilocarpine. Those patients on Pilocarpine had decreased contrast sensitivity when compared to the rest of the sample.

Pelli-Robson contrast sensitivity. No association with any of these factors.

Glare medium brightness. An age related decline was present (p=0.004). Patients on Pilocarpine had worse glare scores than the rest of the sample (p=0.023).

Glare high brightness. An age related decline (p=0.001). Patients on Pilocarpine performed worse than the rest of the sample (p=0.001).

Dark adaptation. Influence of age (p=0.001) and ophthalmic medication (p=0.001). Age and Pilocarpine result in comparatively worse threshold values.

Questionnaire index. A smaller pupil was associated with better performance (p=0.027). Pupil size seemed to have greater influence than visual field loss.

Conclusion. These results seem to indicate that the effects of factors such as ophthalmic medication, pupil size and others have a lot stronger effect on visual function and visual disability than it is currently sought. For example, it would seem that Pilocarpine produces a decrease in contrast sensitivity and an increase

in glare disability that is greater than the difference resulting from glaucomatous damage. If these results will be confirmed in other studies, it could lead to dramatic changes in glaucoma treatment. In another example, it seems that pupil size may have stronger effect on overall performance than visual field loss itself. A number of questions arise considering the outcome. How does this reflect in performance, for example, drivers? Are drivers with smaller pupil at an advantage compared to those with larger pupil? What is the extent of combined pupil size and visual field loss on driving performance? Which influence is greater? A whole new research area opens when considering these questions.

However, it is necessary to note that the above differences could be associated with small differences in the mixture of patients in each of the groups. For example, although these differences were not significant (Table 9), group with severe visual field loss had slightly higher proportion of patients on Pilocarpine.

A few studies recently attempted to estimate to what extent side effects of treatment result in decreased quality of life, however a little is known about the influence of these factors on visual function. More research work is needed if we are to understand visual function and visual disability in glaucoma.

9.6 Summary

Factor analysis reinforced the findings from the pilot study indicating that central and near vision, peripheral vision (or actions demanding functional peripheral vision), dark adaptation and glare, personal care / household tasks and outdoor mobility are major groups of concern for glaucoma patients. The technique simplified 36 questions in the questionnaire into five main groups and indicated a separation between the peripheral function questions, i.e. tripping over and bumping into objects etc., and the specific glare and dark adaptation questions.

Fifteen questions from the original questionnaire were found to have a strong correlation with the severity of binocular visual field loss. These questions were related to three factors: *activities demanding functional peripheral vision* (seeing objects coming from the side, walking on uneven ground, tripping over objects, judging distance of foot to step, walking on steps/stairs, bumping into objects), *dark adaptation & glare disability* (walking after dark, seeing at night, adjusting to dim light, glare, going from light to dark room or vice versa, finding dropped objects) and *outdoor mobility* (crossing the road).

When exploring the relationship between severity of visual field loss and the summary performance measure for the questionnaire, it was found that within the patients, group prediction was possible between mild and severe visual field loss ($p=0.022$), but not between mild and moderate ($p=0.150$) or moderate and severe ($p=0.217$) visual field loss. There was a strong difference between normals and any of the three patient groups ($p<0.01$).

All psychophysical tests, i.e. Esterman binocular visual field test, stereoacuity test, critical flicker frequency, contrast sensitivity using Visual Stimulus Generator, Pelli-Robson contrast sensitivity, glare disability and dark adaptation did show highly significant relationship with a measure of visual field loss ($p<0.01$). The only exception was colour test using Farnsworth desaturated D-15. When looking in detail at the results of each test in our study, it is clear that although tests discriminate well between extremes, i.e. between normals/mild glaucoma and advanced glaucoma, the difference is not quite so pronounced and often not significant when comparing neighbouring groups, particularly mild and moderate glaucoma. Only tests on dark adaptation, glare disability and contrast sensitivity showed significant differences between normals and early glaucoma.

A strong relationship was found between the summary performance measure of the questionnaire and all psychophysical tests (all tests $p<0.01$, stereopsis $p<0.05$). The relationship between function and visual disability was

strongest for Pelli-Robson contrast sensitivity ($p<0.0001$), medium glare test ($p<0.0001$), Esterman binocular visual field test ($p<0.001$), high glare test ($p=0.003$) and dark adaptation ($p=0.007$) and equally/comparably as strong as for the Mean Deviation perimetric value ($p<0.0001$).

Chapter 10

DISCUSSION

10.1 Visual Disability Questionnaire

10.1.1 Comparisons with Previous Research Work

This study has identified *near vision, peripheral vision, dark adaptation and glare, personal care and household tasks,* and *outdoor mobility* as the main groups of difficulties encountered by glaucoma patients. This factor structure confirmed the findings of the pilot study in this research work and also the previous findings of Ross et al (41) (Table 31).

Both the sample in the study of Ross and the sample in this study were comparable in their size and considered the same age group (41). Both studies examined subjects with varying degrees of the visual field loss and used a similar technique to analyse the data.

A factor *central and near vision* corresponded to questions on reading tasks in our questionnaire and was observed in the pilot study as well as in the study by Ross et al (41). Two questions had a strong relationship with a measure of visual field loss in our study and were included in the shortened form of the questionnaire that was used for statistical analysis. These two questions were: recognising faces and reading newspapers.

