Improving the detection of correctable low vision in older people

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Declaration

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To my parents

PARVIZ AND NIZAR JESSA

Thank you for your invaluable support and encouragement and for believing in me

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Thesis Abstract

In the UK, 20-50% of older people have undetected reduced vision and in most of these cases the poor vision can be readily corrected by new spectacles and/or cataract surgery. It is often assumed that older people with vision loss will have regular eye examinations so that these problems can be detected, but for many older people this assumption is wrong. One approach to improving the take-up of eyecare services is to carry out vision screening of older people in the community to raise awareness of the need for professional eyecare.

The present study aimed to investigate which tests would be most appropriate to screen for correctable visual loss in the older population and to incorporate these tests in a screening tool that would be effective yet simple to administer. The present research sought to investigate whether computerised techniques would be an effective method to screen vision in older people.

In Study 1, a computerised vision screener was used to test 180 older people in South London. All participants also received a full, 'gold standard', eye examination. Significant cataract was present in 32%, correctable refractive error in 39%, and overall 58% had at least one of these forms of correctable visual problems. The computerised vision screener was able to detect these conditions in about 80% of cases. In Study 2, 200 participants were screened using a revised version of the computerised vision screener. A new flipchart vision screener including the main tests from the computer vision screener was also investigated. 31% of participants in Study 2 had significant cataracts, 30% had correctable refractive errors, and 51% had at least one of these conditions.

The computer screener and flipchart tool were both good at detecting significant cataract and refractive errors. About 80% of cases of visual loss due to these problems or due to AMD could be detected with either of the screening tools. Using a pragmatic operational criterion, the screening tools detect about 94% of cases who might be considered by an optometrist to be in need of an eye examination (either overdue or reduced visual acuity). Glaucoma is a difficult disease to diagnose and it was found, as expected, that neither screening instrument was very good at detecting glaucoma.

The results showed that the best single test to use for screening of visual loss is HCVA which provides both a high sensitivity (77%) and specificity (73%). Greater sensitivity (80%) is achieved when high contract acuity, low contrast acuity and near acuity are used in combination. Greater specificity (77%) can be achieved by using low contrast acuity alone.

It is concluded that vision screening does not replace the need for professional eyecare, but acts as a tool to better inform the public of the need for regular eyecare.

Chapter 1

Introduction

1.1 The ageing population

The UK has a growing population and an ageing population. Recent national statistics published in August 2007 by the Office for National Statistics state that the population grew by 8% in the last 35 years, from 55.9 million in 1971 to 60.6 million in mid 2006. This change has not occurred evenly across all age groups. The population aged over 65 grew by 31%, from 7.4 to 9.7 million, whilst the population aged under 16 declined by 19%, from 14.2 to 11.5 million.

The statistics also indicate that the largest percentage growth in the population in the year to mid-2006 was at ages 85 years and over (5.9%). The number of people aged 85 years and over grew by 69,000 in the year to 2006, reaching a record 1.2 million. This large increase reflects improving survival of older people and it is predicted that the increase in the ageing population will continue throughout the first half of this century. The rise in the proportion of the population aged 65 and over is set to continue as the large numbers of people born after the Second World War and during the 1960s baby boom approach this age. Advances in medicine, health policies and socioeconomic development have all contributed to people living longer.

With the rising number of older people, research into the ageing process and conditions that are more prevalent with age is becoming increasingly important. The section below outlines how the eye changes with age and eye disorders that are common among the elderly.

1.2 The ageing eye

Figure 1.1 below, shows a horizontal section through the eye outlining the main structures that will be discussed in this section. As the eye ages, certain changes occur that can be attributed to the ageing process. Most of these anatomic and physiological processes follow a gradual decline. The section below has been structured in 3 parts, the first focusing on the changes and disorders that affect the front of the eye followed by the lens and then changes and disorders that affect the back of the eye. The section will end with a brief outline of common systemic conditions that may have an effect on the eye.

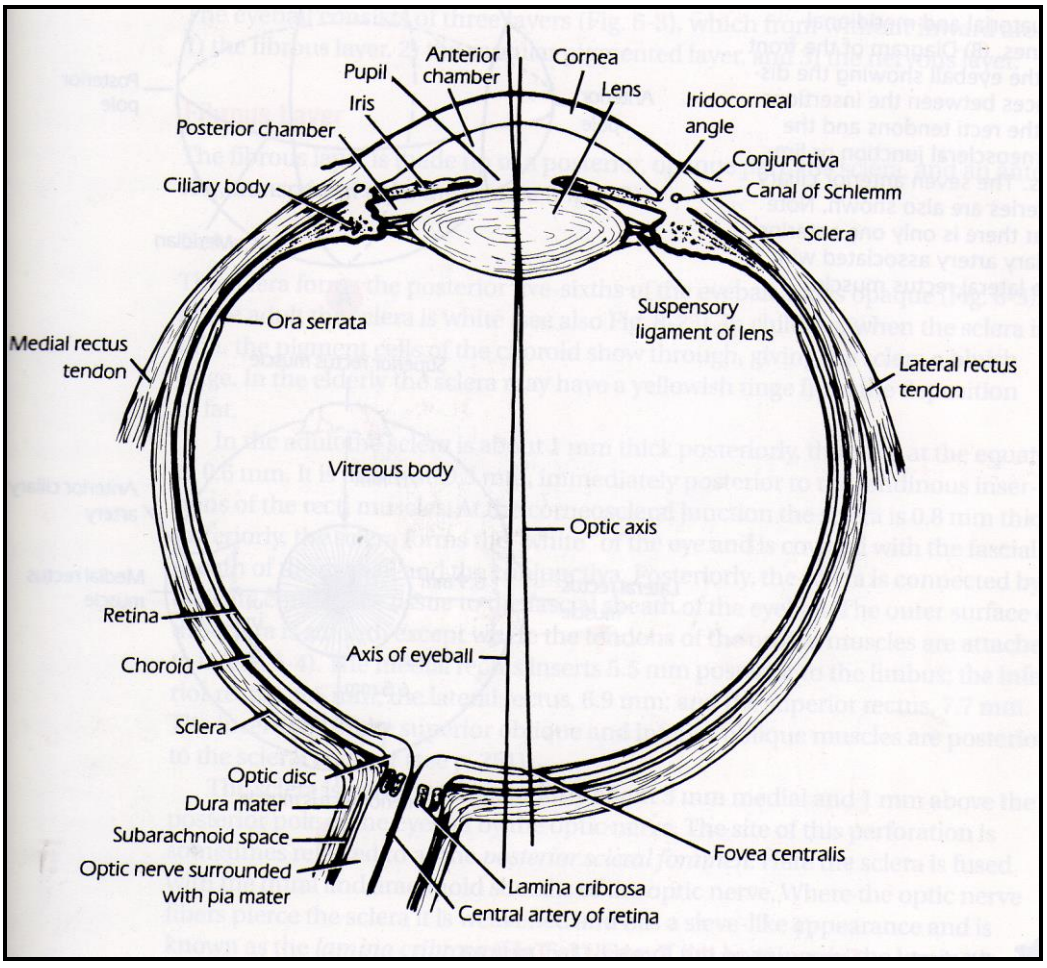

Figure 1.1 Horizontal section through the eye

1.2.1 Anterior Eye

The areas covered in this part include the structure surrounding the eye, tears, conjunctiva, cornea, sclera, trabecular meshwork and aqueous humour.

1.2.1.1 Structures surrounding the eye

A review by Buckley (2004) discussed the changes that occur in the anterior segment with age. The review suggested that many of changes in the external appearance of the ageing eye are caused by an increase in the parasympathetic tone over the sympathetic tone with age. Ageing causes laxity and downward shift of eyelid tissues and atrophy of the orbital fat. These changes contribute to the aetiology of several eye lid disorders such as ectropion (turning out of the eyelid-usually lower lid), entropion (turning in of the eyelid - usually the lower lid) and ptosis (drooping of the upper eyelid). The loss of orbital fat with age causes the globe to sink deeper in the orbit, (enopthalmos). With age, there is also a reduction in pupil size (miosis) which is thought to be attributable to atrophy of the pupillary dilator. Miosis reduces retinal illuminance and adds to light scatter from the edge of the pupil.

Lid margin disease (typically blepharitis) is a common problem in the older population. Blepharitis is the chronic inflammation of the lid margins usually caused by chronic staphylococcal infection which results in an uncomfortable burning sensation (Coakes & Sellors, 1995). Other symptoms that patients may experience are crusting of the eyelid margin, redness of the eyes and a feeling of dryness or sometimes tearing of the eyes. In severe cases, the condition may lead to secondary involvement of the conjunctiva and cornea (Coakes & Sellors, 1995). The goal of management is to relieve symptoms and reduce the risk of complications. This usually includes lid cleansing and the use of an antibiotic ointment.

1.2.1.2 Tears

The tear film is secreted by the lacrimal glands, which together with the secretions from the meibomian glands, the goblet cells, the glands of Zeiss and the accessory lacrimal glands, help to keep the conjunctiva and cornea moist and healthy

(Millodot, 2000). Tear secretion is established at birth and decreases linearly with age. Most patients remain asymptomatic despite the steady decrease in tear secretion. However, symptomatic tear deficiency may occur as part of the natural ageing process or as a result of age-related systemic disease (Buckley, 2004d).

1.2.1.3 Conjunctiva

The conjunctiva is a delicate mucous membrane that covers the front of the eye and lines the inside of the eyelids (Martin, 1996). The ageing conjunctiva shows a reduction in transparency, a yellowish discoloration and increased tortuosity and irregularity of blood vessels.

Common degenerations associated with age include pingueculae and pterygia. A pinguecula is a yellowish white elevation of the bulbar conjunctiva at the limbus. It represents the degeneration of stromal collagen fibres accompanied by epithelial thinning. In most cases surgical intervention is not required. A pterygium is a triangular fold of bulbar conjunctiva with its apex advancing progressively towards the cornea, usually from the nasal side. It is considered to be a degenerative process caused by recurrent dryness or irritation from wind and dust or prolonged exposure to sunlight (Millodot, 2000). In time, pterygia may encroach on the cornea and threaten vision both by changes in refractive error and in severe cases by visual loss from involvement of the visual axis (Kanski, 1999). Surgical intervention is indicated if the pterygium is threatening the visual axis, if the eye is perpetually uncomfortable or if the patient is unhappy with the cosmetic appearance. Recurrence of ptyergia following surgical excision is common (Coakes & Sellors, 1995).

1.2.1.4 Cornea

The cornea is the transparent circular media at the front of the eye. It refracts the light entering the eye on to the lens which then focuses it on to the retina. The cornea should contain no blood vessels and is extremely sensitive to pain (Martin, 1996). The cornea consists of 5 layers; the epithelium, Bowman's layer, stroma, Descemet's membrane and the endothelium (Kanski, 1999). Each of these layers

responds to the ageing process in different ways and a few of the degenerations that occur in the layers of the cornea will be discussed in this section

Ocular astigmatism is a refractive condition which most commonly originates in the cornea, but can also originate from the crystalline lens. It occurs when the image of a point object is not a single point but two focal lines at different distances from the eye. It is generally caused by one or several toroidal shapes of the refracting surfaces, or by light entering the eye obliquely. This refractive condition can be corrected by wearing cylindrical lenses. The axis of astigmatism tends to change with age from 'with the rule' (optical power of the eye greatest in the vertical meridian) in youth to 'against the rule' (optical power of the eye greatest in the horizontal meridian) in old age. The literature review by Buckley (2004) suggests that this change may be due to the decreasing pressure from the lids as they become more lax (Buckley, 2004c).

A very common feature of the ageing eye is arcus senilis. This is characterised by a greyish white ring (or part of a ring) opacity occurring in the periphery of the cornea (Millodot, 2000). It occurs in the stromal layer of the cornea and the peripheral annulus of opacity is separated from the limbus by a clear interval. Its presence is due to the increased permeability of local blood vessels to lipids and is related to serum cholesterol level.

Another change that occurs in the structure of the stroma is an increase in the spacing of collagen fibres resulting in opacities that are termed 'Crocodile Shagreen'. This is characterised by the presence of usually asymptomatic, greyish-white, polygonal stromal opacities separated by relatively clear spaces. The opacities frequently involve the anterior two thirds of the stroma (anterior crocodile shagreen) although on occasion they may be found more posteriorly (posterior crocodile shagreen) (Kanski, 1999). A further degeneration originating in the stromal layer is Vogt's white limbal girdle. This is present in all patients aged over 80 years. It consists of fine white radial lines, usually seen in the nasal cornea. Vogt's limbal girdle is similar histologically to pingueculae and pterygia (Buckley, 2004e).

The corneal endothelium consists of a single layer of hexagonal cells. It plays a vital role in maintaining the deturgescence of the cornea. With age, the number of endothelial cells gradually decreases but because they cannot regenerate, neighbouring cells have to spread out to fill the space (Kanski, 1999). Not only does the total number of cells reduce, they become increasing irregular in shape and variable in size with age. Corneal guttata is an age-related corneal degeneration involving the endothelium and is due to the focal accumulation of collagen on the posterior surface of Descemet's membrane. It is formed by abnormal endothelial cells and examination will show dark spots caused by the disruption of the endothelial mosaic. These lesions are usually innocuous although they may be indicative of early stages of Fuchs' endothelial dystrophy (Kanski, 1999)

Fuchs' dystrophy is a fairly common condition among older people. The review by Buckley (2004) explains that Fuch's dystrophy is characterised by a new layer of abnormal fibrillar collagen forming between the normal Descemet membrane and the endothelial cells. In the later stages of the condition, abnormal collagen also accumulates under the epithelium. Fuchs' dystrophy is an autosomal dominant condition but is surprisingly more common in females than males with a ratio of 4:1. In the early stages of Fuchs' dystrophy patients are asymptomatic and as there is no reduction in vision, no treatment is required at this stage. As the condition progresses, vision may decline and the patient may suffer pain from corneal oedema leading to bullous keratopathy. At this stage hypertonic agents may be required to dehydrate the cornea and soft contact lenses may be used to reduce the pain of keratopathy. The later stages of Fuchs' dystrophy result in a more significant reduction in vision which may require a penetrating keratoplasty (full thickness corneal transplant).

1.2.1.5 Sclera

The sclera is an envelope of dense collagenous tissue that protects the eye against mechanical damage and helps to maintain the shape of the eye. The sclera also provides attachment for the tendons of the recti muscles. In common with other connective tissues, the lipid composition of the sclera increases with age.

The increase in lipid content accounts for the yellowing of the sclera with age (Snell & Lemp, 1998). Calcium deposited between the collagen fibres results in sclera plaque. The lesions appear as yellow or grey/black vertical bands and are more common in patients over 60 years of age. Scleral rigidity also increases with age due to the increase in the number of elastic fibres with age (Buckley, 2004b).

1.2.1.6 Trabecular meshwork, aqueous humour, and primary open angle glaucoma

The aqueous humour is a thick watery substance that fills the space between the lens and the cornea (Martin, 1996). Its functions include maintaining intraocular pressure of the eye and contributing to the dioptric power to the cornea. Aqueous humour is continually produced by the ciliary processes (part of the ciliary body) and this rate of production must be balanced by an equal rate of aqueous humour drainage. Small variations in the rate of production or outflow of aqueous humour will have a large effect on the intraocular pressure. The trabecular meshwork is an area of tissue in the eye located around the base of the cornea near the ciliary body which is responsible for draining the aqueous humor from the eye.

Numerous morphological changes have been described in the aqueous outflow system in glaucomatous eyes. Many of these are also seen in normal aged eyes without glaucoma. This has led to the speculation that glaucomatous changes in the outflow pathway may represent an accelerated ageing process (Buckley, 2004f).

Primary open angle glaucoma is a progressive optic neuropathy characterized by excavation of the optic nerve head and a distinctive pattern of visual field defects (Kanski, 1999). There may also be raised intraocular pressure although this is not always the case (Millodot, 2000). This type of glaucoma is uncommon under the age of 40 but there is a strong hereditary component and particular care should be taken to examine first degree relatives (Coakes & Sellors, 1995). It is not understood how ageing predisposes to the development of glaucoma, but it may increase the vulnerability of the optic nerve head to pressure-related damage (Buckley, 2004a).The visual impairment caused by glaucoma is irreversible but the disease is treatable and this makes early detection of glaucoma essential in the management of the condition (Weinreb & Khaw, 2004c).

1.2.1.7 Lens

The lens is a biconvex, usually transparent body, situated between the iris and the vitreous body of the eye and suspended from the ciliary body by the zonular fibres. It consists of the capsule which envelopes the lens, the anterior epithelium and the cortex which surrounds the nucleus (Millodot, 2000). The primary function of the lens is to transmit visible light and sharply focus it on the retina. It contributes approximately one third of the eye's total optical power and by changing its shape, the pre-presbyopic lens is able to fulfil the requirements of the accommodative process (Lawrenson, 2004a).

Accommodation is the adjustment of the shape of the lens to change the focus of the eye. When the ciliary muscle is relaxed, suspensory ligaments attached to the ciliary body and holding the lens in position are stretched which causes the lens to be flattened. The eye is then able to focus on distant objects. To focus on near objects the ciliary muscles contract and the tension in the ligaments is thus reduced, allowing the lens to increase in curvature and become rounder. With age, the lens undergoes structural changes resulting in a gradual loss of elasticity of the lens which thus becomes progressively less able to increase its curvature in order to focus on near objects. This is known as presbyopia and results in difficulty in performing close work, for example reading at the usual distance (Martin, 1996).

In addition to loss of accommodation, another almost invariable change in the lens with age is a loss of transparency. It has been suggested that 90% of patients aged over the age of 70 have some loss of lens transparency (Zadnik, 1997). Age-related lens opacities can be divided into three categories: nuclear, cortical and posterior subcapsular. The figure below shows where in the lens the opacities occur.

Nuclear opacities are the most common and are often referred to as nuclear sclerosis. Nuclear opacification is an acceleration of the normal ageing of the lens nucleus. The patient experiences a slow, gradual, progressive reduction in the quality of vision. The nucleus begins to take on a milky appearance owing to increased light scatter and yellows as a result of increased absorption of shorter wavelengths. The change in lens colour is also referred to as brunescence. There

may also be a concurrent increase in refractive index of the nucleus, which can result in a myopic shift in refractive error. Finally, localised changes in refractive error may manifest as monocular diplopia. Cortical opacities occur in the cortex of the lens and usually begin outside of the pupil area and in the inferior nasal quadrant. For this reason, the clinician is likely to observe them before the patient is aware they exist. Posterior subcapsular opacities develop near the posterior pole of the lens and can have a dramatic effect on vision owing to their proximity to the visual axis and nodal point of the eye (Zadnik, 1997).