TABLE 31. *Comparison of the factor structure reported by Ross et al 1984* (41) *with the factor structure resulting from the pilot and the present study.*

Present study	Pilot study	Ross et al
Central and near vision	Near vision	Near vision
Peripheral vision	Activities demanding functional peripheral vision and	
Dark adaptation & disability glare	disability glare & lighting	Navigation at night
Personal care and household tasks	Personal care Household tasks	Vision when cooking
Outdoor mobility	Outdoor mobility	Navigation outdoors

Although we are dealing with a disease that attacks peripheral vision primarily, good central vision is so essential to human beings that it is not surprising that it appears in our analysis as a separate issue. We understand that the cut-off point 6/12 for visual acuity in our study would give some space for influences that resulted either from ageing or low tension glaucoma in our patients. For example, clinically non-significant cataract, uncorrected refractive error (many subject fail to visit an optometrist frequently enough) or scotoma near the central vision area may have some influence. In our pilot study this factor did not significantly contribute to the factor structure of the data and was not mentioned in great detail. In the main study the contribution of this factor to the factor structure was much greater. It is presumed that this difference between the pilot and the main study appeared as a result of slightly different patient mixture, possibly more severe stage of the disease in the pilot study as the cut-off point 6/12 for visual

acuity was taken for the better eye only, whereas in the main study we applied it for both eyes. In addition, because we used the cut-off point 6/12 for visual acuity in right and left eye, we have excluded a very severe group of patients with visual acuity below 6/12. These patients may have very considerable disability.

Six out of fifteen questions which were found to be strongly correlated with a measure of severity of visual field loss were related to *peripheral vision* factor. These were: seeing objects coming from the side, walking on uneven ground, tripping over objects, judging distance of foot to step, walking on steps/stairs and bumping into objects. In the pilot study these questions collapsed together with questions on disability glare and lighting into one factor, and we suggested that this seemed to be a factor specific for glaucoma. In the questionnaire for the main study we expanded on the range of questions that were related to both subjects, peripheral vision and glare & lighting and therefore two separate factors have emerged in the main study and came as no surprise.

Questions similar to those used in our study were also listed by Ross et al in their study (41), for example walking on uneven pavement or walking on steps. We presume that in their study these questions would correlate with the factor called *navigation outdoors*. Contrary to Ross et al, in our study we decided to give the title *outdoor mobility* to a separate factor with questions such as walking on the street, crossing the road or using a bus. The difference here therefore is not a matter of different content but a different label.

Difficulty with *navigation at night* as mentioned in the study by Ross et al (41) suggested the presence of difficulty with adaptation to different levels of *lighting* and this issue emerged in the pilot study and also in the main study as a separate factor *dark adaptation and disability glare*. Six questions had a strong statistically significant relationship with a measure of visual field loss. These were: walking after dark, seeing at night, adjusting to dim light, glare (disability glare, i.e.

degree of glare that restricts ability to see), going from light to dark room or vice versa and finding dropped objects. Although the last question initially seem to be out of place in this factor we presumed that it may be a task greatly dependent on the amount of light available and that may be the reason why it correlated on this factor.

Vision when cooking listed by Ross (41) was one of the activities that correlated on the factor with the general heading of *household tasks* in the pilot study. In the main study, the two factors *household tasks* and *personal care* from the pilot study collapsed into one factor and included questions such as pouring tea, working in the garden, cooking, dressing and needlework. Most of these activities would require mainly good central vision and this was preserved in our patients in the main study. None of the activities showed a strong significant relationship with the measure of visual field loss and therefore were not included as part of the final shortened questionnaire that was used for the statistical analysis.

The factor described by Ross (41) as *navigation outdoors* was identical with the group of experienced disabilities that correlated on the factor *outdoor mobility* in our pilot as well as the main study. The questions included the following activities: walking on the street, crossing the road or using a bus. Difficulty when crossing the road was one of the activities with a very strong relationship with a measure of visual field loss and it was selected into the final list of activities used for further analysis (Table 11).

10.1.2 List of Daily Activities with the Strongest Relationship with Visual Field Loss in Glaucoma

Although it is useful to be able to ask as much about patients' difficulties as possible, for the purpose of a clinically usable tool as well as for research investigations it is often more suitable to work with a shorter form of a questionnaire. On the basis of the results in this study a number of daily activities strongly associated with a measure of visual field loss were selected.

The shortened subscale consists of fifteen questions related to those aspects of daily life that seem to be compromised in glaucoma. All the questions were found to have a highly significant relationship with a measure of visual field loss in this study (Table 11) and were confirmed as beneficial in the previous investigations by Ross et al (41) and Mills and Drance (145) who came to similar conclusions.

These questions related to three most important areas of difficulties as they were defined in this study: *activities demanding functional peripheral vision* (activities: seeing objects coming from the side, walking on uneven ground, tripping over objects, judging distance of foot to step, walking on steps/stairs, bumping into objects), *dark adaptation & glare disability* (walking after dark, seeing at night, adjusting to dim light, glare, going from a bright to a dark room or vice versa, finding dropped objects) and *outdoor mobility* (crossing the road). Two questions on *central & near vision* were also included (reading newspaper, recognising faces) because of the importance of information on central vision. The fully worded questions are listed in Table 32.

TABLE 32. *List of daily activities with the strongest relationship with visual field loss in glaucoma (based on the results of this study).*

Patient instruction: Please, circle the correct answer on the scale ranging from 1 to 5 where [1] stands for 'no difficulty' and [5] stands for 'severe difficulty'. If you do not perform any of the activities for other than visual reasons, please circle [0].

Does your vision gives you any difficulty with the following activities?

	None				Severe	Do not perform for non-visual reasons
Reading newspapers	1	2	3	4	5	0
Walking after dark	1	2	3	4	5	0
Seeing at night	1	2	3	4	5	0
Walking on uneven ground	1	2	3	4	5	0
Adjusting to bright lights	1	2	3	4	5	0
Adjusting to dim lights	1	2	3	4	5	0
Going from light to dark room or vice versa	1	2	3	4	5	0
Tripping over objects	1	2	3	4	5	0
Seeing objects coming from the side	1	2	3	4	5	0
Crossing the road	1	2	3	4	5	0
Walking on steps / stairs	1	2	3	4	5	0
Bumping into objects	1	2	3	4	5	0
Judging distance of foot to step / curb	1	2	3	4	5	0
Finding dropped objects	1	2	3	4	5	0
Recognising faces	1	2	3	4	5	0

10.1.3 Relationship between the Questionnaire Performance Index and Severity of Visual Field Loss. Comparisons with the ADVS, NEI-VFQ and VF14 Questionnaires

Validity of the questionnaire subscale (Table 11) used in this study was shown in a significant relationship with a measure of visual field loss (Table 12), as defined in Methods, and perimetric Mean Deviation value ($r=-0.6$, $p<0.0001$). This is similar to the results published by Sherwood et al on Activities of Daily Vision Scores (ADVS) (overall $r=-0.6$, $p<0.0001$) (63) and slightly higher than correlations for the National Eye Institute-Visual Functioning Questionnaire and the Visual Functioning 14 Questionnaire ($r=-0.46$, $p<0.001$, scores adjusted for visual acuity) (135), (136),

In addition to these studies, we have also attempted to discriminate between various degrees of visual field loss and found that, using the questionnaire performance summary measure (questionnaire index), it is possible to discriminate between extremes in the glaucoma group, i.e. between mild and severe visual field loss groups. However, discrimination between mild and moderate or moderate and severe visual field loss groups was difficult as a result of overlap in performance. There was a tendency towards significant results and in the case of larger groups the results might have reached significant levels. The explanation may also lie in the lack of quantifiable objective difference in visual function between these groups. When looking in detail at the results of our objective psychophysical tests, it is clear that although tests discriminate well between extremes, i.e. between normals/mild glaucoma and advanced glaucoma, the difference is not quite so pronounced and often not significant when comparing neighbouring groups, such as normals and mild/moderate glaucoma. In addition, the overlap in performance may also be influenced by different factors

such as age, type of employment, education about disease and others. Based on observation during our study, although this was not noted for statistical analysis, younger people, people who had visually highly demanding jobs such as sculpturers, painters etc., and people with knowledge of how the disease develops and progresses did tend to be more aware of any changes in their vision and progress of their visual field loss.

Reliability of the questionnaire subscale was shown using Cronbach's α = 0.92, which was similar to the above mentioned questionnaires.

Formal test-retest stability/reliability has not been completed at the present time. However it is clear even now that the pilot study and the main study arrived at an identical conclusion with very similar factor structures using a different mixture of patients with similar sample characteristics. This seems to be an indication that a measure of reliability is present in re-testing characteristics of the questionnaire. In addition, the questionnaire was designed using the experience of previous research investigations on visual disability in glaucoma and other ocular conditions that were shown to have good performance characteristics or were shown to be confirmed in other studies (41, 132, 145, 152, 201).

10.1.4 How much disability do patients suffering from glaucoma experience?

Based on the results of the pilot and the main study, it seems that most of the patients up to the moderate stage of the disease as defined in this study experience very little disability as a result of glaucomatous damage to their eyesight. It is a good message for patients' prospects of retaining independence, mobility and general daily living functioning. However, if disability is experienced, this is most likely to be related to three major groups of difficulties:

- dark adaptation and glare disability
- activities related to functional peripheral vision
- outdoor mobility

10.2 Relationship Between Various Psychophysical Measures of Visual Function and Severity of Visual Field Loss in Glaucoma

Virtually all the psychophysical tests demonstrated a highly significant relationship with a measure of visual field loss ($p<0.01$) thus confirming the findings of many other authors who studied psychophysical function in glaucoma in its many aspects (40-42, 48, 52, 56, 59, 62, 101, 145).

The only exception was the colour test using Farnsworth desaturated D-15. This test was intended for screening purposes, rather than for the in-depth study of a colour vision defect. Bassi et al (1993) (100) found this test useful in their study on glaucoma and as a result of our literature search we expected similar results in our study. At the moment we do not have an explanation why this was not the case. The test was performed under the lighting conditions that were recommended by the manufacturer and the colour caps were completely new. Most of our patients performed the test with the correct result.

10.2.1 Comparing Normal Controls to Early Glaucoma and Early Glaucoma to Advancing Disease

A lot of research work has been devoted to the identification of any functional differences between normal controls and early glaucoma in order to eliminate progress of the disease by early treatment. One of the most recent and most comprehensive studies on psychophysical and electrophysiological examination in glaucoma was published by Graham and Drance et al in 1996 (52). These authors concluded that although most parameters reflected glaucomatous damage to a varying degree, no single parameter from the psychophysical tests could identify all patients with early glaucoma and still maintain good specificity. They suggested that a combination of tests that use different visual functions would be useful in detecting early glaucoma or patients at risk for progression to definitive glaucoma and that multiple factor analysis with long-term follow up must be performed to address this possibility.

When looking in detail at the results of each test in our study, it is clear that although tests discriminate well between extremes, i.e. between normals/mild glaucoma and advanced glaucoma, the difference is not quite so pronounced and often not significant when comparing neighbouring groups, particularly mild and moderate glaucoma (Table 33). Only tests of dark adaptation, glare disability and contrast sensitivity showed significant differences when separating normals from early glaucoma.