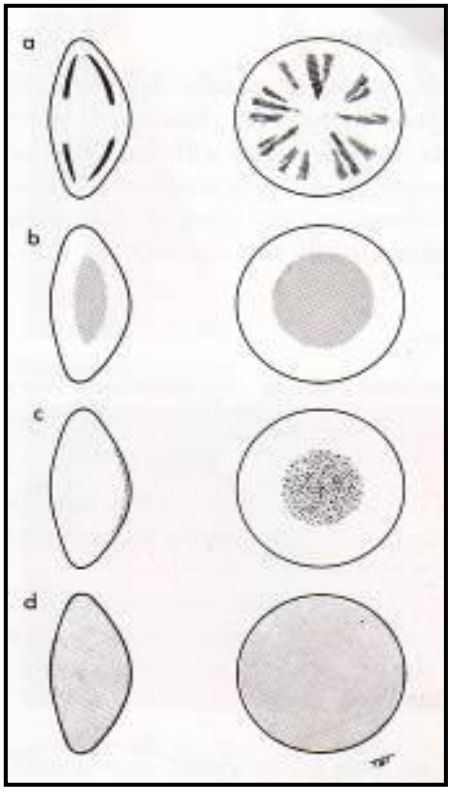

Figure 1.2 The common types age related cataract a) Cortical lens opacities b) Nuclear sclerosis c) Posterior subcapsular opacification d) Mature cataract indicating total opacification of the lens.

Surgical management is the mainstay of treatment for cataract and a number of studies have shown that surgery significantly enhances the quality of patients' lives. In the early stages of cataract, optimal refractive management and advice on

glare reduction can lessen the functional impact of cataracts. Surgery is considered when these measures are no longer adequate for patients' visual needs (Lawrenson, 2004b).

1.2.2 Posterior Eye

This section will outline changes in the vitreous, retina and choroid. Eye disorders prevalent in the older population that are related to these structures will also be discussed. These will include primary open angle glaucoma, age-related macular degeneration and retinal vessel occlusions.

1.2.2.1 Vitreous

The vitreous is a transparent jelly-like structure that fills the chamber behind the lens (Martin, 1996). In ageing eyes, the vitreous gel changes in structure. Synchisis senilis occurs in which the gel becomes liquefied and also syneresis, which describes the process of the gel collapsing in on itself. The 'collapse' of this gel can cause traction on the retina resulting in posterior vitreous detachment which in turn is a risk factor for retinal tears and detachment (Hammond, 2004c). Another less common ageing change in the vitreous gel is Asteroid Hyalosis in which numerous small stellate or discoid opacities develop in the vitreous (Millodot, 2000). These opacities are usually found in one eye and although they are more common with age, no other systemic associations have been found (Hammond, 2004d).

1.2.2.2 Retina and choroid

The retina is the light receptive, innermost nervous tunic of the eye. It is a thin transparent membrane lying between the vitreous and the choroid and extends from the optic disc to the ora serrata (Millodot, 2000) . It contains many layers (see Figure 1.3): the outer part of the retina (retinal pigment epithelium, RPE) next to the choroid is pigmented, acting as a solar barrier protecting the inner retina against excess light damage. The inner part of the retina contains rods and cones (photoreceptor cells) and their associated neural network. The retinal pigment epithelium also regulates the nutrition of photoreceptors and is of vital importance in the health of these cells.

There is interaction between the numerous cells and layers and indeed between the retina and the choroid posterior to it. The retina shows significant change with age and this is because the retina undergoes considerable stresses during a person's lifetime. Unlike so many parts of the body where there is a very high turnover of cells, there is much lower turnover in the retina. This means that the retina is vulnerable to changes with age (Hammond, 2004e).

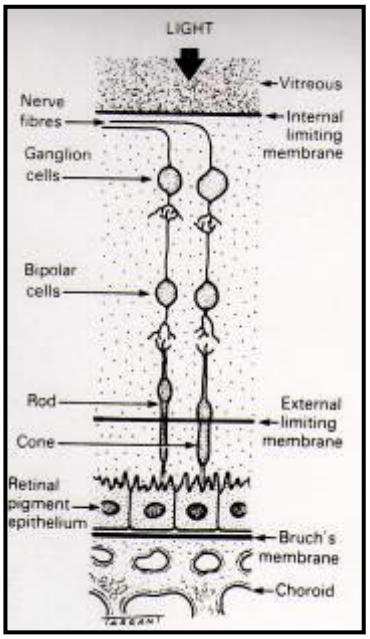

Figure 1.3 Retinal layers

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The retina is prone to oxidative stress, which is cellular damage caused by reactive oxygen intermediates produced during chemical reactions. The retina is very susceptible to this damage as it has a very high oxygen demand and therefore there are numerous chemical reactions producing reactive oxygen intermediates (Hammond, 2004b).

The choroid is a highly vascular tunic of the eye lying between the retina and the sclera and its main function is to nourish the retina. It has five layers: the supra choroid, the vessel layers (Haller's layer and Sattler's layer), the chorio-capillaris and Bruch's membrane (Millodot, 2000). As the eye ages, it is thought that there is

reduced choriocapillaris blood flow, the choroidal blood vessels commonly show evidence of sclerosis after the age of 60 years (Snell & Lemp, 1998). There is also accumulation of waste products (lipofuscin) in Bruch's membrane, which is derived from the RPE. Subretinal epithelial deposits, known as drusen are a common feature and there is some evidence that there is reduced RPE function (with loss of rods) with advancing age. Large, soft drusen and RPE changes predispose the eye to subretinal neovascularisation. There is some evidence that oxidative stress, particularly blue light and the high oxygen usage of the retina, is important in the aetiology of many of the changes seen in ageing eyes (Hammond, 2004a).

1.2.2.3 Glaucoma

Primary open angle glaucoma (POAG) has been defined earlier and is generally a bilateral condition but not necessarily symmetrical. Age is an important risk factor for primary open angle glaucoma and it is unusual for the diagnosis to be made before the age of 40. Raised intraocular pressure, myopia, race (African racial descent), and a family history of glaucoma are also risk factors for glaucoma (Kanski, 1999).

Patients with POAG are usually asymptomatic until a significant loss of visual field has occurred. This is because the initial visual field loss involves parts of the visual field which are also covered by the field of the other eye. Although the disease is usually bilateral, progression is often asymmetrical so patients frequently present with less advanced disease in the other eye. Frequently POAG is first diagnosed by finding a suspicious optic disc or asymmetrical discs during a routine eye examination (Figure 1.4) indicating the importance of regular eye examinations for older people. Population screening for glaucoma using tonometry (measurement of intraocular pressure) alone is not satisfactory because it will label as 'normal' a significant number of cases with other features of POAG such as optic nerve head changes and visual field loss (Kanski, 1999). Glaucoma can be a challenging condition to detect and diagnose and this issue, and the sensitivity and specificity of screening tests is returned to in Chapter 9.

The purpose of treatment of POAG is to preserve visual function by controlling intraocular pressure and thereby preventing or retarding further optic nerve

damage. Regular and careful follow up is also important to ensure that any progression is detected early (Kanski, 1999).

(a) (b)

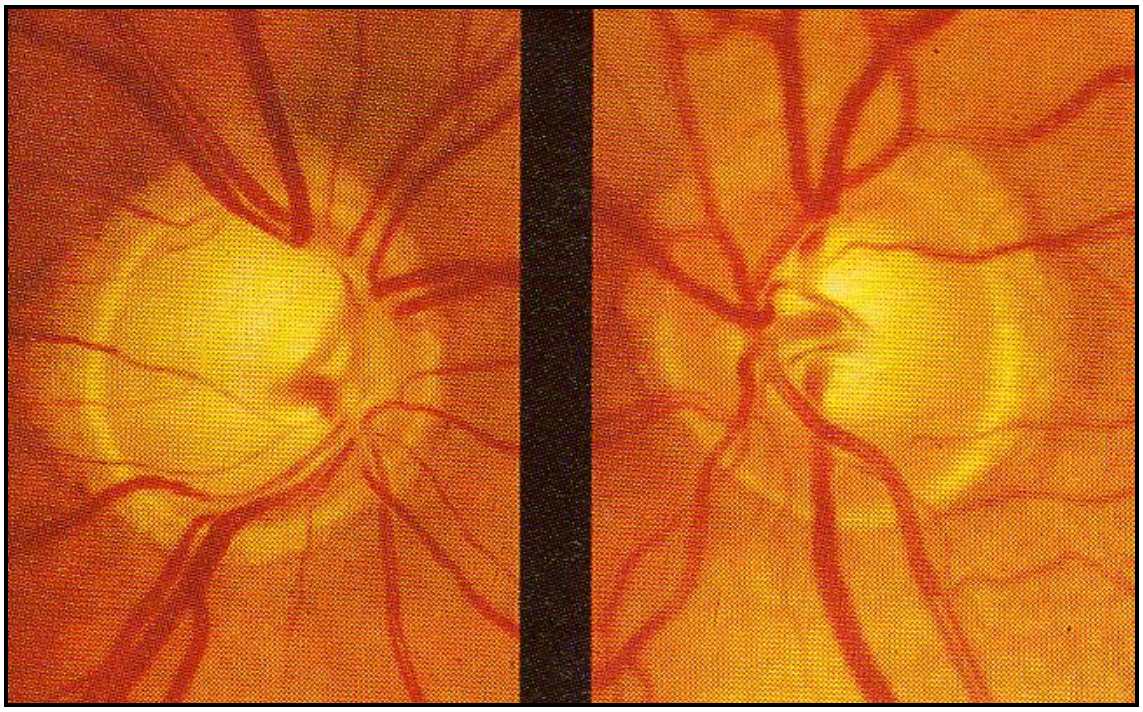

Figure 1.4 Glaucomatous cupping of the optic disc (a) and normal fellow optic disc (b)

1.2.2.4 Macular degeneration

Macular degeneration is a condition found in a large percentage of older patients (Millodot, 2000). Age-related macular degeneration (AMD) is the leading cause of irreversible severe visual loss in the western world in individuals over 60 years of age. AMD can be classified into two types: Non exudative (dry) or Exudative (wet). Non Exudative AMD (Figure 1.5) is a slow progressive disease which accounts for 90% of cases (Kanski, 1999). Exudative, although much less common, is frequently devastating and in some cases all useful vision may be lost within a few days. In fact 88% of legal blindness attributable to AMD is the result of this type. Two important features of exudative AMD are detachment of the RPE and choroidal neovascularisation (CNV) (Kanski, 1999). Exudative AMD occurs when new vessels form to improve the blood supply to oxygen-deprived retinal tissue.

However, the new vessels are very delicate and break easily, causing bleeding and damage to surrounding tissue.

As the disorder involves the central retina or macula, reduced vision and/or distortion of vision are noted quite early in the disease. This is particularly noticeable if the centre of the macula (fovea) is involved. Visual acuity, contrast sensitivity and colour vision are all reduced together with metamorphopsia or distortion seen more commonly in exudative AMD (Saeed & Lee, 2004c;Buckley, 2004g). Loss of central vision in macular degeneration is the result of changes that occur in response to deposition of abnormal material in Bruch's membrane. This abnormal material is derived from the RPE and its accumulation is thought to result from failure to clear debris discharged into this region. Drusen consist of discrete deposits of this abnormal material in the inner portion of Bruch's membrane between the basement membrane of the RPE and the inner collagenous layer. The abnormal material also accumulates diffusely throughout Bruch's membrane. The appearance of drusen represents the earliest clinically detectable feature of macular degeneration. Drusen may vary in number, size, shape, degree of elevation and extent of associated changes in the RPE. In some patients, drusen may be confined to the region of the fovea, whereas in others the deposits may encircle the fovea itself. Drusen are rarely clinically visible before the age of 45 years; they are not uncommon between the ages 45 and 60 years and almost universal thereafter. With advancing age they increase in size and number (Kanski, 1999).

A central scotoma is the hallmark of the condition, which is initially noted on wakening (Saeed & Lee, 2004b). The central scotoma is usually surrounded by a variable degree of distortion, which further hampers visual function. Patients may also experience difficulty in seeing in bright light as well as dim light. This may be due to compromised light adaptation mechanism of photoreceptors. Recovery from bright to dim light is slow. Drusen may be associated with mild symptoms but not necessarily significant visual loss (Saeed & Lee, 2004a).

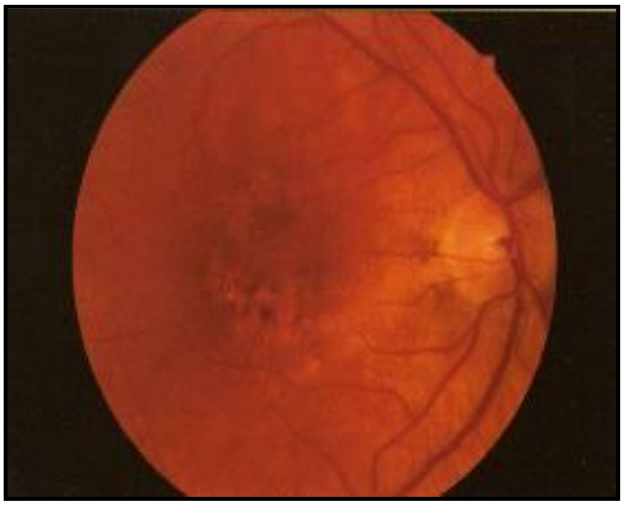

Figure 1.5 Early age related macular degeneration

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Increasing awareness of the condition among the population can lead to early identification of AMD. Patients with dry AMD can be given advice on how to monitor their own vision and signs of wet macular degeneration should be reported immediately with immediate referral for ophthalmological investigation and possible treatment (Saeed & Lee, 2004d).

Extensive research is ongoing into developing new treatments to restore vision and prevent further vision loss in patients with macular degeneration. Significant advances have been made which began with the introduction of photodynamic therapy for the treatment of wet AMD. Visudyne drug treatment (photodynamic therapy) was the first drug therapy for treatment of the wet form of the disease. It is only effective for those patients who have new blood vessel growth under the retina in a well-defined, distinctive pattern known as "predominantly classic." The treatment involves an injection of Visudyne which when activated by a laser light, produces a chemical reaction that destroys abnormal blood vessels.

Further developments have been made since the introduction of photodynamic therapy. While no treatment for macular degeneration is likely to completely restore vision, some drugs may be able to preserve or even improve remaining vision. Also, certain treatments have shown promise for reversing at least some vision loss in many AMD patients. These treatments involve the use of Avastin. Like

Macugen and Lucentis (which is a form of Avastin), the drug is injected directly into the vitreous at the back of the eye and is aimed at stopping the action of a naturally occurring protein (VEGF) responsible for formation of abnormal blood vessel growth that causes eye damage in wet AMD.

It is likely that the efficacy of treatments for macular degeneration will continue to improve which in turn will mean that fewer older people will suffer the devastating consequences of visual loss resulting from macular degeneration.

1.2.2.5 Retinal vein and artery occlusion

The retina receives its blood supply from the central retinal artery and deoxygenated blood exits the eye through the central retinal vein. A blockage in either a retinal vein or artery is known as a 'retinal vessel occlusion'.

A retinal artery occlusion prevents fresh blood reaching the retinal cells. When this happens the retinal cells quickly suffer from the lack of oxygen. The main cause of a retinal artery occlusion is atherosclerosis causing hardening or thinning of the arteries and veins. A patient with an artery occlusion will experience painless loss of vision which usually happens very suddenly with little or no warning. In nearly all cases, one eye is affected. Some people may experience short periods of sight loss (amaurosis fugax) before the sight loss becomes permanent.

Occlusion of the central retinal artery is characterised by a sudden loss of vision and a defective direct pupil light reflex. The retina appears white and swollen and the choroid is seen through it as a cherry red spot (Kanski, 1999). Occlusion is more frequently limited to one branch of the central retinal artery. In this case, the clinical picture is limited to the area supplied by that branch and this is associated with a visual field defect in that region (Millodot, 2000).

Unfortunately there is little treatment available for retinal artery occlusions because the cells on the retina are very sensitive to a lack of blood supply. Depriving the retinal cells of a blood supply for even a short period of time results in permanent sight loss. In some people the blockage that causes the first sight loss may become dislodged and if the blood supply is started again after only a short delay

then some improvement in vision may be seen. However, in most cases there is some vision loss.

The retinal veins drain away the deoxygenated blood from the retina. In a retinal vein occlusion, one of these veins becomes blocked and the blood cannot drain away properly. This obstruction in circulation causes pooling of blood resulting in swelling and areas of haemorrhage. These areas of swelling and backed up blood damage the cells of the retina and therefore damage sight and cause permanent changes to the retinal circulation. There are a number of common risk factors for retinal vessel occlusions including increasing age, high blood pressure and diabetes. Raised intraocular pressure also increases the risk of a central retinal vein occlusion (Kanski, 1999).

Occlusion of the central retinal vein can be either ischaemic or non-ischaemic. The non-ischaemic type is characterised by some loss in vision and slight impairment of pupil responses to light. The ischaemic type which affects older people is a more severe type and the signs and symptoms are much more marked than in the non ischaemic type (Millodot, 2000). Occlusion is more frequently limited to one branch of the central retinal vein. In this case the picture is limited to the retinal area drained by the occluded branch. The extent of vision loss will depend on the involvement of the macular.

In a vein occlusion, sight loss may be gradual and in nearly all cases only one eye is affected. The sight loss caused by this kind of occlusion can sometimes improve on its own. Because the blood 'backing-up' can cause swelling and bleeding, sometimes when this swelling and the blood that has leaked clears up, sight can improve a little. In a few but not all cases, a laser can be used in this type of occlusion to help control bleeding and swelling and this can mean that sight improves a little.

The treatment of vein occlusions depends on the primary cause. In some cases photocoagulation may be used (Millodot, 2000) to stop more damage occurring so although no sight is restored the likelihood of losing more sight is reduced. Ischaemic central retinal vein occlusion may result in glaucoma - in fact it is the

most common cause of secondary neovascular glaucoma. Approximately 50% of eyes with ischaemic central retinal vein occlusion develop neovascular glaucoma within 3 months (Kanski, 1999). Neovascular glaucoma results from the attempt of the retina to revascularise hypoxic areas of the retina by releasing heparin binding growth factors. These factors induce the development of secondary neovascularisation of the retina and are capable of diffusing in to the anterior segment, where they initiate neovascularisation of the iris. The subsequent invasion of the angle by fibrovascular tissue results in elevation of the intraocular pressure as a result of impairment of aqueous outflow. The fibrovascular membrane later contracts to produce secondary angle closure glaucoma (Kanski, 1999).

Since retinal vessel occlusions are often connected to other more general circulation problems, it is important that retinal vessel occlusions are identified early so that steps can be taken to treat the systemic conditions associated with retinal vessel occlusions. This can help to reduce the likelihood of a similar occlusion in the other eye.

1.3 Neurodegenerative changes with age

The quality of visual perception is related to the integrity of the entire visual system. Therefore any consideration of the effects of ageing on visual function must take into account changes in the entire system, not just the eye. There are a wide range of neurodegenerative diseases that occur in adult life and in this section two key conditions; Alzheimer's disease and Parkinson's disease together with their neuro-ophthalmological features will be discussed briefly below.

1.3.1 Alzheimer's disease

Dementia is a loss of mental function in two or more areas such as language, memory, visual and spatial abilities or judgment severe enough to interfere with daily life (Solomons, 2005c). There are currently about 700,000 people in the UK with a form of dementia. One in 14 people over 65 years of age and one in six people over 80 years of age has a form of dementia. It is estimated that by 2021 there will be about 940,000 people with dementia in the UK and this is expected to

rise to over 1.7 million people by 2051 (Alzheimer's society, 2007a). Dementia itself is not a disease but a broader set of symptoms that accompanies certain diseases, e.g., Creutzfeldt-Jakob disease and Alzheimer's disease. Alzheimer's disease is the most common type of dementia accounting for 62% of all patients with dementia (Alzheimer's society, 2007b).

Alzheimer's disease is a degenerative condition that affects the brain. In this disease there is a deposit of abnormal protein outside nerve cells and also an accumulation of abnormal filaments of protein inside nerve cells in the brain. There can also be atrophy of the affected areas of the brain and enlargement of the ventricles as well as loss of certain neurotransmitters (Solomons, 2005b).

Alzheimer's disease begins gradually and progresses at a variable rate. Although the condition may manifest in different ways, the pattern of cognitive decline usually follows a recognised series of stages. Initially patients suffer from short term memory defects. More profound deficits follow, including selective and sustained attention, planning, understanding of the consequences of actions, recognition of what is socially appropriate and control of own emotions. Depression and paranoia are common and compounded by social isolation. Specific cognitive effects, such as problems recognising and naming familiar objects generally occur later in the disease (Mort & Kennard, 2000a).

Patients with Alzheimer's disease can suffer from visual disturbances caused by the brain rather than the visual system. That is, their problem can be having difficulty perceiving what they see rather than how sharply they see it. Problems most commonly occur in four areas- motion, depth, colour and contrast (Solomons, 2005a). Visual hallucinations have been reported to increase with loss in acuity in some patients with Alzheimer's disease (Chapman *et al.*, 1999). It has also been reported that patients can appear to be confused and lost due to a form of motion blindness, as if the world is seen in a series of still frames (Tetewsky & Duffy, 1999). This damage to the area of the brain concerned with perception of motion may cause patients to appear lost even in familiar surroundings.

Patients with Alzheimer's disease seem to be impaired at low spatial frequencies instead of the high spatial frequencies as in old age. This implies that regions controlling the low spatial frequency processing in the primary visual cortex would be more affected than those for high frequency processing (Wong-Riley *et al.*, 1997). The affect of Alzheimer's disease on the visual areas of the brain was also investigated by Hof et al. Hof and colleagues conducted neuropathological examination of the brains of those with visual impairment and their research showed that correlations could be established between clinical symptoms and the distribution of neurodegenerative lesions. They found a high density of pathological lesions in brains with Alzheimer's disease in the primary visual areas of the brain with Alzheimer's and certain visual association areas within the occipital lobe and posterior parietal cortex. A high distribution of pathological lesions in the cerebral cortex of Alzheimer's disease cases with visual symptoms was also noted (Hof *et al.*, 1997).

1.3.2 Parkinson's disease

Parkinson's disease is a progressive neurological condition affecting movements such as walking, talking, and writing. The Parkinson's disease society states that in the UK one in 500 people (approximately 120,000 individuals) have Parkinson's and about 10,000 people in the UK are diagnosed each year. The condition commonly affects middle-aged and elderly people. The symptoms first appear, on average, when a patient is older than 50 and statistically, men are slightly more likely to develop Parkinson's than women (Parkinson's disease society, 2008).

Parkinson's disease occurs as result of a loss of nerve cells in the part of the brain known as the substantia nigra. These cells are responsible for producing a chemical known as dopamine, which allows messages to be sent to the parts of the brain that co-ordinate movement. With the depletion of dopamine-producing cells, these parts of the brain are unable to function normally.

The three most characteristic signs of Parkinson's disease are akinesia (slowness of movement), rigidity and tremor. In addition, patients treated with levodopa may exhibit dyskinesia or dystonia. Dyskinesia is a state in which the patient fidgets,

twitches or is generally restless, while dystonia is a spasm of one of the set of muscles often deforming a limb into an abnormal position (Armstrong, 2008a). Some patients with Parkinson's disease develop memory problems and mood changes and a few individuals develop dementia similar to that found in Alzheimer's disease (Armstrong & Syed, 1996).

Many patients with Parkinson's disease may be visually asymptomatic. However, the disease can be associated with visual signs and symptoms including defects in eye movements and pupillary function and in more complex visual tasks involving the ability to judge distance or the shape of an object (Armstrong, 2008b). Repka and colleagues found that visual complaints were significantly more common in patients with Parkinson's disease than in the age-matched controls and this seemed to be correlated with a decline in visual acuity (Repka *et al.*, 1996) with low contrast acuity also being affected (Jones & Donaldson, 1995). The decline in visual acuity can be attributed to the lack of dopamine in the retina (Jones *et al.*, 1992) and this can also contribute to the development of hallucinations in Parkinson's disease (Matsui *et al.*, 2006a). Visual hallucinations are experienced by 30-60% of people treated for Parkinson's disease (Diederich *et al.*, 2005) and this is especially associated with those that are treated with L-dopa.

Eye movement problems are a particularly important aspect of Parkinson's disease and abnormal saccadic and pursuit movements have been reported in about 75% of patients (Shibasaki *et al.*, 1979). Abnormal optokinetic nystagmus and convergence (Corin *et al.*, 1970) have also been reported. It is possible that the abnormal convergence can be associated with an exophoria and sometimes leads to the complaint of diplopia for near vision only (Mort & Kennard, 2000b).

Pupil reactivity is also affected in Parkinson's disease. Different varieties of pupillary abnormalities have been described in Parkinson's disease but it is not clear if this is due to the disease itself or to the pharmacological treatment. Significantly larger pupil diameters with anisocoria after light adaptation have been reported with no differences being observed after dark adaptation. In addition reduced amplitude of contraction and a prolonged contraction time at light reflex

have also been observed indicating an autonomic imbalance involving the parasympathetic system (Micieli *et al.*, 1991).

The exact presentation of Parkinson's disease seems to be highly variable and it is likely that many patients with Parkinson's disease will be visually asymptomatic. Visual deficits may develop during the course of the disease and may be an important factor in influencing overall motor function (Diederich *et al.*, 2002) and a risk factor for developing hallucinations (Matsui *et al.*, 2006b). Some of the visual problems that may develop may be adverse reactions to treatment.

The beginning of this Chapter has highlighted that the ageing population is increasing and with this it is likely that the prevalence of neurodegenerative disorders such as Alzheimer's disease and Parkinson's disease will also increase. While it could be argued that those with cognitive dysfunction such as that seen in dementia are less likely to notice reduced vision, a counter argument is that everything possible should be done to help improve the quality of life of those with these conditions and this should include identifying and correcting any visual defects.

1.4 Changes in visual performance and function

This section will briefly explore how age affects visual performance and relate this to changes in the anatomy and physiology of the eye described above. The change in visual function with age is also highlighted in Chapter 2 and Figure 2.1 shows a wide range in decline among visual functions with age.

The formation of a retinal image is the first stage in perception and any degradation in the optics of the eye with age will have a corresponding impact on visual performance. A review by Thomson (2008) describes the principal changes that occur in the structure of normal, healthy, ageing eyes and how these changes relate to changes in visual function. The review explains that the main age related changes in the eye affecting visual function are: (1) an increase in light scatter in the lens; (2) a reduction in optical quality resulting in some degree of defocus; (3) a decrease in retinal illuminance caused by age related miosis and increasing

absorption of light by the crystalline lens; and (4) neural loss in the retina and the visual cortex..

The affect of age on a few key aspects of visual function will be briefly discussed below.

1.4.1 Visual acuity

Most studies report a decline in visual acuity with age, although there is some dispute as to when the decline commences. The commonly held belief among clinicians is that visual acuity remains stable throughout adulthood until the age of approximately 50 years, after which it shows more or less a linear decline. This belief is largely based on the reviews of Pitts and Weale (Pitts, 1982;Weale, 1975). The age related decline in visual acuity has also been noted by Elliott et al where acuity was shown to decrease by approximately one line on the letter chart across the third and sixth decades of life (Elliott *et al.*, 1995).

1.4.2 Contrast sensitivity

Contrast sensitivity is the reciprocal of the contrast threshold, defined as the ratio between threshold stimulus difference and a base line stimulus (Weale, 2004). The contrast sensitivity function provides information about visual performance over the entire spectrum of spatial frequencies, whereas visual acuity measures the highest spatial frequency that can be resolved at maximum contrast (Thomson, 2008). Most studies have shown a preferential loss at high and medium spatial frequencies with age and much of the reduction in contrast sensitivity is attributable to a neural loss (Elliott, 1987). The review by Thomson (2008) suggests other possible explanations for this loss in contrast sensitivity including a reduction in retinal luminance and an increase in light scatter.

1.4.3 Binocular vision

Accurate and steady fixation is a prerequisite for binocular vision and stereopsis. While there is some evidence that fixation is less stable in older subjects under scotopic conditions (Dannheim & Drance, 1971), under photopic conditions accurate fixation seems to be maintained into old age.

Binocular summation is defined as an increase in the binocular response compared with the monocular occurring when the sensitivities of the two eyes are equal or similar so that two eyes produce a better sensitivity than one (Pardhan *et al.*, 1990a). The threshold for perceiving a stimulus should be lower when undertaken binocularly than monocularly and this has been shown to be the case with a wide range of visual stimuli (Thomson, 2008). The degree of binocular summation is reduced in older subjects, for central high spatial frequency stimuli (Gagnon & Kline, 2003a) and for peripheral stimuli (Pardhan & Whitaker, 2003a). The decline in binocular summation with age has been attributed to an age related loss in cortical cells, a decline in binocular stability or an increasing asymmetry between the two eyes (Pardhan, 1996;Pardhan & Whitaker, 2003b).

Studies have shown that stereoacuity declines with age, although the extent of the decline is dependent on the test used (Garnham & Sloper, 2006b;Lee & Koo, 2005). The reasons for the reduction in stereoacuity include a decrease in retinal illuminance, a deterioration in VA and perhaps a loss in cortical cells (Yap *et al.*, 1994).

1.4.4 Visual Fields

Visual field thresholds decline with age at a rate in the range of 0.5-1.0dB per decade (Weale, 2004). Spry and Johnson showed that this age related reduction in sensitivity is non-linear, showing a small decline in the early decades of life which increases particularly from the seventh decade onwards. The reduction in sensitivity tends to be greater in the periphery and the superior hemifield (Spry & Johnson, 2001a).

The reduction in sensitivity with age is likely to be partly attributable to the reduction in pupil size and increased absorption of the lens, but there is also good evidence that neural changes play an important role (Spry & Johnson, 2001b).

1.4.5 Dark adaptation and absolute threshold

Thomson (2008) explains that the eye operates over a large range of light levels and it achieves this by having two classes of photoreceptors; rods and cones (see

Figure 1.3). The sensitivity of the eye can be measured by determining the absolute threshold, that is, the minimum luminance of a test spot required to produce a visual sensation. This can be measured by placing a subject in a dark room and increasing the luminance of the test spot until the subject reports its presence. Consequently, dark adaptation refers to how the eye recovers its sensitivity in the dark following exposure to bright lights. The time course of dark adaptation is a two branched function; starting with a cone phase followed by a longer rod phase with a characteristic rod-cone break after approximately 5 minutes. Dark adaptation is relatively slow taking 30 -40 minutes to reach the absolute threshold for the rods.

Absolute threshold tends to increase with age as sensitivity decreases (DOMEY *et al.*, 1960). This is an expected finding taking into account age related miosis and the reduced transmittance of the lens. Jackson et al controlled pupil diameter and individual lens absorption. They recorded an age related slow down in the recovery of rod sensitivity following light adaptation and hypothesized that this may be due to a reduction in the regeneration of rhodopsin (Jackson *et al.*, 1999). Whatever the cause, it is important to note that the absolute threshold of an 80 year old is likely to be about 2 log units (100 times) less than that of a 20 year old (Thomson, 2008).

Studies have shown that it takes longer for visual acuity to recover in older people following exposure to bright light (Margrain & Thomson, 2002). Not only does recovery time increase with age, but also increases significantly in the presence of age related macular degeneration (Binns & Margrain, 2007;Wu *et al.*, 1990).

This section has given a brief overview of the changes in visual function with age. The section below will discuss common systemic conditions that are prevalent in the older population and the ocular effects of these conditions will be described.

1.5 Systemic conditions that have ocular manifestations

Systemic diseases may affect the eye at any age. However, the manifestations of systemic diseases in the ageing eye represent in general a more significant problem. First, certain systemic diseases are much more common in old age and second, even disorders which manifest from an early age can deteriorate in the ageing eye as a result of cumulative damage over the years.

1.5.1 Diabetes

Diabetes mellitus is characterised by sustained hyperglycaemia secondary to lack, or diminished efficacy, of endogenous insulin (Kanski, 1999). The two common types of diabetes are Type 1 diabetes (insulin dependent) and Type 2 diabetes (non insulin dependent) (Millodot, 2000). Type 2 diabetes is the most prevalent form of diabetes. It usually develops in older people, most often between 50 and 70 years (Kanski, 1999;Karadimas, 2004e). In addition to these two main types, other more rare specific types of diabetes also exist. Diabetes is not exclusively a problem of older people. However, at an older age the consequences of the disease are more evident, reflecting the accumulated damage over the years (Karadimas, 2004d).

Diabetes can result in retinal vascular complications known as diabetic retinopathy (Figure 1.6). The most important factor for the development of diabetic retinopathy is the duration of the diabetes (Kanski, 1999). This explains the frequency and severity of diabetic retinopathy with increasing age. Other risk factors include poor metabolic control, vascular hypertension, elevated lipids and renal disease (Karadimas, 2004c;Kanski, 1999).

Diabetes can also result in extraretinal ocular pathology; corneal abrasions are more common in diabetes compared to normals and corneal sensitivity is also reduced in diabetic patients in accordance with the duration of the disease. Transient changes in refractive error may occur in diabetic patients possibly as a result of secondary osmotic swelling of the lens. Diabetes may also result in isolated nerve palsies and the presence of a nerve palsy may be the first indication of a latent diabetic condition (Karadimas, 2004b).

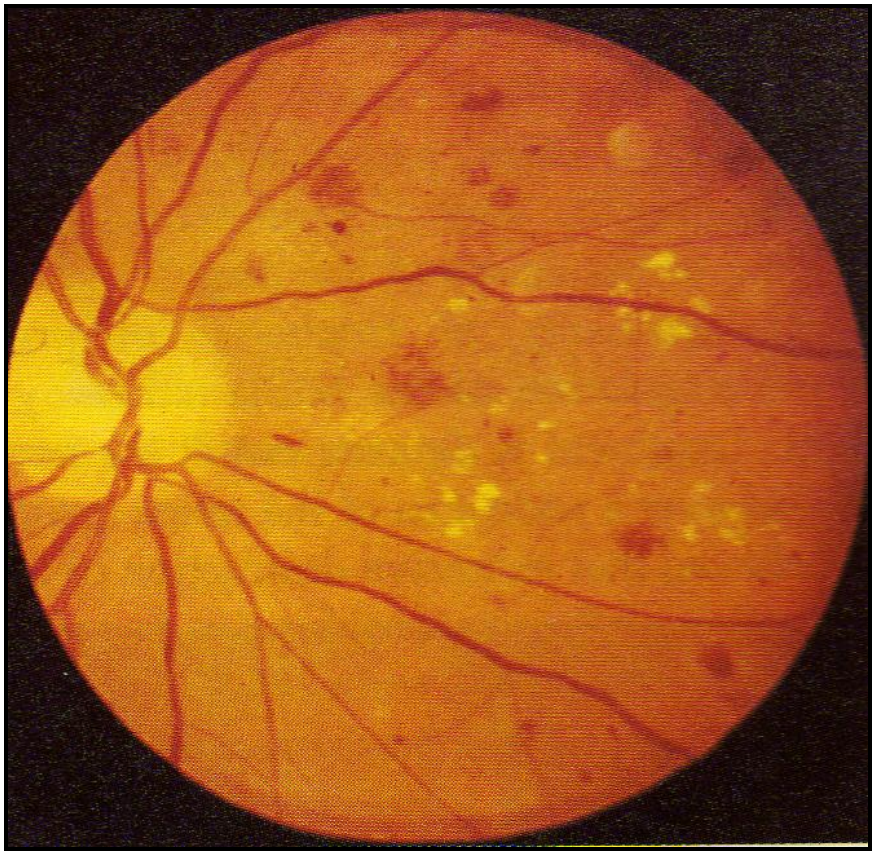


Figure 1.6 Background diabetic retinopathy

The presence of diabetes has shown to significantly increase the risk of cataract. In diabetic patients under the age of 65 years, the prevalence of cataract increases 3 to 4 fold compared to demographically similar individuals without diabetes. In those patients over the age of 65 with diabetes, the prevalence of cataract increases 2 fold compared with demographically similar individuals without the disease (Negi & Vernon, 2003;Klein *et al.*, 1998a). The Beaver Dam Eye Study evaluated diabetes, cardiovascular disease, selected cardiovascular disease risk factors and the 5-year incidence of cataract and progressive lens opacification. The investigators found that diabetes was associated with an increased incidence of cortical and posterior subcapsular cataract and with progression of cortical and posterior subcapsular lens opacities (Klein *et al.*, 1998b).