Table 33. *Psychophysical test in relation to the severity of visual field loss. Specific groups.*

Psychophysical tests	Normals vs. Mild VF loss (p-value)	Normals vs. Mod. VF loss (p-value)	Mild VF loss vs. Mod. VF loss (p-value)	Mod. VF loss vs. Severe VF loss (p-value)
Esterman VF test	0.971	**0.013**	**0.013**	**0.011**
Stereopsis	0.598	0.497	0.879	**0.000**
CFF	0.058	**0.002**	0.215	0.082
CS (VSG)	**0.028**	**0.013**	0.785	**0.006**
Pelli-Robson CS	**0.039**	**0.001**	0.241	**0.014**
Glare disability	**0.023**	**0.029**	0.900	**0.008**
Dark adaptation	**0.013**	**0.001**	0.354	**0.047**

Comparing normal subjects and patients with mild visual field loss. When separating normals from mild glaucoma, a group of tests emerged including dark adaptation, glare disability and contrast sensitivity giving significant results when separating these two groups. The best results were obtained for dark adaptation (p=0.013) and glare disability (p=0.023). This supports the findings by Drum, Quigley, Congdon, Glovinsky and others (55-57) who found abnormal scotopic sensitivity in glaucoma, and Hoshino and Mizokami (59) who studied glare in glaucoma. Contrast sensitivity was found useful in many studies, by Tyler et al in 1981, Ross et al in 1984, Adams et al in 1985, Teoh et al in 1990, Sample et al in 1991, Korth et al in 1989, Essock et al and Graham and Drance et al in 1996 (40, 45). We used two methods, contrast sensitivity as measured using Pelli-Robson chart and contrast sensitivity using the Visual Stimulus Generator controlled by

Psycho V2.0 (Cambridge Research Systems, Cambridge, U.K.). Essock et al (62) successfully used the Pelli-Robson chart in their study claiming that binocular testing was generally more effective at detecting group differences than monocular testing. The difference in results between the two methods in our study was very small and for its practical advantages we would recommend the use of the Pelli-Robson chart.

Critical flicker frequency, contrary to the results of Kosmin (82) did not show significant separation between normals and glaucoma patients with mild visual field loss in our study although it was linked to perceived glare. Essock et al similarly did not find differences between normals and early glaucoma for either monocular or binocular CFF testing (62).

No significant results were found for stereopsis and Esterman visual field test in our study between normals and early glaucoma (Table 33).

Comparing normal subjects and patients with moderate visual field loss. Stereopsis was the only test in our study that did not discriminate normals from patients with moderate binocular visual field loss. Essock et al (62) found that the mean stereoacuity of glaucoma patients and suspects was significantly worse than the level of stereoacuity expected for normals with the same Snellen acuity level. In our study we confirmed the presence of abnormality between patients as a group and the normal controls, but this difference was not obvious between normals and glaucoma in the mild and up to moderate stage of the disease. It is well known that poor stereoacuity is associated with poor Snellen acuity (103). However, this was not the relevant consideration for either of the two studies because of the high acuity of the patients and that the groups did not differ significantly in terms of acuity.

Comparing patients with mild visual field loss and patients with moderate visual field loss. None of the tests, with the exception of Esterman binocular visuai field test, separated patients with mild from patients with

moderate binocular visual field loss. The positive results of the Esterman test are not surprising as the initial grouping of patients into three groups was based on their perimetric results from Humphrey 24-2 Programme. In the pilot study we mentioned that there was virtually no difference between these two groups in relation to their disability and that patients could progress from mild to the moderate stage of the disease (as defined herein) without noticing much change in their daily life. This finding is supported by the above results from psychophysical tests. This suggest that there does not seem to be significant difference between the two groups in most aspects of their visual function as measured by objective methods. The lack of difference in visual disability is supported by lack of difference in such aspects of visual function as stereoacuity, critical flicker frequency sensitivity, contrast sensitivity, glare disability and dark adaptation.

Comparing patients with moderate visual field loss and patients with severe visual field loss. All tests with the exception of CFF separated significantly ($p<0.05$) between moderate and severe glaucoma. This is very interesting because we stated earlier that there does not seem to be much difference in objective visual function between mild and moderate visual field loss groups. It may be the case that while progressing to moderate stage, many aspects of visual function remain relatively well preserved, however as the damage progresses to the severe stage, all aspects of visual function suddenly show rapid deterioration.

10.3 Relationship Between Visual Disability and Various Psychophysical Measures of Visual Function in Glaucoma

A strong relationship was found between the questionnaire summary performance measure and all psychophysical tests (all tests $p<0.02$, stereopsis $p<0.05$). The relationship between function and visual disability was strongest for Pelli-Robson contrast sensitivity, glare disability, Esterman binocular visual field test and dark adaptation ($p<0.01$) and equally as strong as for the mean deviation perimetric value ($p<0.001$).

Our results support the findings of Ross et al (41) who found a relationship between visual disability and contrast and flicker sensitivity and findings by Mills and Drance (145), who reported Esterman visual field test as a useful tool for assessing visual disability in severe glaucoma. We were unable to find any study to which we could directly compare our findings about the relationship between dark adaptation, glare sensitivity, stereopsis and visual disability in glaucoma. However, some authors indicate that both glare disability and dark adaptation, as well as stereoacuity may be compromised in glaucoma (55-57, 59). It may be an important finding from the patient's point of view, as a lot can be done in order to minimise the effect of glare in the environment. Information can be given to the patient which also influence his behaviour so that he/she takes precautions when driving or carrying out other activities where glare is unavoidable.

10. 4 Consequences for Clinical Management and Enhancement of Quality of Life of a Patient with Glaucoma

In traditional clinical practice, optic disc appearance, perimetric findings, Snellen visual acuity and side-effects of treatment have been used to monitor and evaluate the success or failure of different treatment methods for glaucoma. Of these clinical outcome measures, visual acuity testing may be the most important indicator of day-to-day functioning (228). Several authors have asserted that visual acuity, even when supplemented by other measures of visual functioning, may be inadequate as an indicator of degree of visual impairment, because it does not tell what patients can expect to accomplish with their residual vision (229, 230).