There is also a possible correlation between diabetes and age-related macular degeneration. In the recent Age-Related Eye Disease Study (AREDS) (Chiu *et al.*, 2007), a positive correlation was found both between dietary glycemic index and age related macular degeneration and between dietary glycemic index and the severity of age-related macular degeneration. There was a 49% increase in the risk of advanced macular degeneration in subjects with glycemic ratings higher than the median. The investigators concluded that higher glycemic dietary levels increase the risk not only for diabetes and heart disease, but also for age-related macular degeneration.

Fundus photography has been shown to be a useful screening tool for the detection of diabetic retinopathy. A study by Rhatigan and colleagues showed that the majority of visual impairment in patients with diabetes is not from diabetic retinopathy (Rhatigan *et al.*, 1999). The factors contributing to loss of vision were found to be failure of laser treatment, rapidly progressive disease and poor patient attendance. This has important implications for screening programmes and also highlights the importance of regular eye examinations despite regular screening for diabetic retinopathy.

1.5.2 Vascular hypertension

Hypertension is a major public health problem due to its high prevalence and severe consequences. It is a risk factor for coronary artery disease and is also the most important risk factor for cerebral vascular disease. Increasing age represents a major risk factor for the presence of the hypertension and it is well known from epidemiological studies that the prevalence of hypertension increases with each decade of life. Over half of the population above 60 years of age in most industrialised countries have hypertension (Karadimas, 2004a).

The ocular fundus picture in hypertension is related directly to the status of the retinal arteries and the rate of rise and degree of systemic blood pressure. The term hypertensive retinopathy refers to any retinal vascular change related directly to the systemic hypertension. Changes in typical chronic hypertension include focal narrowing and dilation of retinal vessels. When hypertension is severe, additional

retinal changes may develop. These include arteriolar closure, retinal haemorrhages and lipid exudates (Karadimas, 2004f). Systemic hypertension may also result in branch retinal vein occlusions and retinal artery occlusions. Uncontrolled systemic hypertension also has an adverse effect on diabetic retinopathy (Kanski, 1999)

The signs of hypertensive retinopathy are associated with severity and duration of the disease. These signs are encountered much more commonly in older people. The treatment of hypertensive retinopathy, choroidopathy and optic neuropathy consists of blood pressure control. No specific ocular therapies exist to reverse the changes. Treatment of the underlying systemic condition usually slows down the progression of the retinal changes, but arteriolar narrowing and arteriovenous crossing signs are usually permanent (Karadimas, 2004g).

Hypertension and diabetes mellitus are classic examples of systemic diseases affecting the eye. Both are very common and both are accompanied frequently by ophthalmic manifestations. Both diseases represent a more significant risk for older people, given their long duration and the accumulating damage that they both create.

The above section indicates that older people need regular eyecare to monitor age-related changes to the eye that may affect vision or that may be indicative of other systemic disorders. The next section will look at the eyecare that is currently available for older people and the accessibility of and participation in these eyecare services.

1.6 Eyecare for older people

There is a wide range of eyecare services available to the elderly in the UK. These services span different sectors of the National Health Service (NHS) and can be divided in to two areas; primary eyecare and secondary eyecare. In Chapter 5, the provision of NHS eyecare will be looked at more closely.

1.6.1 Primary eyecare

The term primary eyecare refers to eye services that are readily available in local communities. Optometrists are the main providers of primary eyecare. They are usually based in community practices and are more often than not, the first point of contact that a patient may have with eyecare services. The role of an optometrist within a primary care setting is to perform sight tests. This not only involves assessing a patient's need for spectacles but also an external and internal eye health check (Association of Optometrists, 2003) in which signs of injury, disease or abnormality in the eye can be detected. It is then the role of the optometrist to decide on the course of management for the patient. This may involve management of the condition within the primary care setting or an accurate referral to the hospital eye service where secondary eyecare is available. Most referrals to the hospital eye departments are initiated following a routine eye examination by an optometrist (Association of Optometrists, 2001). Primary care optometrists are now increasingly able to provide a range of services within a community based setting, often in conjunction with GPs and ophthalmologists, in order to screen for and monitor eye disease.

Primary eyecare is the most accessible form of eyecare for the elderly. Patients aged 60 and above are entitled to an eye examination, the cost of which is fully covered by the NHS. In contrast to NHS dentistry, nearly all community optometrists provide NHS eye examinations (see Chapter 5). Older patients are entitled to have an NHS eye examination once every two years until the age of 70 after which they are entitled to annual examinations. If a patient has diabetes, glaucoma or is experiencing eye related symptoms then they are entitled to have an eye examination earlier than the intervals recommended. Although the NHS funds the eye examinations for people aged 60 and over, they do not automatically contribute towards the cost of spectacles. However, older people on low incomes who receive Pension Credit are also entitled to an NHS voucher and this contributes towards the cost of spectacles. In some practices the NHS voucher may cover the complete cost of the spectacles (see Chapter 5).

1.6.2 Secondary eyecare

The term secondary eyecare refers to eyecare that is delivered by the hospital eye service. Secondary eyecare is usually provided by a team of eyecare professionals including ophthalmologists, optometrists and orthoptists. Secondary eyecare enables various conditions such as glaucoma to be diagnosed and treated.

Recently there has been an increased overlap between primary eyecare and secondary eyecare and this trend is likely to continue in the future. Referral management, diagnostic and treatment services of eye conditions normally seen in secondary care have been developed within community settings. This change from delivering certain types of secondary care in primary care settings will make the eyecare services even more accessible for older patients and reduce the time that patients wait to receive treatment, and the distances that they have to travel.

1.6.3 Take-up of eyecare services

The above section indicates that eyecare is readily available for older people, yet a recent systematic review revealed that 20-50% of older people have undetected reduced vision (Evans & Rowlands, 2004d). The majority of these people have correctable visual problems (refractive errors or cataract). It is particularly startling that, in a “developed country”, between 7% and 34% of older people have visual impairment that could be corrected by appropriate spectacles.

Intuitively, one would have thought that symptoms (e.g., worsening vision) would cause older people to seek eyecare to discover whether their vision could be improved. Clearly, for many older people this assumption is wrong and the review suggests that this is particularly the case for people from ethnic minorities and those who are suffering from the effects of poverty.

In a large study of a North London population, the prevalence of bilateral visual impairment (visual acuity <6/12) was 30%, of which 72% was potentially remediable (Reidy *et al.*, 1998m). The study outlined several reasons that may be responsible for the high level of undetected and untreated morbidity in the population. These are, firstly, inadequate levels of attendance at the high street optometrist or failure to purchase corrective spectacles; secondly, suboptimal

integration of vision checks into the general primary care of elderly people, possibly linked with a reluctance to add to the lengthy waiting lists; and, thirdly, patients' perception of the extent to which their vision has gradually diminished, the point at which help should be sought, and uncertainties about the treatment and the outcome.

Although the cost of an eye examination for people aged 60 and over is covered by the NHS, it has been suggested that many older people are deterred from visiting an optometrist because of fear of the cost of spectacles. Older patients may not be aware of their entitlement to Pension Credit or those that are claiming it may have difficulty in finding a practice that will dispense glasses where the complete cost is completely covered by the NHS voucher (see Chapter 5).

A recent report by the RNIB (Conway & McLaughlan, 2007) also highlights the cost of spectacles and a lack of appreciation of the importance of eye tests as an essential health check as significant barriers to the uptake of primary eyecare services among older people. The report stated that the most common reason among older people for not having an eye examination in the past two years was because they were not having any problems with their eyes. This suggests that a significant barrier to having an eye test is people's assumption that sight tests are for people with problems already, yet conditions such as glaucoma and diabetic retinopathy can progress significantly before patients notice any symptoms.

The survey conducted by RNIB (Conway & McLaughlan, 2007) also identified transport problems as a potential barrier for older people not receiving regular eyecare. The number of practising optometrists working in the UK has increased by 37 per cent between 1996 and 2006. However, lack of coverage by optometrists in certain geographical areas or difficulties in older people traveling to community optometrists has been thought to be a barrier to older people going for an eye test (FODO, 2007). Social isolation problems are pronounced in less mobile older people and may well be a factor in preventing them from having regular eye tests. Lack of awareness and availability of domiciliary services has been highlighted before by the RNIB and the Domiciliary Eyecare Committee (FODO, 2007).

Many of the reasons outlined above regarding the low uptake of eyecare services among the elderly stem from a lack of awareness about eye health and accessing eyecare services. Table 1.1 below summarises the main barriers to eyecare and highlights the importance of increasing awareness among the older population.

Table 1.1 Barriers to eyecare

Barriers to eyecare	Increasing awareness
Cost of spectacles	Older people need to be made aware of their entitlement to benefits that may help towards the cost of spectacles.
Older people report that they have no problems with their eyes and see no need to have an eye examination.	Older people need to be made aware of eye health, eye disease and its management to encourage them to have an eye examination even if they feel their eye sight is good.
The assumption that reduced vision is a consequence of ageing and nothing can be done to help	A significant number of visual problems may be correctable, possibly by updating spectacles or by routine cataract procedures
Poor mobility and lack of transport facilities to access eyecare services in the community	Domiciliary services are available and older people need to be made aware of this and their entitlement to it.
Fear of eye disease	Older people need to be made aware that most eye conditions can be treated or stabilised by treatment from the hospital eye service and may not necessarily result in losing vision.
Fear of being told to cease driving	A simple change in spectacles or cataract procedure may help to improve vision to meet driving standards. Older patients may not necessarily be told to stop driving completely but possibly to refrain from driving at night or in poor weather conditions.

It is clear the barriers to eyecare outlined above need to be addressed and older people need to be encouraged to attend for regular eye examinations. Two different (but not mutually exclusive) approaches to improving the detection of visual problems in older people are to better publicise the need for regular optometric eye examinations and to screen for visual problems. Publicising the need for regular eye examinations is important, but the limitation of this approach is that many older people seem to assume that such publicity is “not for them”. Often, older people fail to seek eyecare because they assume that nothing can be done to improve their vision (Evans & Rowlands, 2004c;Reidy *et al.*, 1998l;Reidy *et al.*, 1998k;Reidy *et al.*, 1998j;Reidy *et al.*, 1998i). If the person attended a vision

screening programme and was told directly that their visual problem has a high likelihood of being treatable, or at least that they might benefit from low vision services, then perhaps they would be more likely to seek help. It is likely that such personalised information, taking account of a person's individual situation, would increase the individual's understanding of their correctable visual loss in a way that generalised publicity would not.

1.7 Screening

The chapter so far has established that older people need to have regular eye examinations in order to monitor age-related changes in the eye and changes in spectacle prescriptions. The chapter has also outlined what eyecare is available and reasons why older people might be reluctant to access eyecare services. The next section will give a general overview on what screening is and the accepted criteria that is advocated for any screening programme.

1.7.1 What is screening?

The UK National Screening Committee (2007) defines screening as 'a public health service in which members of a defined population, who do not necessarily perceive they are at risk of, or are already affected by a disease or its complications, are asked a question or offered a test, to identify those individuals who are more likely to be helped than harmed by further tests or treatment to reduce the risk of a disease or its complications.' Screening has important ethical differences from clinical practice as screening targets apparently healthy people, offering to help individuals to make better informed choices about their health.

Whilst intuitively screening seems beneficial because it has the potential to improve quality of life through early diagnosis of conditions, it is not a fool-proof process. Screening can reduce the risk of developing a condition or its complications but it cannot offer a guarantee of protection. In any screening programme, there is an irreducible minimum of false positive results (people wrongly reported as having the condition) and false negative results (people wrongly reported as not having the condition). The National Screening Committee is increasingly presenting screening as risk reduction to emphasise this point.

1.7.2 The Wilson criteria: when is screening appropriate?

The National Screening Committee employs set criteria for appraising the viability, effectiveness and appropriateness of a screening programme. These criteria are based on those developed by Wilson and Jungner in 1968 (Wilson & Jungner, 1968) and address the condition, the test, the treatment and the screening programme.

Table below states the Wilson-Jungner criteria for screening.

Table 1.2 Wilson and Jungner screening criteria (Wilson & Jungner, 1968)

Knowledge of the disease	The condition being screened for should be an important health problem
	The natural course of the condition should be well understood, including development from latent to declared disease
	There should be a detectable early stage or early symptomatic stage.
Knowledge of the test	There should be a suitable test or examination to detect the condition
	The test should be acceptable to the population
	Case findings should be continuous (not just a 'once and for all' project)
Knowledge of the treatment	The treatment for patients recognised with the disease should be acceptable. The risks of treatment should be less than the benefits.
	Adequate health service provision should be made for the extra clinical workload resulting from screening.
	There should be agreed policy on whom to treat as patients
Cost Considerations	Costs of case findings (including diagnosis and treatment of patients diagnosed) should be economically balanced in relation to possible expenditures on medical care as a whole.

1.8 Chapter summary

This chapter has shown that the population in the UK is increasing and ageing. With age, the eye changes and certain eye disorders are more prevalent in the older population. Older people are also more at risk from certain systemic disorders and many of these have ocular manifestations. As such, there is a need for older patients to have regular eye examinations. However, there is a low uptake of eyecare services among the elderly.

Vision screening may be of value as a tool to encourage older people to have eye examinations but any screening programme would need to conform with guidelines accepted by the UK National Screening Committee. In the next chapter, the literature on vision screening in older people will be reviewed to see whether it possible to determine from the available evidence whether the Wilson and Jungner screening criteria are met.

Chapter 2

A review of vision screening in older people

2.1 Introduction

A recent systematic review (Evans & Rowlands, 2004b) investigated the prevalence of correctable visual impairment (VI; defined below) in older people in the UK. The review also sought to determine to what extent these cases are undetected by current healthcare systems, to suggest reasons for the poor detection, and to make suggestions for improving detection. As outlined in Chapter 1, the main conclusions of this review were that between 20% and 50% of older people have undetected reduced vision. The majority of these people have correctable visual problems (refractive errors or cataract).

The effects of this undetected, yet correctable, reduced vision are significant. The systematic review (Evans & Rowlands, 2004a) found considerable evidence that the reduced vision is associated with impaired quality of life and ability to carry out activities of daily living, depression, falls and other accidents. Those with low vision are approximately twice as likely to have falls compared with people with normal vision (Legood *et al.*, 2002;Harwood, 2001)

For older people to suffer these disadvantages when in many cases the low vision is easily corrected with spectacles or cataract surgery is clearly unacceptable. Furthermore, this correctable reduced vision is likely to be particularly prevalent amongst people who suffer from the effects of poverty (Reidy *et al.*, 1998h) and/or are from ethnic minorities (Lindesay *et al.*, 1997;Pardhan & Mahomed, 2002).

At present, it seems to be widely assumed that older people with low vision will automatically detect their problems and seek optometric and/or medical care. Yet, 88% of older people with treatable visual disorders do not avail themselves of eye

care services (Reidy *et al.*, 1998g). It is possible that screening for visual problems may prompt older people to attend for an eye examination.

Screening for visual problems in older people has also been suggested in the context of general health screening (Bulpitt *et al.*, 1990). Another study that advocated widespread screening calculated that the cost of falls attributable to VI in the UK is £¼ billion (Scuffham *et al.*, 2003). In addition to falls, VI alone will have an adverse economic impact, although discussion of this is beyond the scope of the present review.

Although screening seems intuitively beneficial, several authors (Smeeth, 1998) have pointed out that vision screening of older people would need to meet the accepted criteria that are advocated for any screening programme for disease as outlined in Chapter 1 (Wilson & Jungner, 1968). An adaptation of the criteria has been proposed in Table 2.1 (Cadman *et al.*, 1984) and also used in other reviews (Mulrow & Lichtenstein, 1991).

Table 2.1 Effectiveness of screening programmes: Criteria for assessment (Cadman et al. 1984)

1. Does the burden of suffering warrant screening?
2. Is there a good screening test?
3. Are efficacious treatments or preventative measures available?
4. Will those at risk attend for or accept screening?
5. Do people with positive screening results accept interventions or advice?
6. Can the health system cope with the programme?

The criteria in Table 2.1 have been discussed in the context of vision screening of older people in a previous review by Smeeth (Smeeth, 1998). The present review seeks to build on this earlier work and also to specifically address two issues that were highlighted in Smeeth's paper. Smeeth (1998) noted, concerning point 2 in Table 2.1 that "the assessment of visual screening tests is hampered by the lack of a 'gold standard', and the literature in this area is far from comprehensive" and that "there are no agreed criteria for the level of visual acuity which warrants intervention". This last point assumes that vision screening should only rely on one vision test and that this vision test should be visual acuity. This assumption will now be discussed below.

The usual aim of vision screening of older people is to detect a range of visual problems that are likely to impact on visual performance in a variety of ways. It therefore seems unlikely that one test of visual function will be adequate; although it must be acknowledged that increasing the number of tests will increase the cost of screening. Several previous researchers have only used visual acuity measurements in their studies (Strahlman *et al.*, 1990a;van der Pols *et al.*, 2000a), and it is thought that if one test of visual function is to be assessed in screening programmes, then the best single test is likely to be visual acuity. This chapter attempts to broaden this discussion by reviewing whether a battery of vision tests might provide a more complete assessment of visual function in older people and might be better related to the consequences of a range of visual problems in terms of adverse effects on daily living. For example, most definitions of blindness and some definitions of low vision (visual impairment) include criteria for visual field loss as well as visual acuity loss. In addition, standard visual acuity charts have high contrast optotypes, yet most visual objects in the real world are of lower contrast. Many visual problems affecting older people have a greater effect on low contrast resolution than high contrast resolution, and many authors have therefore highlighted the potential of contrast sensitivity for vision screening (Brabyn *et al.*, 2001f;Brabyn *et al.*, 2001e;Lord & Dayhew, 2001). Another factor that has often been ignored is the issue of binocularity. Stereopsis has been described as the "barometer of binocularity" (Saladin, 2005) and may play an important role in preventing falls (Evans & Rowlands, 2004n).

Another issue that Smeeth (1998) raised is the most appropriate venue(s) for vision screening. This was not addressed in detail in the review by Smeeth (1998), and therefore the literature on this subject was searched for the present review.

To summarise, the purpose of this chapter is to review the research on vision screening in older people to evaluate the effectiveness of screening, to assess which screening tests are most appropriate and to consider the most appropriate venues for screening. The questions in Table 2.1 are returned to in the Discussion of the review at the end of this chapter.

It became apparent when reading the literature on this subject that the terms VI and low vision do not have consistent meanings in the literature. Different definitions are used by various authors. The terms VI and low vision will now be defined and then when a paper is cited which uses different terminology, this is noted in the thesis.

The World Health Organisation (WHO) (2007) refers to VI as poor vision resulting from any cause including uncorrected refractive error. The term low vision is used to describe visual impairment for which full remediation is not possible by conventional spectacles, contact lenses or medical intervention. The terms VI and low vision can be quantified. The WHO definition of visual impairment includes low vision and also blindness: blindness is defined as visual acuity of less than 3/60 or a corresponding visual field loss to less than 10 degrees in the better eye with best possible correction (ICD-10:54 visual impairment categories 3,4,5); low vision is defined as visual acuity of less than 6/18 but equal to or better than 3/60, or a corresponding visual field loss of 20 degrees in the better eye with best possible correction (ICD-10 categories 1 and 2).

2.2 Objectives and methodology of review

The key objectives are summarised in terms of research questions inTable 2.2. Table 2.2 also summarises the search methodology. The search was last updated on 03/02/2009.

Table 2.2 Objectives (key questions) and methodology of review

Question	Rationale/detail	Initial search & keywords
PRIMARY QUESTION		
Is vision screening effective at detecting correctable low vision in older people?	Correctable is taken to mean refractive errors and cataracts.	PubMed, Visugate, Lighthouse International, Low Vision: The Reference and Health information for London online for: (vision screening AND aged OR aged, 65 and over).
SECONDARY QUESTIONS		
Which tests should be included in vision screening of	Self reported measures are not an adequate method of screening for visual problems. Can the effectiveness of	PubMed, Visugate, Lighthouse International, Low Vision: The Reference and Health information for London online for: (Vision

older people	screening be improved by using tests of visual function and if so which tests?	screening tests) and “older population).
Which venues are appropriate for vision screening of older people	This secondary question aimed to compare the feasibility of using different venues for vision screening in older people	Publications identified from the above searches were inspected for details of venues. Also, PubMed, Visugate, Lighthouse International, Low Vision: The Reference and Health information for London online were searched for: (Vision screening and community setting)

2.2.1 Selection criteria

This review is confined to publications in English. After applying the search criteria, publications that are obviously inappropriate to the review were excluded by viewing the abstract. For the remaining publications, the full manuscript was studied and other relevant publications were identified from the bibliographies. This review chapter concentrates on papers in refereed journals, but any relevant manuscripts that were discovered from other sources have also been included.

For the primary question a literature search was carried out to identify research on the effectiveness of vision screening for detecting reduced vision in older people. The search was carried out in February 2009 from the databases listed in Table 2.2 using the terms: *vision screening* AND (*aged* OR *aged, 65 and over*). This revealed 318 papers. Titles and abstracts were inspected to reveal those obviously irrelevant (e.g., amiodarone and optic neuropathy). Of the remaining, 43 were found which described or proposed methods of screening vision in older people and these were studied in more detail. Further appropriate references were identified from the bibliographies of these papers and from an earlier review (Evans & Rowlands, 2004m). Only 8 papers were identified which investigated experimentally methods of screening vision in older people in the UK (Evans *et al.*, 2002;Evans *et al.*, 2004b;Jack *et al.*, 1995;Reidy *et al.*, 1998f;Scott *et al.*, 2002;Smeeth *et al.*, 2003a;Squirrell *et al.*, 2005a;Squirrell *et al.*, 2005d;van der Pols *et al.*, 2000c;Wormald *et al.*, 1992).

The purpose of vision screening is to detect remedial visual problems. The effectiveness of a screening test is normally described in terms of its sensitivity and specificity relative to a “gold standard”. In practice, this involves comparing the

outcome of the vision screening test(s) with a comprehensive eye examination. This “gold standard” should be ideally carried out on all participants that had the screening tests (Haynes *et al.*, 2006). The gold standard should be conducted on participants that test positive on the screening test and those that test negative to avoid verification bias (Haynes *et al.*, 2006). The only study that was found which has closely followed this approach is that of Squirrell et al (2005). This study used several tests to identify common easily corrected visual problems in the older population including the presence of cataract and uncorrected refractive error. Although other studies have assessed sensitivity and specificity of screening tests for identifying individual visual conditions, they do not meet the primary objective of this review which relates to correctable low vision (from refractive error or cataracts).

For the secondary questions, “which tests should be included in vision screening of older people?” and “which venues are most appropriate for vision screening of older people?” an initial literature search (using [vision screening and older population] AND [setting OR primary care OR test methods]) revealed publications, several of which were expert opinion or anecdotal comments. The additional term “control” was added to refine this search by concentrating on case-control studies or cohort or cross-sectional studies, which controlled for confounding variables.

The literature suggests that quite basic tests will be able to detect uncorrected refractive errors and cataract. The review has focused on these two conditions because a) they have a relatively high prevalence, (b) they are remediable, and (c) their treatment is of direct and immediate benefit to the public through correcting VI and improving quality of life (Koole *et al.*, 2001a). Vision screening systems inevitably include a test of visual acuity, which will also detect other forms of VI including age-related macular degeneration. Although this is not readily correctable in most cases, it is helpful to detect cases so that they can be referred when appropriate for ophthalmological investigation and for further support and low vision aids. Although visual acuity testing will detect cases of significant macular disease, the diagnosis of age-related macular degeneration can only be made following ophthalmoscopic evaluation, preferably through dilated pupils. Other tests

of macular function (e.g., Amsler grid, photostress test) may also be helpful in making the diagnosis. Fluorescein angiography is a powerful diagnostic tool but is impractical in screening studies because, amongst other reasons, of the risk of complications.

Glaucoma is also relatively common in the older population but this poses a significant challenge for community-based vision screening programmes. Although visual loss from glaucoma is irreversible, early detection and treatment has been shown to slow progression of the associated visual loss. It is difficult to screen for glaucoma, since all three commonly used glaucoma tests have a low sensitivity and/or specificity in isolation (Ivers *et al.*, 2001e) and using all three tests (Tuck & Crick, 1997a) in screening by non-healthcare professionals is impractical. This issue is considered further below.

2.3 Results of literature review

Most research in this field has not set out to specifically answer one of the objectives of the present review Table 2.2, but nonetheless produces results that are pertinent to these objectives. The research will be considered in this section under two headings: studies that meet the selection criteria and relevant studies that do not meet the selection criteria. Within each of these sections, studies will be described in chronological order. The objectives of the review are each addressed under specific subheadings in the Discussion.

2.3.1 Research meeting selection criteria

Squirrell and colleagues targeted a selected group of patients who were recruited from an orthopaedic rehabilitation ward recuperating from hip fractures after a fall (Squirrell *et al.*, 2005b). The study aimed to test the validity of a simple screening programme to identify patients with visual impairment. A nurse and ophthalmologist independently screened 89 patients aged 75 years and older. The screening included high contrast VA using a 3m chart, pinhole, confrontation and assessment of red reflex with a direct ophthalmoscope (an attempt to detect cataract). The "gold standard" included "full ocular examination using slit lamp biomicroscopy". However, the eye examination appeared to lack an assessment of refractive error,

ocular motor tests, cataract grading, and visual fields. The screening proved to be reliable, with a high sensitivity (94%) and specificity (92%) for detecting VI. The screening had a sensitivity of 70% and a specificity of 92% for identifying patients with potentially remediable VI. The difference in sensitivity for the detection of VI and potentially remedial VI was due to the inadequacy of the test to identify early cataracts. The nurse screener identified 28 of the 40 patients with potentially remediable VI.

The above study represents a relatively small sample of older patients all of whom achieved a good mental test score and as such it is difficult to generalise the results to the wider population of older people. The participants in this study were all patients who had sustained a fracture after a fall and only those patients with medical or social needs that necessitated a period of rehabilitation after surgery were recruited. Those patients who did not require rehabilitation were not included as they were often discharged before assessments could be undertaken.

This study by Squirrell indicates that there is a strong argument for performing visual assessment in all patients after hip fracture as part of a strategy to prevent further falls, regain independence and improve the patients' overall well being. However, it would be preferable to detect VI and provide appropriate intervention before a fall occurs.

The literature review revealed several papers that, although not meeting the selection criteria, nonetheless included information that is relevant to the present review. These papers are now briefly summarised under the headings of: prevalence studies, screening studies involving older people but not meeting the age criteria, and other studies.

2.3.2 Prevalence Studies

These studies are summarised in Table 2.3. Wormald and colleagues (1992) examined 207 participants sampled at random from the database of people aged 65 years and over at an inner London health centre. Binocular Snellen acuity was assessed with any habitual correction and central visual fields were also tested. The prevalence of blindness was 1% by the WHO criteria and 3.9% by the

American criteria. The prevalence of low vision (WHO criteria; worse than 6/18) was 7.7%. The prevalence of VI (American criteria; worse than 6/12) was 10.6%. Cataract accounted for 75% of cases of low vision and it was argued that 27% of participants would probably have benefited from refraction. This latter conclusion is based on testing with a pinhole, and the limitations of this are discussed later in the chapter. The study found that only half the patients with low vision were known by their GP to have an eye problem.

Wormald's study concludes that a significant proportion of VI in older people can be attributed to causes such as refractive error and cataract. These causes of visual impairment are not only remediable but easily detectable by screening tests that are simple, quick and well suited to use in primary care, for example those implemented by Squirrell and colleagues (Squirrell *et al.*, 2005c). When reduced vision is detected, the first step should be referral to an optometrist (Wormald *et al.*, 1992) but it is suggested that the costs associated with the eye examination may act as a disincentive for the older population. In April 1999 the UK government reinstated state funding for primary care sight tests for people aged 60 or over. In most community optical practices, this has eliminated the cost of a basic sight test. However, the cost of supplementary tests and of spectacles may still discourage older people from having an eye examination as discussed in the previous chapter.

Another prevalence study by Jack et al (1995) investigated 200 consecutive patients aged 65 years and over with acute medical illness at the Royal Liverpool University Hospital. Using distance Snellen acuities with any distance glasses that were usually worn, 50.5% were found to have impaired vision (binocular acuity 6/18 or worse). This figure rose to 66% for those over the age of 85 years. The patients with impaired vision were given a full eye examination. Of the 101 patients with impaired vision, 79% could be corrected or cured and there was a higher prevalence of low vision than in community studies. In the group with refractive errors, 59.5% had not visited an optometrist in the past three years. The prevalence of uncorrected refractive errors contributing to the impaired vision was 40%. These authors found a particularly high prevalence (76%) of VI in people who

were admitted with falls. The study concluded that VI may be compounding or causing falls.

Jack et al's study included hospital in-patients only and therefore, like Squirrell et al's study, represented a selected population of frail older patients. Severe cognitively impaired patients were excluded to ensure accuracy in the vision screening methods. For these reasons it is difficult to generalise the results to the wider population.

It was recommended by Jack and colleagues that screening of the older population may be beneficial to the patient and cost effective as in many cases the VI was remediable. The authors recognise that this may not be feasible due to resource limitations. Therefore it was suggested that selected groups be targeted such as fallers or those aged 80 and over.

A detailed study of the prevalence of VI in North London was carried out by Reidy et al. (1998). These authors sampled patients aged 65 or older registered with general medical practices, and obtained data from 84% of those contacted. Reidy et al. assessed the effect of refractive errors using a pinhole and with an autorefractor, but it is not clear how they used these data to determine which cases of VI were remediable by spectacles. In the study population of 1,547, the prevalence of bilateral VI (visual acuity <6/12) was 30%, of which 72% was potentially remediable (by spectacles or surgery). In other words, the unmet need in this population-based study was 22% of the population aged 65 or over. Overall, 88% of those with VI or glaucoma were not in touch with eye care services. Three quarters of the people with confirmed glaucoma were not known to the eye care services. The study conducted by Evans et al. (2002) described below, found reduced visual acuity (VA<6/12) in 20% of the sample, less than the 30% found by Reidy et al. This could be because Reidy et al. concentrated on the North London area which may not be representative of the wider UK population.

The reasons for this high level of remediable low vision are under-researched, but Reidy and colleagues noted that most of this morbidity was not known to the eye services. They suggested several factors that could be responsible for the high

level of undetected and untreated morbidity in the population. These include amongst others: inadequate levels of attendance at community optometrists, failure to purchase corrective spectacles and suboptimal integration of vision checks into the general primary care of older people. Furthermore, some older people may accept reduced vision as an inevitable effect of ageing.

Van der Pols et al. (2000) measured visual acuity at 3m with and without a pinhole in 1,362 randomly selected people aged 65 and over who were not mentally impaired. A nurse that visited participants at their home measured visual acuity and a brief questionnaire relating to ocular health was also administered. It was found that the prevalence of VI increased significantly with age and was more common in participants living in nursing homes. Vision improved 0.2 log units or more (typically, 2 Snellen lines) with a pinhole in 21% of participants.

The study concluded that a substantial proportion of the older population have poor distance acuity. It was suggested that undetected refractive errors are probably an important cause of visual problems among the elderly in Britain. Van der Pols acknowledges that further study of the measurement of vision and the role of visual function in the well being of mentally impaired elderly will be needed (van der Pols *et al.*, 2000b).

In a large scale MRC study, Evans et al. (2002) investigated the prevalence of VI in people aged 75 years and older in Britain. Acuities were measured with Glasgow acuity cards with subjects wearing their usual spectacles. The sample was obtained from 53 practices in the MRC general practice framework. Of the 21,241 people who were invited to participate, visual acuity measurements were available for 14,600 (69%). Of these, 12% had a binocular visual acuity worse than 6/18 (WHO criterion), of whom 10% had a binocular visual acuity between 6/18 and 3/60 (low vision) and 2% worse than 3/60 (blind). Even when age was controlled for, women had poorer acuity than men. Overall, 19.9% of study participants had a binocular VA worse than 6/12 (the American definition of VI). The risk of VI increased markedly with age: for example, at ages 75-79 years, 5.6% had low vision compared with 30.0% for those over 90 years of age. Using mid-2001 population estimates for the United Kingdom, the authors estimated that

approximately 506,000 people are living in the community with low vision in the UK. Evans et al (2002) noted that their estimates of the prevalence of VI in older people are likely to be conservative. In particular, they did not measure visual fields and excluded patients in nursing homes. Taylor et al. (1997) found that three times more people have VI because of visual field loss than visual acuity loss and Klein et al. (1991) showed that people who are resident in nursing homes are 3.3 times more likely to have VI than those living independently. Recent prevalence figures for sight loss in the UK have been derived from an as yet unpublished review by Fletcher et al (2006) available from the RNIB website. The figures for this recent estimate are given at the end of this section.

A supplementary study to the MRC trial investigated the causes of vision loss in a large sample of visually impaired people aged 75 years and older drawn from 49 general practices selected to be representative of the population of Britain (Evans *et al.*, 2004a). For all patients, data regarding the cause of visual loss were extracted from medical notes. Additional follow up questionnaires were also sent to the hospital ophthalmologist to confirm the cause of visual loss. Based on a definition of VI of binocular acuity worse than 6/18, 12.5% of the sample was visually impaired. Measuring VA with and without a pinhole suggested that refractive error was likely to be the principal reason for vision loss in 26% of the visually impaired participants. Macular degeneration was also an important cause of visual loss in people aged 75 years and older affecting 52.9% of people as a main or contributory cause of their VI. This was followed by cataract (35.9%) and glaucoma (11.6%).

One limitation of the Evans et al. data is that the study population was selected through GPs practices. There may be a subpopulation of older people with visual disability who are not active participants in health care services and who have accepted low vision as an inevitable consequence of ageing and thus not sought optometric or ophthalmic services. However, detecting low vision in a sub-population who might avoid healthcare services would clearly be extremely difficult. In addition, some may be deterred from seeking health care because of social or ethnic factors.

Evans et al. concluded that a substantial proportion of VI in the older population is caused by refractive error and cataract - conditions that have safe and effective interventions. With regard to AMD, advances are continuing in developing effective interventions. In cases for which treatment is not appropriate low vision services are important (Reeves *et al.*, 2004a).