The patient's self-assessment provides information on direct visual limitations consequent to the disease (131) and therefore, may be a more pertinent measure of visual functioning (63, 231). Sherwood et al suggest that information about purely physiologic results is inadequate when a physician and patient make decisions about treatment options that are comparable in their therapy effects but have different impacts on the patient's health-related quality of life (63). At this point it becomes important to consider global health issues as well as vision-specific quality of life. Thus, showing a way to improve the quality of life of a patient may become a key measure of success of a treatment, just as important as the traditional clinical outcome measures (63). In addition, in the context of managed healthcare, many patients, doctors, researchers and policymakers may require information that goes beyond traditional biologic and physiologic outcomes (63). A questionnaire designed to investigate visual disability and indicate a level of quality of life is the tool needed to fill an existing gap. Research investigations on subjective aspects of visual function and quality of life in patients with glaucoma has been initiated only recently and the work of

Sherwood et al (63), Parrish et al (136) and Gutierrez et al (135) as well as ours has attempted to establish correlations between visual disability/quality of life and clinical indicators. It is encouraging that similar conclusions have been drawn from these few studies.

Zimmerman et al pointed out the other issues that were important in the relationship between visual disability and clinical measures: "Is a nasal step in one eye visual disability? Bjerrums in both eyes? Field defects within 10 degrees of fixation? Some guidelines speak to this but, these need to be refined specifically for glaucoma..."((2), p.153). And more questions could be asked: "How much vision does the average glaucoma patient have left? How much vision is lost per year by the average patient in the entire sighted glaucoma population or some subpopulation?", etc. In our study we attempted to answer some of these questions at least to the extent of comparing patients with mild, moderate and severe visual field loss as, to our knowledge, no previous study documents this relationship. The conclusion from our study suggests that patients may progress up to moderate stage of the disease without experiencing much disability in their every day life. It is good news for the patients' prospect of retaining independence, mobility and all aspects of daily living functioning. However, visual function tests show a gradual decline in various aspects of visual function and it is important to find out how much remaining vision can compensate for lost parts of visual field in relation to day-to-day functioning and particularly, driving. Johnson and Keltner, through their study with the California motor vehicle department, showed more violations and accidents in people with visual field defects (120). As this issue is so important for preserving one's independence, it would be useful to know where is the borderline between visual defects that lead to visual disability and visual defects which can be compensated by the remaining vision. A lot more research work will have to be done before we are to address what constitutes true visual disability in glaucoma.

From the patient's point of view, knowledge of difficulties may also provoke more responsible behaviour when driving or performing other potentially hazardous activities. On the other hand information about difficulties experienced by the patients suffering from glaucoma may initiate environmental changes being carried out in homes of visually impaired people, eye hospitals and in public areas to prevent accidents and increase comfort levels for those who suffer from glaucoma. For example, if dark adaptation and glare disability are affected in glaucoma, design of an interior should prevent rapid changes in lighting levels, avoid or diminish glare problems by increasing brightness levels in dark areas like staircases with narrow windows that can be a source of disability glare. It is also possible to design window positioning, large glass and mirror areas in accordance with having glare in mind. Dark walls can be repainted pale, curtains changed or blinds installed. All these simple measures can help to alleviate the problem (208).

10.5 A Way Forward ...

Ageing of the population is becoming an increasingly important factor in quality-of-life studies because although most elderly people continue to live independently, it was reported that over 40% of people over 65 experience difficulty in performing their usual daily tasks as a result of age-related chronic disorders (105).

Primary open angle glaucoma is a chronic disorder predominantly affecting the population aged 65 and over. World-wide, glaucoma is ranked as the third greatest cause of visual impairment, and blindness affects an estimated 5.2 million people (63). In economically prosperous countries it is the second commonest cause of blindness. Glaucoma causes irreversible visual field damage and measurable deterioration in many aspects of visual function, however in most cases good central vision is retained for many years. Little is known about visual disability resulting from glaucoma.

One of the new findings coming out from this study on glaucoma was the relationship between visual disability and the dark adaptation/glare disability function. Only a few research groups have investigated visual disability in glaucoma and hardly any research work has been done which specifically addresses disabling glare in glaucoma. Our results show that glare disability is one of the most frequently reported problems experienced by patients. Furthermore, perceived glare and objectively measured glare disability were the most important factors in significantly discriminating between patients with different levels of visual field loss.

Learning from the Present Study ...

We would like to draw attention to several points that are important when considering future research work.

When examining glare disability, it is vital to isolate the effects of pre-receptoral light scatter caused by even minor, clinically non-significant cataract. This is very difficult to achieve. After excluding any subjects with clinically significant cataract only a few options remain. In this study, we only included subjects above a cut-off point for distance visual acuity (Snellen visual acuity 6/12 or better in each eye). Some studies choose to statistically adjust formula for differences in visual acuity while enrolling subject with visual acuity below 6/12 (136). Gutierrez et al (135) used a cataract Lens Opacities Classification System II (232) grade of 1 or less as the inclusion criterion for patients with nonvisually significant cataract.

Similarly, patients who have undergone trabeculectomy may develop peripheral iridectomy which may increase the amount of scatter entering the eye. In this study we did not consider this influence and therefore some patients may have been included with peripheral iridectomy.

Local ophthalmic medication may in some cases result in visual disturbance (see chapter 'Visual Disturbance Due to Treatment'). Transitory reductions in visual acuity caused by ciliary spasm following the instillation of Pilocarpine have been well documented (23, 24). Ideally, patients on Pilocarpine should also be excluded. This was not possible in our study and we aimed for non-significant differences between patient groups and statistical adjustment for this influence. However, the group with severe visual field loss had a slightly higher proportion of patients on Pilocarpine (Table 9).

Snellen visual acuity was used in this study because of its value as a clinical measure, however the Bailey-Lovie chart is more reliable instrument (65, 87).

Differences in visual field loss pattern between normal-tension and high-tension glaucoma should not be overlooked (233). Visual field defects in normal-tension glaucoma are relatively more localized and closer to fixation (233). As a result, normal-tension glaucoma patients could experience increased visual disability in central vision activities. In this study central vision seemed to play a relatively important role. Was it because of a lack of correction for refractive error in the daily lives of patients or was it due to the proportion of normal-tension glaucoma subjects in our sample? Further studies should consider these possibilities

The Brightness Acuity Tester is a tool designed for monocular testing and therefore we had to use transformation formula (225) for glare disability results. Although certain techniques of converting monocular data to binocular results have been advocated (225), we would recommend that where a study is focusing on actual quality of life of patients, binocular measures would be preferred wherever possible.