Table 2.3 Summary of prevalence studies. VA, visual acuity; LVA, low contrast visual acuity; HCVA, high contrast visual acuity; WHO, World Health Organisation; ARMD, Age Related Macular Degeneration; POAG, Primary Open Angle Glaucoma

Authors	Study design	Outcome	Comment
Wormald et al. 1992	Cross sectional random sample survey involving 207 people aged 65 and over. VA was measured to classify the prevalence of blindness, visual impairment and low vision.	The prevalence of low vision was 7.7%. Cataract accounted for 75% of cases of low vision and 27% of those with VI may have benefited from refraction. The prevalence of blindness was 1% (WHO, criteria) and 3.9% by American criteria. The prevalence of visual impairment was 10.6%.	The study suggests that there is considerable amount of undetected ocular disease and potentially remedial disability in the community. Only half the visually disabled subjects were known to their doctor. The only measure of visual function was VA and the only assessment of refractive error was based on the pinhole test
Jack et al, 1995	Prospective study involving 200 patients over the age of 64 at the department of Geriatric medicine at Liverpool Hospital. Visual impairment was assessed binocularly with a Snellen chart.	101 patients (50.5%) were found to have visual impairment (binocular VA<6/18). The figure rose to 66% for those over the age of 85 years. 79% had a reversible cause including uncorrected refractive error (40%) and cataracts (37%).	The study involved hospital in-patients and therefore represented a selected population. The only measure of visual function was VA.
Reidy et al. 1998	Cross sectional study of a random sample of 1547 people aged over 64. The sample of people was drawn from a defined population of older people registered from 17 general practice groups.	VA was measured and there was a detailed ophthalmological assessment. Participants were classified into 4 groups: cataract, ARMD, POAG, and refractive error causing visual impairment. The population prevalence of bilateral visual impairment (VA<6/12) was 30%, of which 72% was potentially remedial. The prevalence of cataract was 30% and 88% of these were not in touch with eye care services.	The study concluded that untreated visual impairment and eye disorders affect a substantial proportion of people aged 65 years and older. The ability of visual acuity to predict eye disease was not calculated, although visual acuity was used as part of the definition of several eye diseases.
Van der pols 2000	1362 participants aged 65 and over, living in 80 different randomly	VI (WHO criteria) was detected in 14.3% of subjects and it was found	The study shows that poor distance VA exists in a substantial part of the older

	selected postcode areas of mainland Britain, were visited at their home by a nurse who measured VA. In addition a brief questionnaire related to ocular health was administered.	that the prevalence of VI increased significantly with age. 11.5% had been informed that they had a cataract. In 21.2% of participants, vision improved by at least one Snellen line with the aid of a pinhole.	community. Undetected refractive errors are probably an important cause of visual problems in British older people. The only measure of visual function was VA and the only assessment of refractive error was based on the pinhole test.
Evans et al. 2002	The aim of this study was to measure the prevalence of visual impairment in a large representative sample of older people. The study involved 14600 participants aged > 74y from 53 general practices.	Participants were classified as having low vision (binocular acuity of <6/18-3/60), visual impairment (binocular acuity of <6/18) or were classified blind (<3/60) The results indicate that visual impairment is common in the older population and that this risk increases rapidly with age, especially for women.	The only measure of visual function was VA and the only assessment of refractive error was based on the pinhole test. Only 62% of people with visual acuity less than 6/18 in either eye could complete a pinhole test satisfactorily.
Evans 2004	Tested VA in patients aged >74y in 53 general practices. For visually impaired people in 49 of the 53 practices (1742 patients) data regarding the cause of visual impairment were extracted from medical notes.	It was found that the principal reason for visual loss was uncorrected refractive error. This was detected by an improvement in VA with a pinhole occluder. This was followed by age related macular degeneration, cataract, glaucoma and diabetes. There is considerable potential for visual rehabilitation in this age group as many conditions causing VI can be attributed to remediable causes.	The size of the study improves the precision of the results. However a limitation of the study was that the assessment of the cause of visual loss relied upon abstraction of correspondence between the hospital eye service and the general practitioner. The only measure of visual function was VA and the only assessment of refractive error was based on the pinhole test Table 2.5.

The data on prevalence have recently been reviewed by (Reeves *et al.*, 2004b;Tate *et al.*, 2006). These figures have been used by RNIB to produce estimates of the number of people in the UK with sight problems (RNIB, 2006). This concluded that in the UK there are approximately 1.7 million people aged 65 or over with visual acuity worse than 6/12 and 0.7 million with visual acuity worse than 6/18. Furthermore, there are approximately 0.5 million people aged 75 and over with acuity of worse than 6/12 and approximately a quarter of a million with acuity of worse than 6/18.

2.3.3 Screening studies not meeting age criteria

These studies are summarised in Table 2.4.

A door-to-door survey was carried out in Australia to identify non-institutionalised residents aged 40 or over, who were invited to attend a clinic for an eye examination (Taylor *et al.*, 1997). Of those eligible, 83% (3,271) participated and the eye examination included refraction and visual field testing. Refraction improved the best eye's acuity by at least one Snellen line in 60% of people. It should be noted that one line is not a very demanding criterion, and is close to the test-retest confidence intervals for some individuals (Lovie-Kitchin & Brown, 2000). Taylor and colleagues concluded that "it is quite extraordinary that the number of people with VI could be halved simply by the provision of new spectacle correction", despite primary eyecare in Australia being covered by a national health insurance system (Taylor *et al.*, 1997). This study is likely to have under-estimated the prevalence of VI, since people in nursing homes were excluded and these people are 3.3 times more likely to have VI than those not residing in a nursing home (Klein *et al.*, 1991). Taylor and colleagues (1997) also highlighted the desirability of an assessment of visual fields. These authors found that nearly three times more people had VI because of visual field loss than visual acuity loss. In this study, VI was defined as best corrected visual acuity score of less than 6/18 or visual field constriction to within 20 degrees of fixation, or both.

A study conducted by Woods and colleagues (1998) investigated whether contrast sensitivity and visual acuity had a role in primary care screening. This retrospective cross sectional study involved 3283 participants aged 50 years and older. Ophthalmic diagnosis was confirmed for 2522 of the participants. The aim was to investigate the ability of visual acuity and contrast sensitivity to detect any disease condition identified by ophthalmic diagnosis. The analysis of results showed that contrast sensitivity could better discriminate ophthalmic disease in an older population than Snellen visual acuity. Woods and colleagues did not actually detect eye disease but used the diagnosis by the subject's ophthalmologist in the previous three years as a measure of eye disease. It was concluded that in a primary care setting, a person older than 50 years of age with reduced contrast

sensitivity requires extra care in subsequent examinations because this person is likely to have an ophthalmic disease (Woods *et al.*, 1998c).

Another study conducted by Wang et al (1998) aimed to evaluate a questionnaire and a battery of tests for their performance in eye disease screening at a primary care clinic. The study involved 405 patients aged 40 years or older who were interviewed and received a comprehensive eye examination. The tests included VA, VF, tonometry, slit lamp biomicroscopy, dilated fundoscopy and fundus photography. Sensitivity and specificity for the identification of eye disease were calculated for each test and various combinations of tests, giving the following results: questionnaire, sensitivity 90%, specificity 44%; distance VA with presenting correction, sensitivity 61%, specificity 72%; dilated fundus examination, sensitivity 79%, specificity 82%. In screening for glaucoma, tonometry gave a sensitivity of 27% and a specificity 96%. Suprathreshold visual field testing gave a sensitivity of 70% and a specificity of 67%. It was found that in screening for glaucoma a two-stage strategy with the questionnaire then VA and ophthalmoscopy, gave a sensitivity of 83% and specificity of 76%. Wang and colleagues noted the importance of fundus examination in the detection of eye disease. However, for vision screening to be cost-effective, it should be able to be carried out by lay personnel, which precludes ophthalmoscopy.

Lord and Dayhew (2001) investigated which screening tests are most predictive of falls in older people. This study involved 156 participants aged 63 to 90, which is only just outside the age range of the present review. They evaluated a range of vision tests (high and low contrast visual acuity, edge contrast sensitivity, depth perception, visual fields) and a range of general tests (measures of sensation, strength, reaction time, balance). Visual factors were associated with increased risk of falls, with the strongest risk factors being impaired depth perception, contrast sensitivity, and low-contrast visual acuity.

Ivers and colleagues in 2001 conducted a cross-sectional study involving 3654 participants aged 49 years and older. The study involved each of the participants having a comprehensive eye examination in order to compare the ability of each test to detect the presence of eye disease. Although best corrected distance visual

acuity or contrast sensitivity proved to be significantly better than other tests of visual function, Ivers et al. stated that neither they nor other potential screening tests have sufficiently good sensitivity or specificity to be widely used as screening tests for common eye disorders. The study concluded that a detailed eye examination was the gold standard at detecting eye disease and primary care workers suspicious of eye disease in the older population should recommend a full eye examination rather than attempting vision screening.

Ivers and colleagues (2001) did not combine the results of various tests in an attempt to find a combination with both good sensitivity and specificity. They felt that a combination of tests would take away the ease and simplicity of screening for non-ophthalmic personnel administering the screening. Ariyasu and colleagues (1996) found that combining tests did not result in a more accurate detection of ocular disease. Their study assessed four commonly available visual function tests to detect visually disabling or vision threatening eye conditions among new patients of a general ophthalmology clinic. The sample size of 317 aged between 61 and 27 were tested for contrast sensitivity, Amsler grid abnormalities and visual acuity for distance and near and they also had a complete eye examination. Of the four screening tests studied, distance and near threshold acuities were judged to have the best correlations of an abnormal result with ocular disease.

A large study by Brabyn et al. (2001), which investigated 900 participants, listed as one of its goals the establishment of a practical test protocol for assessing vision in older people. Participants aged between 58-102 years at the first visit were screened using a battery of tests including high and low contrast acuity, disability glare, contrast sensitivity, colour vision, stereo-acuity, recovery from glare and attentional visual fields (Haegerstrom-Portnoy *et al.*, 1999). The results indicate that high contrast acuity is reasonably well maintained on average, even into very old ages. Spatial vision measures under conditions of reduced contrast or luminance reveal significant impairment in a large proportion of older people. Many older individuals were found to have greatly reduced stereopsis, poor colour discrimination and restricted peripheral fields under conditions of divided attention. The results indicate that spatial vision of individuals cannot be well predicted from

acuity measurements alone (Brabyn *et al.*, 2001d). This highlights the importance of incorporating additional vision tests, and particularly those that more closely resemble everyday viewing conditions.

Foran et al (2002) described data from the Blue Mountains Eye Study, which initially evaluated 3,654 (a participation rate of 82%) non-institutionalised permanent residents aged 49 years or older. After five years another cross-section of the population was examined, comprising 3,509 persons, 2,335 of who were in the original cohort and 1,174 of whom had moved into the area and age group. The eye examination included distance visual acuity with the patients' usual spectacles and testing with an auto-refractor. VI was defined as acuity worse than 6/12. Despite the relatively young age of the study population, in the initial cross-section 7.5% of participants had correctable VI and 3.6% had non-correctable impairment. The corresponding rates in the second cross-section were 5.6% and 2.7%. Correctable VI was associated with poorer general health, living alone, and lower socio-economic status and/or increasing dependency. Uncorrected refractive errors accounted for over two thirds of cases of VI in both cohorts (Foran *et al.*, 2002a). This study is likely to have under-estimated the prevalence of VI, since people in nursing homes were excluded and these people are 3.3 times more likely to have VI than those not residing in a nursing home (Klein *et al.*, 1991;Klein *et al.*, 1983a).

Quigley and colleagues used a combination of tests including a risk factor questionnaire, visual acuity measurement and a screening visual field test administered by lay volunteers and technicians. This cross-sectional retrospective study involved 5352 participants with a median age of 45. The study entailed a screening examination and a definitive eye examination (Quigley *et al.*, 2002d). The eye examination was offered if any of the following referral criteria were met: greater than 1 positive answer to risk factor questions, less than 20/30 distance acuity despite pinhole, less than 20/40 near acuity, more than 1 missed point on the Damato or FDT visual field test. From the 2000 participants who were offered eye examinations, 1331 scheduled an appointment and only 480 had the examination. In 53% of those examined the sole diagnosis was uncorrected

refractive error while cataract accounted for 15%. It was found that 72% of examinees needed new spectacles (Quigley *et al.*, 2002c).

Although the study by Quigley and colleagues outlined above proved that community screening for eye disease in an urban setting identifies many people with VI and eye disease, screening did not result in a significant proportion accessing eye care. Failure of patients screened to come for examination and loss to follow up were serious problems. There were a number of reasons found for this: defaulters predominantly blamed poor memory, failure to receive an appointment, confirmation letter, or personal scheduling conflicts as the reasons that they did not attend. However, among those who rescheduled visits after missing the first one, many still failed to attend the examination (Quigley *et al.*, 2002b). It was suggested by Quigley and colleagues that perhaps fear of the medical care system or of the health care facility is deeper than originally thought.

Table 2.4 Summary of screening studies involving older people but not meeting age criteria. VA, visual acuity; LVA, low contrast visual acuity; HCVA, high contrast visual acuity; CS, contrast sensitivity; VF, visual field; D, distance; N, near; IOP, intraocular pressure

Authors	Study design	Outcome	Comment
(Taylor *et al.*, 1997)	Population-based screening of D & N VA & VF in 3,271 people aged 40-98.	Nearly three times more people had visual impairment because of VF loss than VA loss.	It is desirable for visual screening to include VF testing.
(Woods *et al.*, 1998a)	A retrospective cross sectional study involving 3283 participants aged >49 years. Snellen VA, CS and ophthalmic diagnosis were reported previously. Ophthalmic diagnosis was confirmed for 2522 of the participants.	The aim was to evaluate whether CS and VA had a role in primary care screening for ophthalmic disease. CS proved to be a more effective measure than VA in screening for ophthalmic disease.	'If those in need of ophthalmic care could be identified simply with a CS measure, for example in general medical practice or health clinics there may be long term savings.'
(Wang *et al.*, 1998b)	Tested 405 patients aged >39y attending primary care clinic using a questionnaire and a battery of tests.	The sensitivity and specificity for the identification of eye diseases were calculated for each test and various combinations of tests. HCVA had only a 61% sensitivity and 72% specificity	The authors conclude "More effective tests are needed to improve performance of eye disease screening".
(Lord & Dayhew, 2001)	Prospective cohort study to determine the tests most predictive of falls in 156 people aged 63-90y.	Multiple fallers had decreased vision as indicated by all tests, with impaired stereo-acuity, edge CS, & LCVA being the	HCVA, the most common single visual screening test, did not feature in the main visual predictors of falls.

	Assessed HCVA, LCVA , CS, VF, stereo-acuity.	best predictors. Poor vision in one eye with good vision in the other had a similar risk to poor vision in both eyes. Stereopsis and edge CS found to be particularly important.	
(Ivers *et al.*, 2001b)	Study of 3,654 people aged >48y. Assessed: VA, CS, VF, IOP, lens & retinal photos with grading.	No single vision test predicted the presence of eye disease with any consistency. VA & CS were best, but still poor sensitivity & specificity.	"Further work in this area should be carried out before vision screening programs can be recommended for implementation among older people".
(Brabyn *et al.*, 2001c)	Longitudinal study of visual function in 900 older people. Assessed HCVA ,LCVA at D & N with & without glare source, glare recovery, CS, dark adaptation, reading, VF, stereo.	Wide range of decline in visual functions with age. Concerning the establishment of a practical test protocol for vision in the elderly: "spatial vision of individuals cannot be well predicted from acuity measurements alone". Advocate testing vision under real-world situations (e.g., glare, low contrast).	Many older individuals were found to have greatly reduced stereopsis, poor colour discrimination and restricted peripheral fields under conditions of divided attention. The results indicate that spatial vision of individuals cannot be well predicted from acuity measurements alone.
(Quigley *et al.*, 2002a)	Cross sectional retrospective study involving 5352 participants with a median age of 45 years who presented at multiple community sites.	The screening examination had a questionnaire, VA measurement and a screening field test. Participants also received a full eye examination. Among 1331 who scheduled an eye examination, only 41% completed the visit.	After community screening for eye disease, efforts to provide ophthalmic examination were only modestly effective. Failure of patients screened to come for examination and loss to follow up were serious problems.
(Foran *et al.*, 2002b)	Study of two cross sections of a community, 6 years apart. The Blue Mountains Eye Study examined 3654 persons aged 47-97 during 1992-1994 and 3509 (2335 cohort survivors plus 1174 new recruits) during 1997-2000.	VA was measured before and after refraction. In both cross sections, similar proportions of those visually impaired had correctable visual impairment (68%). Persons with correctable visual impairment were older than those with no impairment or non-correctable impairment.	Correctable visual impairment accounted for two thirds of all cases of visual impairment in 2 cross sections of an older community. It was further suggested that practitioners conducting aged care services should also screen VA and actively refer those found impaired.

2.3.4 Other studies

Smeeth and colleagues conducted a cluster randomised trial involving 4,340 home-dwelling people aged 75 years or over randomly selected from the lists of 20 general practices. The screening programme involved a questionnaire and distance visual acuity. Vision screening was carried out either (a) universally or (b) only in patients with health problems. At an interval of 3-5 years after screening,

the risk of VA<6/18 in either eye was not significantly different in the two groups. As such, the study concluded that although some people benefited from screening, the number was small in the context of a population-based screening programme (Smeeth *et al.*, 2003f).

The above study by Smeeth and colleagues revealed 29% of participants to have presenting distance acuity of worse than 6/18 in either eye. Of these, 17% had pinhole corrected acuity of better than 6/18, suggesting that the reduced vision could be at least partly attributed to refractive error. However, the authors note the proportion attributable to refractive error will have been under-estimated because many people did not complete a pinhole assessment, reporting that it was difficult to use (Smeeth *et al.*, 2003b). Table 2.5 summarises the limitations of the pinhole test. These factors may explain why some studies such as that conducted by Smeeth et al. have reported difficulties in using the pinhole test in older people.

Table 2.5 Limitations of the pinhole test

Limitation	**Reference**
Prone to errors from imprecise positioning	(Rabbetts, 2000)
Prone to errors from non-uniform cataracts	(Rabbetts, 2000)
The pinhole test produces extremely variable results, underestimating and overestimating post refraction acuity.	(Eagan *et al.*, 1999)
Prone to errors from luminance effects.	(Eagan *et al.*, 1999)
"the pinhole test result should not be used as a dichotomizer for clinical decisions regarding the need for a refraction"	(Eagan *et al.*, 1999)

The only measure of visual function that Smeeth and colleagues included was VA. There was a long interval between screening and assessment of outcome (median 3.9 years), so visual status will have changed in many cases. Just over one third of participants died by the time of assessment.

2.4 Discussion

In this section, the extent to which previous reviews have addressed the objectives outlined in Table 2.2 will be discussed. Then the various venues in which vision

screening can be implemented together with the best tests that can be used in vision screening will be discussed. Finally, the effectiveness of detecting correctable low vision in people aged 65 and older, will be addressed.

2.4.1. Previous reviews

Smeeth and Iliffe reported a systematic review of evidence from randomised controlled trials on the effectiveness of screening older people for impaired vision in community settings (Smeeth & Iliffe, 1998). An updated version of this review was published in 2000 and a further update was published in 2006, both as Cochrane reviews, which will now be summarised. The outcome measure of this review was the level of VI in the population at the end of the trial, at least six months after screening (Smeeth & Iliffe, 2006;Smeeth & Iliffe, 2000). Only five such trials were found, and surprisingly in all five trials the “vision screening” was simply questions about vision and the outcome was assessed by an interview or postal questionnaire. A similar proportion of participants in the screened and non-screened groups reported visual problems at follow-up, so the reviewers concluded that there is no evidence that community-based screening of asymptomatic older people results in a change in the prevalence of VI. The reviewers note several possible explanations for the lack of effectiveness: the visual assessment was just one component of multi-phasic screening; failure to access effective interventions; participants may not have perceived a need for intervention; and questions about vision have been shown to have a poor sensitivity for detecting VI. None of the trials used any clinical assessment of visual function, so it is likely that the last factor regarding the poor sensitivity of questions for detecting VI is the most significant in the possible explanations for the lack of effectiveness of screening.