The definition adopted for grouping of our glaucoma patients into three categories with mild, moderate or severe visual field loss was strongly correlated ($r=0.95$, $p<0.001$) with the technique recommended by Johnson and Nelson-Quigg for prediction of binocular sensitivity from monocular data (225). At the same time a system of grouping into three categories was recommended by professional statisticians for analytical purposes (Dr. Bruce Worton, Department of Statistics, University of Edinburgh). However, for the purpose of comparison with other studies, the Esterman Disability Rating (145) or AGIS system (234) are more suitable alternatives.

A Way Forward ...

On the basis of the pilot work published in this thesis we applied for research funding for a project that would explore this subject in greater detail. This research funding was approved by the Engineering and Physical Sciences Research Council for a project duration of three years.

The title of this new research work is: "Glare disability and its practical consequences in patients with glaucoma". The purpose of the study is:

- to confirm the relationship between glare sensitivity and field loss in glaucoma
- to quantify self-reported glare sensitivity by objective assessment of glare
- to identify those situations of primary concern to patients in relation to glare disability and give advice on minimising glare effects

In the first phase of the proposed study specific lighting situations giving rise to glare will be identified and measured. Glare sensitivity will be objectively measured in relation to other aspects of visual function including field loss. Finally patients will be invited to set preferred lighting for different tasks so that guidelines for lighting can be established and practical advice to patients made available.

APPENDIX I

Questionnaire used in the pilot study

Glaucoma Clinic (Dr. Colm O'Brien), Edinburgh 1996
Vision Disability Questionnaire

We are carrying out research aimed at finding out more about everyday problems of people with visual impairment. Please help us in this and answer to the questions about the problems your vision gives you in particular tasks.

Age: ..... **Gender:** M F

G1) Although you may be attending the clinic on a regular basis are you aware of any aspect of visual loss? (Please circle the appropriate answer.)

none 1 little 2 some 3 large loss 4 severe loss 5

G2) If yes, which eye is it? right 1 left 2 both 3

In general, to what extent does your <u>vision</u> give you difficulty in carrying out the following activities?

Please, say whether you do not have difficulty at all [1], or whether you have a little bit of difficulty [2], some difficulty [3], quite a lot of difficulty [4], severe difficulty [5] or whether you do not do the particular activity for other than visual reasons [0]. Please, circle the appropriate answer.

	not at all	a little bit	some	quite a lot	severe	don't do for other reasons
G3) Your usual daily activities	1	2	3	4	5	0
G4) Problems in every day activities when working under dim light	1	2	3	4	5	0
G5) Indoor mobility	1	2	3	4	5	0
G6) Outdoor mobility	1	2	3	4	5	0
G7) Does glare give you any difficulty in your usual daily acti vities	1	2	3	4	5	0

Does your <u>vision</u> give you any difficulty with?
If you usually carry out the particular activity with your glasses on answer our question as if you had your glasses on, please.

	not at all	a little bit	some	quite a lot	severe	don't do for other reasons
1) Seeing things because they appear hazy or washed out	1	2	3	4	5	0
2) Adjusting to bright lights	1	2	3	4	5	0
3) Adjusting to dim lights	1	2	3	4	5	0
4) Do you notice any variation in colour richness from time to time	1	2	3	4	5	0
5) Going from dark to light room or vice versa	1	2	3	4	5	0
6) Getting dressed	1	2	3	4	5	0

	not at all	a little bit	some	quite a lot	severe	don't do for other reasons
7) Washing yourself	1	2	3	4	5	0
8) Seeing food on a plate	1	2	3	4	5	0
9) Cooking and preparing food	1	2	3	4	5	0
10) Cleaning up and housework	1	2	3	4	5	0
11) Recognising faces	1	2	3	4	5	0
12) Seeing facial expressions	1	2	3	4	5	0
13) Walking on uneven ground	1	2	3	4	5	0
14) Seeing the edges of outside steps, kerbs or stairs	1	2	3	4	5	0
15) Bumping into people or things off to the side	1	2	3	4	5	0
16) Tripping over things	1	2	3	4	5	0
17) Objects suddenly appear when you should have noticed them before	1	2	3	4	5	0
18) Judging distance of foot to kerb or stair	1	2	3	4	5	0
19) Judging distance of objects	1	2	3	4	5	0
20) Moving in unfamiliar places	1	2	3	4	5	0
21) Going out in the street	1	2	3	4	5	0
22) Crossing the road	1	2	3	4	5	0
23) Seeing moving vehicles	1	2	3	4	5	0
24) Reading shop, street or traffic signs while walking	1	2	3	4	5	0
25) Walking in the dark	1	2	3	4	5	0
26) Seeing distant objects at night	1	2	3	4	5	0
27) Shopping, reading price labels and instructions on packets etc.	1	2	3	4	5	0
28) Making phone calls	1	2	3	4	5	0
29) Going by bus and train	1	2	3	4	5	0
30) Reading newspapers, magazines or books	1	2	3	4	5	0
31) Reading small print	1	2	3	4	5	0
32) Reading in dim light	1	2	3	4	5	0
33) Following the line of print or finding the next line	1	2	3	4	5	0
34) Reading or writing letters	1	2	3	4	5	0
35) Watching television	1	2	3	4	5	0
36) Reading TV text (subtitles)	1	2	3	4	5	0

Does your vision give you any difficulty with:

	not at all	a little bit	some	quite a lot	severe	don't do for other reasons
37) Seeing photos and pictures	1	2	3	4	5	0
38) Doing needlework	1	2	3	4	5	0
39) Seeing views	1	2	3	4	5	0
40) Seeing flowers	1	2	3	4	5	0
41) Gardening	1	2	3	4	5	0
42) Going to restaurants	1	2	3	4	5	0
43) Visiting friends	1	2	3	4	5	0

44) Does your vision hinder you in any other activities? yes no

If yes, what is it? .....

How much does your vision hinder or limit you in this?

not at all	a little bit	some	quite a lot	severe	don't do for other reasons
1	2	3	4	5	0

Falls and fear of falling:

F1) Have you fallen in the last 12 months? yes no

F2) In the last 12 months have you ever been anxious or worried about falling or been aware of being frightened of falling? This may or may not be associated with a feeling of unsteadiness. yes no

Would you, please, tell us how confident you feel in carrying out the following tasks. Please circle your answer on one of the five points of the scale from very confident [1] to not confident at all [5].

	very confident					not confident at all
C1) Getting dressed	1	2	3	4	5	
C2) Cooking and preparing food	1	2	3	4	5	
C3) Cleaning up and housework	1	2	3	4	5	
C4) Recognising faces	1	2	3	4	5	
C5) Walking on uneven ground	1	2	3	4	5	
C6) Walking on outside steps, kerbs or climbing stairs	1	2	3	4	5	
C7) Judging distance of foot to kerb or stair	1	2	3	4	5	
C8) Judging distance of objects	1	2	3	4	5	
C9) Moving in unfamiliar places	1	2	3	4	5	
C10) Going out in the street	1	2	3	4	5	
C11) Crossing the road	1	2	3	4	5	
C12) Reading shop, street or traffic signs while walking	1	2	3	4	5	

	very confident 1 2 3 4 5 not confident at all
C14) Shopping, reading price labels and instructions on packets etc.	1 2 3 4 5
C15) Going by bus and train	1 2 3 4 5
C16) Reading newspapers, magazines or books	1 2 3 4 5
C17) Doing needlework	1 2 3 4 5
C18) Going to restaurants	1 2 3 4 5
C19) Visiting friends	1 2 3 4 5

G8) In general, how much trouble do you have with your vision? Is i none, a little, some amount, quite a lot or a great deal?

none **1** little **2** some **3** quite a lot **4** great deal **5**

Please, answer the following questions only if you drive a car or hav driven one but had to give up driving <u>because of problems with your eyesight.</u>

When driving, does/did your vision give you difficulty with:

	not at all	a little bit	some	quite a lot	severe	don't do for other reasons
D1) Vehicles appearing unexpectedly	1	2	3	4	5	0
D2) Other vehicles appearing to go too fast	1	2	3	4	5	0
D3) Driving towards the sun or oncoming headlights	1	2	3	4	5	0
D4) Difficulties with reading road signs	1	2	3	4	5	0
D5) Problems when reversing	1	2	3	4	5	0
D6) Driving at night	1	2	3	4	5	0
D7) Seeing distant objects at night	1	2	3	4	5	0
D8) Reading the instrument panel at night	1	2	3	4	5	0

D9) Have you driven more carefully since you became aware of visual impairment?
not at all /1 a little bit /2 some /3 quite a lot /4 extremely /5

D10) Have you changed the distance that you leave between your own car and the car in front when driving since you became aware of visual impairment?
not at all /1 a little bit /2 some /3 quite a lot /4 extremely /5

D11) If you have stopped driving because of the problems with your vision, please tell us how long ago it was: .....

When you have finished, please, leave this questionnaire at the reception desk. Thank you very much for all your effort and help.

APPENDIX II

Questionnaire used in the main study

Dear .....

We would like to thank you very much for your decision to help us in our research aimed to help people with glaucoma in their everyday life.

Enclosed is a questionnaire that is crucially important for finishing our research study. Please, complete it carefully giving yourself a plenty time, probably up to 30 minutes.

Thank you for your kindness.

Yours sincerely

Patricia Nelson
(Research Assistant to Dr. O'Brien)

VISION DISABILITY QUESTIONNAIRE

Glaucoma Clinic (Dr. C O'Brien)

This questionnaire is confidential and no information from it will be passed on under any circumstances.

Please, give yourself plenty time to complete this questionnaire probably 30 minutes.

We are carrying out research aimed at finding out more about everyday problems of people with visual impairment. Please help us in this and answer the questions about the problems your vision gives you in particular tasks. Please, circle the appropriate answer.

ID: ..... **Age: .....** **Gender: M F**

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1) **In general, how much trouble do you have with your vision in your daily life? Is it none, a little, some amount, quite a lot or a great deal?**

none **1** little **2** some **3** quite a lot **4** great deal **5**

2) **Have you noticed any deterioration of your vision over the last few years?**

none **1** little **2** some **3** large **4** severe **5**

3) **If yes, which eye is it?**

right **1** left **2** both **3**

We are going to ask you about how much your vision gives you difficulty when carrying out particular tasks. Please, say whether you do not have difficulty at all **[1]**, or whether you have a little bit of difficulty **[2]**, some difficulty **[3]**, quite a lot of difficulty **[4]** or severe difficulty **[5]**. If you do not do the particular activity for other reasons or health problems rather than your vision your answer will be **[0]**.

If you usually carry out the particular activity with your glasses on then answer our question as if you had your glasses on.