Smeeth conducted a systematic review of evidence from randomised controlled trials to assess the likely effectiveness of screening older people for impaired vision in primary care (Smeeth, 1998). It is noted that in a primary care setting, screening tests need to be quick, inexpensive, available and able to be carried out easily by different members of the primary health care team. However, the assessment of visual function is hampered by the lack of a ‘gold standard’, and literature in this

area is far from comprehensive (Smeeth, 1998). Also, no firm recommendations can be made about what level of reduced vision should prompt further action.

The review by Smeeth (1998) indicated that little is known about the needs of older people who have not previously reported a visual problem but are found to have VI on screening. Furthermore it is unclear whether older people accept interventions for visual problems discovered by screening. Fear of costs may prevent some older people from accepting a recommendation to attend an optometrist for an eye examination. It is recognised that interventions are effective for symptomatic patients (e.g. cataract surgery and correction of refractive errors) but the effects of treating older people with unreported visual problems have not been evaluated. The review concluded that visual screening is of unproven value, but that the care of older people with symptomatic eye problems could be markedly improved through improving education of eye care in general practice and improving eye services to meet demand

A review by Abdelhafiz and Austin (2003) explored visual factors associated with falls. Whilst some studies identified VI as one of the predictors of falls in older people (Tromp et al., 2001; Oliver et al. 1997), others have found that poor visual acuity is not related to falling (Campbell et al. 1989, Lord et al. 1991). These studies used standard tests of visual acuity to measure VI. However, the review suggests that investigation of VI should not be limited to visual acuity but should also include contrast sensitivity and depth perception. The review included evidence that correcting VI results in improved mobility, orientation and avoidance of falls. Simple intervention strategies (e.g., change of glasses or cataract extraction) may have the potential of improving visual function and preventing falls in older people. Improving vision will not only help in preventing falls but is also likely to lead to improved physical and social function and improved health-related quality of life (Ivers *et al.*, 2002).

The literature on the risks and types of injuries associated with VI was reviewed by Legood and colleagues (2002). From the 30 studies reviewed, the majority assessed falls. The evidence from these studies suggests that those with reduced visual acuity are 1.7 times more likely to have a fall and 1.9 times more likely to

have multiple falls compared with “fully sighted” populations. The review stated that effective vision screening programmes are required but cautioned that any vision screening programme would require careful design with objective measures and appropriate treatment to be available.

2.4.2 Venues for screening

A general conclusion of this review is that more research is necessary to determine whether vision screening in older people is worthwhile. Researchers will need to determine appropriate venues for their research and the question of suitable venues for screening is therefore now discussed.

Screening by general medical practitioners has the potential for reaching the vast majority of older people: 98.5% of patients aged 65 years and over who attended an Accident and Emergency Department were registered with a GP (Reinstein *et al.*, 1993). Bulpitt and colleagues reviewed the history of health screening in older people and concluded that screening by general practitioners may be worthwhile for VI (Bulpitt *et al.*, 1990). Reinstein and colleagues felt that a pinhole test would be a useful procedure for GPs to carry out as part of their general health screen to detect correctable undetected visual acuity deficits. However, as noted above there are limitations to the usefulness of the pinhole test (Table 2.5). Evans et al. (2002), in a large-scale study, attempted to use a pinhole test to detect uncorrected refractive errors. They noted that the pinhole test was not easily used in their population. Indeed, only 62% of people with visual acuity less than 6/18 in either eye completed a pinhole test satisfactorily, and this aspect of the study could not be described as a success (Evans *et al.*, 2002). Smeeth and colleagues also reported that many people with reduced acuity could not complete a pinhole assessment (Smeeth *et al.*, 2003e).

Smeeth noted that although attendance rates for the over-75 GP screening (that was mandatory at the time), was reported to be 48-63%, a total of 90% of people in the over-75 age group see their GP at least once a year, making high coverage rates feasible (Smeeth, 1998). On the other hand, doubts about the usefulness of screening for visual problems by GPs have been raised (Mangione *et al.*,

1992;Brabyn *et al.*, 2001b;Brabyn *et al.*, 2001a). Where opportunistic screening of vision occurs, for example during a consultation with a GP, this typically consists of measuring high contrast distance visual acuity. Several studies reviewed above confirm that this is of limited use as an indicator of visual function in older people. Additionally, this approach to vision screening would not be likely to detect the visual problems that are most strongly associated with falls (Abdelhafiz & Austin, 2003).

Annual health checks for older people, including at least verbal questioning about visual health, have been part of general medical practitioners' statutory requirements under the GP contract (The Department of Health, 1989). This was then superseded by a new contract making no mention of screening for health problems in older people, or of screening for visual problems in the wider population (The Department of Health, 2003c). More recent re-organisation in GP services, with its focus on quality of care for patients with chronic conditions, has shifted GP focus back towards screening for visual problems, at least for those patients with Diabetes Mellitus (The Department of Health, 2003a), but there is still no incentive, training, or resources to screen patients, young or old, for visual problems not related to this disorder. However, the new GP contract has , introduced more flexible commissioning and provision of services to enable GPs to develop the services needed by the populations they serve (The Department of Health, 2003d), raising the possibility of the development of vision screening services. In addition the NHS is developing and piloting new eye care pathways, including pathways for low vision and age-related macular degeneration, focusing on delivery of eye services by optometrists (NHS eye care services, 2007). Given these opportunities it may be that screening for VI can be best offered by those primary care practitioners with specialist skills and equipment, namely optometrists, with funding flowing through new GP commissioning services (The Department of Health, 2003b). However, whatever solution is proposed should note the finding of Smeeth (1998), namely that fear of costs is consistently cited by a proportion of older people in studies looking at reasons for non-attendance at optometrists (Smeeth, 1998;Smeeth & Iliffe, 1998).

Research that is relevant to a consideration of the optimum venues for vision screening in older people is summarised in Table 2.6 together with comments on the advantages and disadvantages of potential venues. Comparative studies of which venues are likely to be most effective at detecting correctable visual problems have not been found. Further research is needed to compare the feasibility of using different venues for vision screening in older people. Suitability of potential venues will be linked to the screening method that is used and this is discussed in the next section.

Table 2.6 Possible venues for Vision Screening

Venue	Advantages	Disadvantages
GP surgery (Brabyn *et al.*, 2001i;Bulpitt *et al.*, 1990;Mangione *et al.*, 1992;Reinstein *et al.*, 1993;Smeeth, 1998)	• 98.5% of people aged >64y attending A&E are registered with GPs • Only half of patients with low vision are known by GPs to have an eye problem • 43% of people aged >64y attended their GP at least once a month, but 87% said their GP had never checked their eyes or vision • 90% of people aged >75y see their GP at least once a year	• There might be a small, but neglected, body of people who avoid healthcare services • Attendance rates for the over-75 GP health screening was reported to be 48-63%
Surgical & orthopaedic wards (Grisso *et al.*, 1991)	• In older people, over 90% of hip fractures are associated with falls and both are correlated with visual impairment(Grisso *et al.*, 1991)	• It would be preferable to detect visual problems before people have falls • Most falls are not associated with fractures (Grisso *et al.*, 1991)
Accident & emergency (A&E) clinics (Reinstein *et al.*, 1993)	• Helps to detect people whose vision might have caused an accident	• It would be preferable to detect visual problems before people have falls • In one study of A&E patients, 41% could not be screened because the department was too busy • Most medical & surgical problems are independent of vision • Not all falls occurring in the community present to A&E
Out patient clinics (McMurdo & Baines, 1988)	• Even patients in the care of several medical practitioners have high levels of treatable but severe visual disability	• there might be a small, but neglected, body of people who avoid health services

Falls clinics	• Conducting vision screening in "Falls clinics" would target the more vulnerable population. This may prevent falls occurring due to undetected yet correctable low vision in the future.	• there might be a small, but neglected, body of people who avoid healthcare services • It would be preferable to detect visual problems before people have falls
Residential rehabilitation centres	• Often, older people who have been hospitalised (e.g., after falls or strokes) stay in rehabilitation centres before returning home. • Staff at these centres can be less pressured for time than in hospital	• There appears to be no previous research using these centres
Community centres	• An opportunity to test large groups of older people	• People attending community centres might tend to be those with better vision • These people might tend to be the more confident, who may be likely to already use eye care services
Nursing homes (Grisso *et al.*, 1991;Lord *et al.*, 1991)	• People in nursing homes are more than three times more likely to have visual impairment than those living at home (Klein et al. 1991).	• Some nursing homes already receive domiciliary optometric services.
Individual residencies (Sinclair *et al.*, 2000)	• Certain areas, for example with a concentration of people on low income, could be targeted	• Logistically difficult and expensive

2.4.3 Methods for screening: which tests might be appropriate?

2.4.3.1 Self reported measures

A questionnaire is probably the simplest method of screening for visual problems among the elderly. A systematic review evaluated five trials, all of which used self-reported measures to assess impaired vision, both as the screening assessment and as the outcome measure (Smeeth & Iliffe, 1998). This review found a reduction, associated with screening, of only 11% in the number of older people with VI. The review states several factors that may have contributed to the lack of improvement seen in these trials which are discussed in the section on Previous Reviews. The most obvious limitation of self-reported measures is that a patient's perception of their visual status may only weakly correlate with their actual visual function. This is particularly likely when the vision deteriorates slowly or only in one

eye and additionally older people with poor vision may feel that their visual function is ‘normal for age’, when in fact it could be improved.

2.4.3.2 High Contrast Visual Acuity

Most studies that have screened for visual problems in older people have solely relied on visual acuity testing (Long *et al.*, 1991;Strahlman *et al.*, 1990b). Some of these studies repeated the visual acuity testing with a pinhole, assuming that an improvement with a pinhole is indicative of reduced vision attributable to refractive errors (McCarty *et al.*, 2002). However, this assumption is unsafe because the pinhole test is prone to the errors outlined in Table 2.5. Many studies evaluating visual acuity still use the standard Snellen chart (Evans & Rowlands, 2004i;Evans & Rowlands, 2004j), although others use improved designs such as Bailey-Lovie (Bailey & Lovie, 1976) and ETDRS charts (Klein *et al.*, 1983b) and other designs (Johansen *et al.*, 2003). Many authors have noted the limitations of visual acuity tests for screening vision in older people (see Table 2.5).

It is understandable why many studies have used visual acuity to screen for visual problems because the WHO-ICD 10 definition of VI is based on high contrast visual acuity (World health organisation, 2006a). However, the world health organization does have an alternative definition that does take account of visual field (World health organisation, 2006b). As noted elsewhere in this thesis, there are a variety of visual problems affecting older people which impair vision in different ways.

2.4.3.3 Low Contrast Visual Acuity

The study by Brabyn and colleagues described above showed that spatial vision of individuals cannot be well predicted from acuity measurements alone (Brabyn *et al.*, 2001j). This highlights the importance of incorporating additional vision tests, and particularly those that more closely resemble everyday viewing conditions. Figure 2.1 shows a wide range in decline among visual functions with age. It can be seen that high contrast acuity changes very little with age but despite maintained acuity, many older people are effectively visually impaired under conditions of everyday life (e.g., in situations of changing light levels). Figure 2.1

below shows that measures of low contrast visual acuity and glare decrease more rapidly with age than measures of high contrast visual acuity.

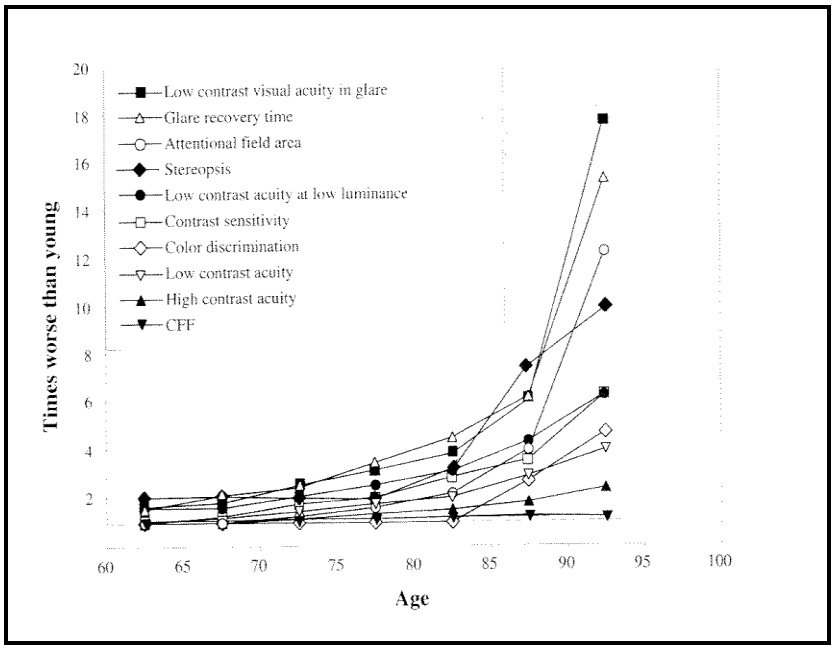


Figure 2.1 Visual Functions and Age. Illustrating the factor by which older individuals' median values are worse than those of young normal values as a function of age. Reproduced with permission from: Brabyn J, Chneck M, Haegerstrom-Portnoy G, Lott L; The Smith-Kettlewell Institute (SKI) longitudinal study of vision function and its impact among the elderly: an overview; Optom Vis Sci.78(5):264-9; ©The American Academy of Optometry, 2001.

The importance of low contrast acuity was emphasised by Schneck and colleagues (2004). Their study revealed that tests of low contrast spatial vision are strong predictors of significant subsequent vision loss. It was found that 55% of those in the worst category of low contrast low luminance acuity at baseline subsequently had acuity loss, compared to none of those with good initial low contrast low luminance acuity. The results also showed that glare recovery time, stereopsis and sensitivity to flicker were not significant predictors of future acuity loss in the multivariate analysis.

This raises the question of which other vision tests might be useful to identify significant and correctable visual problems in older people? Several authors have therefore attempted to determine a screening test battery that will detect visual problems, these are summarised in Table 2.7. Lord and Dayhew investigated

which screening tests are most predictive of falls in older people. They evaluated a range of visual tests (high and low contrast visual acuity, edge contrast sensitivity, depth perception, visual fields) and non-visual tests (measures of sensation, strength, reaction time, balance). Visual parameters were associated with increased risk of falls, with the strongest visual risk factors being impaired depth perception, contrast sensitivity, and low-contrast visual acuity (Lord & Dayhew, 2001).

2.4.3.4 Visual Field Testing

The present review is primarily concerned with correctable visual problems, but clearly it is desirable to detect glaucoma since modern treatments often can arrest visual loss from this disease which is prevalent in older people (Weinreb & Khaw, 2004b). The desirability of an assessment of visual field was highlighted by Taylor and colleagues who evaluated 3,271 residents (83% of those eligible) aged 40-98 years. These authors found that nearly three times more people had VI because of visual field loss than visual acuity loss (Taylor *et al.*, 1997). Testing visual fields is difficult to administer in a screening situation and is dependent on the testing protocol that is adopted (Topouzis *et al.*, 2004).

Visual field testing on a modern automated instrument has been shown to be successfully administered with 81% of unselected people aged 65 years and over (Wormald *et al.*, 1992). Taylor and colleagues also managed to carry out automated perimetry on 89% of those aged 40 years or over (Taylor *et al.*, 1997). Oculo-kinetic perimetry is one possible test for screening for visual field defects in glaucoma (Greve & Chisholm, 1993). Recent developments have led to new rapid methods of screening visual fields. The best known of these is frequency-doubling perimetry, which compares well with conventional visual field testing for the detection of glaucoma (Allen *et al.*, 2002b;Tatemichi *et al.*, 2002b), but is less effective at detecting rarer visual field defects from neurological causes (Fong *et al.*, 2003a). However, other relatively simple approaches have also shown promise (Schiefer *et al.*, 1996).

Recently, computerised methods of automated vision testing and reporting have been used with success in occupational vision screening (Thomson, 1994) and in

children's vision screening (Thomson & Evans, 1999;Thomson & Evans, 2001;Thomson, 2002). A combination of tests could be included in a computerised program. This is discussed further in Chapter 3. Such a system might be an effective method of screening for visual problems in older people, for example, in GP surgeries and falls clinics.

In summary, the literature allows some inferences to be drawn about which vision tests might *potentially* be most useful in vision screening of older people. Table 2.7 summarises the tests that could be used for vision screening in the older population. These include: high contrast visual acuity, low contrast visual acuity, contrast sensitivity, visual fields, stereo-acuity. Other tests may also be useful (e.g., glare recovery, vertical heterophoria). Further work is needed to evaluate these tests to determine which combination of tests is most effective for vision screening and indeed to determine the effectiveness of this combination of tests.