PERSONAL CARE AND DOMESTIC TASKS

Does your vision give you any difficulty with:

	not at all	a little bit	some	quite a lot	severe	don't do for other reasons
4) Indoor mobility	1	2	3	4	5	0
5) Getting dressed and groomed	1	2	3	4	5	0
6) Cooking and preparing food	1	2	3	4	5	0
7) Pouring tea into a cup	1	2	3	4	5	0
8) Gardening	1	2	3	4	5	0
9) Shopping, reading price labels and instructions on packets, etc.	1	2	3	4	5	0
10) Finding things that you have dropped	1	2	3	4	5	0

GLARE, ADAPTATION AND COLOUR

Does your vision give you any difficulty with:

11) Adjusting to glare or being "dazzled" on sunny days or in bright lighting	1	2	3	4	5	0
12) Adjusting to dim lights	1	2	3	4	5	0
13) Going from dark to light room or vice versa	1	2	3	4	5	0
14) Do you notice any variation in colour richness from time to time	1	2	3	4	5	0

NAVIGATION AND MOBILITY

Does your vision give you any difficulty with:

	not at all	a little bit	some	quite a lot	severe	don't do for other reasons
15) Walking on uneven ground	1	2	3	4	5	0
16) Difficulty on outside steps, kerbs or stairs	1	2	3	4	5	0
17) Tripping over things	1	2	3	4	5	0
18) Bumping into things	1	2	3	4	5	0
19) Difficulty to see people or things coming from the side	1	2	3	4	5	0
20) Judging distance of foot to kerb or stair	1	2	3	4	5	0
21) Going out in the street on your own	1	2	3	4	5	0
22) Crossing the road	1	2	3	4	5	0
23) Going by bus and train	1	2	3	4	5	0
24) Seeing bus numbers	1	2	3	4	5	0

NAVIGATION AT NIGHT

Does your vision give you any difficulty with:

25) Walking in the dark	1	2	3	4	5	0
26) Seeing distant objects at night	1	2	3	4	5	0

NEAR VISION

Does your vision give you any difficulty with:

	not at all	a little bit	some	quite a lot	severe	don't do for other reasons
27) Reading newspapers, magazines or books	1	2	3	4	5	0
28) Reading or writing letters, cheques, mail etc.	1	2	3	4	5	0
29) Following the line of print or finding the next line	1	2	3	4	5	0

SOCIAL CONTACT, LEISURE ACTIVITIES, ETC.

Does your vision give you any difficulty with:

	not at all	a little bit	some	quite a lot	severe	don't do for other reasons
30) Recognising faces	1	2	3	4	5	0
31) Visiting friends, participating in church activities or in social and sports clubs	1	2	3	4	5	0
32) Seeing hymn numbers in the church	1	2	3	4	5	0
33) Seeing the activity at bingo, theatre, concerts, cinema and sports events	1	2	3	4	5	0
34) Watching television	1	2	3	4	5	0
35) Reading TV text (subtitles)	1	2	3	4	5	0
36) Doing needlework	1	2	3	4	5	0

FALLS AND FEAR OF FALLING

F1) Have you fallen in the last 12 months? Please, circle the right answer.

yes **no**

F2) In the last 12 months have you ever been anxious or worried about falling or been aware of being frightened of falling? This may or may not be associated with a feeling of unsteadiness.

yes **no**

GENERAL HEALTH

H1) Apart from the difficulties with your vision would you say your health is:

excellent **1** very good **2** good **3** fair **4** poor **5**

H2) How much pain in your body have you had during past 4 weeks?

none **1** very mild **2** mild **3** moderate **4** severe **5**

Apart from the difficulties with your vision, does your health limit you in any of the following activities? Please, say whether you are "not limited at all" [1], "limited a little" [2] or "limited a lot" [3].

	no, not limited at all	yes, limited a little	yes, limited a lot
H3) Moderate activities (moving a table, pushing a vacuum cleaner, carrying groceries, bowling or playing golf).	1	2	3
H4) Climbing several flights of stairs.	1	2	3
H5) Walking more than a mile.	1	2	3
H6) Walking 100 yards.	1	2	3
H7) Eating, dressing, bathing or using the toilet.	1	2	3

For each of the following questions, please circle th one answer that comes closest to the way you have bee feeling during the past month.

Our question is how much of the time in the past month you have been feeling in a certain way. Your answer can be either "none of the time" [NT], "little of the time" [LT], "some of the time" [ST], " a good bit of the time" [GBT], "most of the time" [MT] or "all of the time" [AT].

	NT None of the time	LT Little of the time	ST Some of the time	GBT A good bit of the time	MT Most of the time	AT All of the time
M1) Have you been a very nervous person?	1	2	3	4	5	6
M2) Have you felt downhearted and low?	1	2	3	4	5	6
M3) Have you been a happy person?	6	5	4	3	2	1
M4) Has your health limited your social activities (like visiting friends or close relatives) ?	1	2	3	4	5	6

M5) Do you find your visual condition irritating? Please, circle the appropriate answer.

not at all	1	quite a lot	4
a little bit	2	great deal	5
moderately	3		

M6) Do you find taking your eye drops a burden?

not at all	1	quite a lot	4
a little bit	2	great deal	5
some	3		

FEELINGS AND ATTITUDES

I would like you to read the following statements and tell me whether you personaly agree or disagree with them on a scale from strongly agree to strongly disagree. You can respond with "strongly agree" **[SA]**, "agree" **[A]**, "neutral" **[N]**, "disagree" **[D]**, "strongly disagree" **[SD]** or **"do not know".**

	SA	A	N	D	SD	do not know
F1) I am able to do things as well as most other people.	1	2	3	4	5	0
F2) I have little or no control over my progress from now on.	5	4	3	2	1	0
F3) In spite of my eye problem I don't feel too miserable most of the time.	1	2	3	4	5	0
F4) My eye problem is so annoying that I can't enjoy anything.	5	4	3	2	1	0
F5) When I make plans, I am certain that I can make them work.	1	2	3	4	5	0
F6) If something looks too complicated, I will not even bother to try it.	5	4	3	2	1	0
F7) Most of my life gets spent doing things that are relatively worthwhile.	1	2	3	4	5	0
F8) I really look forward to each new day.	1	2	3	4	5	0
A1) Visually impaired people are used to succeeding at most things that they do.	1	2	3	4	5	0
A2) Most visually impaired people are dissatisfied with their life.	5	4	3	2	1	0

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