Table 2.7 Research systematically comparing methods of vision screening of older people. VA, visual acuity; CS, contrast sensitivity; VF, visual field; D, distance; N, near

Authors	Study design	Outcome	Comment
(Davison, 1985)	Screened drivers using battery of tests on Keystone Telebinocular to determine correlation with driving accidents.	In those over the age of 55y and 65y, hyperphoria >1prism Dioptre was significantly correlated with accidents.	This is the only study suggesting that measuring hyperphoria would be a relevant test, Study only used Keystone Telebinocular.
(Taylor et al., 1997)	Population-based screening of D&N VA & VF in 3,271 people aged 40-98.	Nearly three times more people had visual impairment because of VF loss than VA loss.	Although measuring VA is important, it is also desirable fo visual screening to include VF testing.
(Wang et al., 1998)	Tested 405 patients aged >39y attending primary care clinic using: questionnaire, VA, VF, tonometry, slit lamp biomicroscopy dilated fundoscopy, fundus photograph.	Questionnaire for detection of eye disease was sensitive (90%) but not specific (44%). D VA with presenting correction: sensitivity 61%, specificity 72%. Dilated fundus examination: sensitivity 79%, specificity 82%. In screening for glaucoma, tonometry was ineffective (sensitivity 27%, specificity 96%), suprathreshold visual field testing: sensitivity 70%, specificity 67%. Two-stage strategy wit the questionnaire then VA & ophthalmoscopy gave best sensitivity	The study found that the desirable tests included a combination of questionnaires VA measurements and ophthalmoscopy . This combination gave the best sensitivity and specificity. However for vision screening t be cost-effective, it should be able to be carried out by lay personnel. This precludes ophthalmoscopy. The authors conclude “More effective tests are needed to

		(83%) & specificity (76%).	improve performance of eye disease screening".
(Woods et al. 1998)	Compared ability of VA and CS to detect presence of ophthalmic disease in 2,522 randomly selected people aged >49y.	Arden plate 7 (6.4cpd) correctly identified 96% of patients with disease and was better than Snellen VA at detecting disease.	As in the above study, using one test alone proved not to be sufficient and the results showed that a combination of VA and CS was little better than CS alone.
(Lord & Dayhew, 2001)	Prospective cohort study to determine the tests most predictive of falls in 156 people aged 63-90y. Assessed high & low contrast VA, CS, VF, stereo-acuity.	Multiple fallers had decreased vision as indicated by all tests, with impaired stereo-acuity, edge CS, & low contrast VA being the best predictors. Poor vision in one eye with good vision in the other had a similar risk to poor vision in both eyes.	High contrast VA, the most common single visual screening test, did not feature in the main visual predictors of falls. Stereopsis and edge CS found to be particularly important test when assessing visual risk factors for falls
(Brabyn et al. 2001)	Longitudinal study of visual function in 900 older people. Assessed high and low contrast VA at D & N with & without glare source, glare recovery, CS, dark adaptation, reading, VF, stereo.	Wide range of decline in visual functions with age. Concerning the establishment of a practical test protocol for vision in the elderly: "spatial vision of individuals cannot be well predicted from acuity measurements alone". Advocate testing vision under real-world situations (e.g., glare, low contrast).	Another study demonstrating that measures other than just high contrast VA needs to be assessed. It was found that vision in the presence of glare; glare recovery time and attentional visual field size are the functions that decrease most rapidly with age. It would then be appropriate to use tests such as these when screening the older population
(Ivers et al., 2001)	Study of 3,654 people aged >48y. Assessed: VA, CS, VF, IOP, lens & retinal photos with grading.	No single vision test predicted the presence of eye disease with any consistency. VA & CS were best, but still poor sensitivity & specificity. The study did not investigate combinations of tests.	The study concluded that current vision tests are not good at detecting eye disease compared with a full eye examination. "Further work in this area should be carried out before vision screening programs can be recommended for implementation among older people".
(Smeeth et al 2003).	Trial of 4,340 people aged >74y sampled from 20 GP practices. Screening by questionnaire & VA only.	Vision screening was carried out either (a) universally or (b) only in patients with health problems. 3-5y after screening the risk of VA<6/18 in either eye was not significantly different in the two groups.	The only measure of visual function was VA. The results suggest that screening solely by questions about vision & VA assessment is inadequate.
(Rubin et al., 2007)	The role of vision and visual attention	Glare sensitivity and binocular visual field loss were significant predictors of	This study suggests that current vision screening for

	factors in automobile 'crash' involvement was determined on 120 older people aged between 65-84 years.	crash involvement. Acuity, contrast sensitivity and stereoacuity were not associated with crashes.	drivers' licenses based primarily on visual acuity may miss important aspects of visual impairment

Vision screening may lead to a referral to an optometrist. The optometric eye examination would detect the many cases where visual acuity can be improved by refractive correction alone (Tielsch *et al.*, 1990a;Taylor *et al.*, 1997;Liou *et al.*, 1999;Foran *et al.*, 2002c). Additionally, more than 40% of older eyes with ocular pathology have more than one type of pathology (Leibowitz *et al.*, 1980) and the optometrist can diagnose the disease(s) and prioritise the referral when this is required.

2.4.4 Does vision screening for older people meet the Wilson criteria?

The questions raised in Table 2.1 will now be discussed:

2.4.4.1 Does the burden of suffering warrant screening?

The systematic review of Evans and Rowlands established that low vision is relatively common among older people and that this has a significant effect on the quality of life of those affected and is associated with an increased risk of falls (Evans & Rowlands, 2004e). Identifying and treating VI is an important preventative intervention in the older population with a history of falls. Studies such as those conducted by Wolffsohn and Cochrane support the intuitive notion that clinical vision impairment measures are highly correlated with the capacity to perform activities associated with everyday life (Wolffsohn & Cochrane, 2000). Based on the available evidence, the burden of suffering due to undetected, remediable low vision among the elderly warrants further research.

However, it is important to recognise the limitations of screening as outlined by the National Screening Committee (2007) in Chapter 1. They emphasise that whilst screening has the potential to save lives or improve quality of life through early diagnosis of serious conditions, it is not a foolproof process. Screening can reduce

the risk of developing a condition or its complications but it cannot offer a guarantee of protection.

2.4.4.2 Is there a good screening test?

The UK National Screening Committee states that the screening test should be simple, safe, precise and validated. The test should also be acceptable to the population and the distribution of test values in the target population should be known and a suitable cut off level defined (UK National Screening Committee, 2003).

Smeeth suggests that in a primary care setting a screening test needs to be quick, cheap, available and able to be carried out easily by different members of the primary health care team (Smeeth, 1998). Different methods of screening are discussed above. There is a definite need for more research to evaluate whether a vision screening tool comprising a battery of relevant tests can be developed with adequate sensitivity and specificity. If it cannot, then it would seem to be more appropriate to devote resources to increasing the number of older people having regular eye examinations with optometrists.

2.4.4.3 Are efficacious treatments or preventative measures available?

The UK National Screening Committee suggests that there should be an effective treatment or intervention for patients identified through early detection with evidence of early treatment leading to better outcomes than late treatment (UK National Screening Committee, 2003). The evidence reviewed suggests that many older people with low vision could be helped greatly by refractive correction or cataract surgery. Treatment for symptomatic cataracts is effective (NHS Centre for reviews and dissemination, 1996b), improving quality of life and physical and mental functioning (Javitt *et al.*, 1993). Visual acuity can be improved for most patients with refractive defects (Tielsch *et al.*, 1990b). Reidy and colleagues found that the prevalence of cataract causing VI was 30% and the prevalence of refractive error causing VI was 21% (Reidy *et al.*, 1998e). The fact that these conditions are so easy to detect and correct makes it likely that this criterion is met on the basis of these conditions alone.

Quality of life and functioning are also improved by the treatment of a variety of other chronic eye disorders (Brenner *et al.*, 1993). For example new treatments for age-related macular degeneration are now becoming available. Even cases that are not treatable will benefit from support and low vision aids. Registration as blind, and to a lesser extent registration as partially sighted, mobilizes social support (Bruce *et al.*, 1991).

2.4.4.4 Will those at risk attend for and accept screening outcomes?

This issue is related to the choice of venue in which to conduct a screening programme. A good venue would ensure high coverage rates and should be easily accessible to the older population. The new integration of primary health care services can be used as an opportunity to develop more acceptable and patient-centred eye care for older people, especially those not presently in contact with the NHS. Various venues for screening are discussed above. More research is needed in this area to investigate the most appropriate venues to conduct vision screening in the older population to ensure that those at risk attend for screening. Other factors that are likely to affect whether older people attend for screening include their perceived benefit from the screening, which will also influence whether they accept any recommendations that they are given on completion of the screening. These effects are poorly quantified, but good publicity for screening that stresses the high prevalence of correctable visual problems is likely to help.

2.4.4.5 Do people with positive screening results accept interventions or advice?

A study conducted by Quigley and colleagues found that from the 2000 participants who were offered eye examinations after being screened, 1331 scheduled an appointment and only 480 had the examination. It was suggested that fear of the medical care system or of the health care facility is deeper than originally thought (Quigley *et al.*, 2002e). Smeeth suggests that fear of costs may prevent some older people from accepting a recommendation to attend an optometrist for sight testing and vouchers towards the cost of glasses for those on income support may cover only a fraction of the cost of glasses (Smeeth, 1998).

Mansberger and colleagues conducted a study involving community visual field screening with frequency doubling technology. Those with abnormal screening results were encouraged to have an eye examination and were followed up 3-6 months later. The results indicated that although more than two thirds of patients with abnormal results did have an eye examination following the screening, the most common reason not to undergo an eye examination was failing to recognise the importance of an abnormal screening result (Mansberger *et al.*, 2007). A paper by Charles and colleagues also identified barriers to the uptake of eye examinations by older people and these included : perceived lack of need for eyecare, caring for a spouse, attitudes to eye health, poor knowledge of the causes of sight loss and of the role of optometrists, affordability of spectacles and language barriers in people from ethnic minorities (Charles *et al.*, 2005).

Further investigation is required into patients' perspectives on the extent to which their own vision has gradually reduced, the point at which they feel help should be sought, uncertainties about the treatment and the outcome and barriers to effective interventions to reduce VI among older people.

2.4.4.6 Can the health system cope with the programme?

Smeeth suggests that the development of a national vision screening programme may lead to an increase in referrals to the eye services and acknowledges that this would need to be resourced (Smeeth, 1998). On the other hand it can be argued that in addition to the pain and distress that low vision causes to the person affected, uncorrected visual problems may also cause a considerable drain on resources, both of the NHS and of care providers, due to the increase in falls and accidents that are associated with VI.

Smeeth also stated that cataract surgery is likely to be a large part of the workload generated by vision screening in older people and many regions already have long waiting lists (NHS Centre for reviews and dissemination, 1996a). However, due to investment in the health system, waiting lists for cataract procedures in the UK have been shortened. Literature issued by The Department of Health states that no one was waiting more than 3 months for their operation and most patients can be expected to be treated within 6 weeks (The Department of Health, 2005).

2.5 Conclusions and chapter summary

The notion that older people with poor vision will all regularly attend optometrists for refractive corrections and the detection of ocular pathology is clearly little more than an ideal. Properly funded publicity may help to encourage more of the older population to view optometric care as an essential annual health check. However, this approach seems intrinsically limited and it seems likely that even a major publicity campaign will still leave many older people avoiding regular eye care.

If older people will not come to the consulting room for clinical tests then a complementary approach is to take the clinical tests to the public. This already happens through domiciliary eye care services, but again the take up of these is "patchy". A more universal and affordable approach might be a vision screening program using a battery of vision tests. The literature reviewed indicates that vision screening of older people meets most of the Wilson criteria for an effective screening programme, but there is still uncertainty over which tests are most appropriate. Only when this question has been answered can another issue, of suitable venues, be fully addressed because the appropriateness of venues will partly depend on the type of testing that needs to be carried out.

If a vision screening programme using a battery of vision tests, perhaps computerised, can be established then this should be tested to determine the sensitivity and specificity for detecting the target conditions. Ultimately, longitudinal studies are necessary to determine whether such a screening programme will lead to improved visual performance and quality of life in older people.

Having established that vision screening in the older population may be an effective way to detect vision loss in the older population and encourage older people to have eye examinations, the following chapter will focus on the development of two particular types of screening tools that can be used to screen for vision loss in the older population. The next chapter will also outline the aims of the research study.

Chapter 3

New screening methods & research aims

3.1 Introduction

In Chapter 1 the need for improved detection and management of visual problems in older people was established and the Wilson criteria for determining whether a screening programme is appropriate were reviewed (Wilson & Jungner, 1968). In Chapter 2 the literature on vision screening of older people was reviewed and it was concluded that more research is needed to establish whether vision screening of older people is appropriate. In particular, new screening tools might be more effective than those previously studied and ought to be developed and investigated. If a vision screening programme using a battery of vision tests, perhaps computerised, can be developed then the sensitivity and specificity for detecting the target conditions can be established. Furthermore the screening programme can be used to determine which tests are most appropriate for screening and which venues are most appropriate.

Previous research on screening vision in older people was summarised in Chapter 2. It was noted that methods have ranged from simply asking patients if they have any visual problems (Smeeth & Iliffe, 1998) to combining various tests (Woods *et al.*, 1998e;Wang *et al.*, 1998a). Recent developments in computerised screening may have an application in vision screening in older people and these developments will be reviewed here.

3.2 New methods of vision screening

Vision screeners are instruments designed to allow semi-skilled personnel to identify those with various forms of visual anomalies. Conventional screeners are capable of presenting a variety of targets at various optically simulated distances, e.g. infinity (to simulate distance vision), 30cm (to simulate near vision) and more

recently at intermediate distances to simulate visual display unit (VDU) distances. The range of visual functions assessed by these instruments and the degree of automation varies between models but most instruments permit an assessment of visual acuity, ocular motor balance, binocularity, stereopsis and colour vision (Henson D, 1995). A limitation of these devices is that they are based on the Brewster-Holmes stereoscopic design (Evans 2007) which has the disadvantage of creating unnatural viewing conditions.

The recent development of computerised vision screening has opened up exciting new opportunities for vision screening. Not only are computer displays well suited to presenting visual stimuli but the implementation of computerised vision screening also means that expert systems can be built in to help analyse the results and perform back-office tasks such as maintaining a database and printing reports. So far, this approach has been applied successfully to visual screening for vocational requirements and for visual problems in children. The potential for vision screening of older people using computerised methods merits further investigation and the exploration of this is a key part of the study. Computerised vision screening can be considered as an evolution of earlier methods of automated vision and these approaches will now be described.

3.2.1 Automated vision screening

Automated vision screening has enabled vision tests to be administered quickly and effectively and increasingly without much input from personnel and in a number of screeners the only input that is needed is for the scoring of results. Examples of automated screening are outlined below.

The Titmus Vision Screener is compact (Madigan, 2005a) and is therefore lightweight and portable with a number of screening tests including near acuity, distance acuity, depth perception, colour perception, muscle balance (lateral and vertical heterophoria) and visual fields (peripheral vision of 130 degrees in each eye). The Titmus Vision Screener can also test visual acuity at intermediate distances. The screener has a number of testing sequences enabling it to be used on children (preschool testing and school testing), adults and for occupational

purposes. The scoring system requires the input of a test assistant to record the results on a score sheet (Madigan, 2005b).

The Keystone Vision Screener is another automated screener which incorporates a number of tests including distance acuity, near acuity, intermediate distance acuity, depth perception, binocular function, colour, field of vision and low light vision. Although the screening system is automated, the scoring system is manual as with the Titmus Screener. However, more recently the Keystone Vision Screener has been modified to be under computer control. The results are stored in a database from which reports can be easily generated. The screening system is not completely computerised but 'computer controlled' and the actual screening tests are still administered through the original screening unit. Keystone has a range of computer controlled vision screeners which are suitable for different patients including a Standard Screener, Paediatric Screener and Drivers' Screener; each including tests suitable for that situation.

The screeners outlined above are typical of those that are commercially available and these have been reviewed by Madigan (Madigan, 2005c). It is evident when reviewing these screeners that the tests incorporated have been geared towards screening in schools or screening for occupational purposes and these screeners have not been used to test older people nor have they been adapted to be suitable for use with older people.

Despite the advantages of automated screeners there are also a number of disadvantages. The screeners tend to be 'luggable' rather than portable and the Brewster-Holmes optics that are typically used can result in instrument accommodation and convergence. The simulated viewing distances may not be appropriate and there can also be problems using the screeners with bifocal or varifocal spectacles. There may also be hygiene issues with the head rest and chin rest.

3.2.2 Computerised vision screening

The vision screeners discussed below are computer vision screeners which are completely computer based, only requiring the use of a laptop or desk top computer.

The City Vision Screener for Schools provided a radical new computerised solution to provide high quality vision screening for children of a variety of ages (Thomson & Evans, 1999). The program manages the entire process from obtaining parental consent, performing the vision tests, and producing customised reports for parents, teachers and optometrists. All of the tests (except for colour vision), are presented on the computer screen. The operator simply has to record the children's response to each test by clicking on the buttons at the bottom of the screen. The tests include colour vision, stereopsis, fixation disparity, visual acuity and a blur test. The program automatically analyses the symptoms, history, family history and test results to put together a customised letter for the child's parents. The letter explains the exact nature of any problems and explains what action the parents should take.

The City Vision Screener also has a version suitable for VDU users and is designed to be a cost effective way for employers to comply with Display Screen Equipment (DSE) Regulation (The Health and Safety (Display Screen Equipment) Regulations, 1992). This screening system is based on a computer program with the basic aim of identifying those individuals who are experiencing eye problems and to determine if the symptoms are related to visual defects or environmental factors or a combination of these (Thomson, 1994). The test conditions for the City Vision VDU Screener are the same as the normal DSE viewing conditions and as a result this computerised screening technique for VDU occupational purposes provides a very reliable measure of the user's vision under their normal working conditions. The screening can be conducted in a supervised environment or if conducted in an unsupervised environment the program can be configured to give more detailed on-screen instructions (Thomson, 1994). The program performs an analysis of the results and automatically generates reports for the user and the employer.

As stated above methods of computerised screening allow results to be automatically stored, reports to be generated and gives a level of flexibility not found in other screening techniques. The screeners discussed above are once again geared towards screening in schools or for occupational purposes, but not towards older patients. Computerised vision screening for the older population is under researched and warrants further investigation.

3.2.2.1 Adaptation of computerised vision screening to older people

Thomson has researched extensively in the field of vision screening and developed the City Vision Screeners discussed above (Thomson, 1994;Thomson & Evans, 1999). Recently, Thomson implemented a modular approach to the City Vision Screeners and this facilitates adaptation to new applications. This modular design means that the user can customise the screening tool for a specific use. This customisation involves the user selecting from a list of symptom and history questions and from a list of tests to define a test battery that is appropriate for the population that is being screened. This would be an ideal way to adapt an existing successful screener to test the older population. The flexibility of being able to choose the most appropriate tests to include in the computer screener enables the test methods discussed in Chapter 2 to be incorporated in order to evaluate their suitability in detecting correctable visual loss. Initially this may involve adding a significant number of tests. However, once the suitability of the tests has been evaluated, the computer screener can be easily refined to only include the tests that are shown to be of most value in detecting the target conditions.

Implementing the above method for adapting a current vision screener is an effective way of experimenting with certain tests resulting in a battery of tests most suited to a specific population. This level of flexibility would not be possible with a non computerised screening technique (i.e. a paper based screener) and would require a lot of time in reproducing various versions of the screener.

3.2.3 Flipchart screeners

While there are limitations to non-computerised screening methods, there are nonetheless some situations where simpler approaches might still be of value.

This may be the case in situations where computer screening is too complex either for the patient, the person administering the screening, or where there are logistic constraints on the use of computers. For example, computerised screening may not be suitable in developing countries where the cost of running a computerised screening program may be too high. In these conditions paper based screening tests would be easy to administer and cost effective. Advances in computerised technology have enabled paper based testing to be more easily generated and reproduced.

As discussed above, despite the developments in automated, computerised screening the need for simple, perhaps paper-based screening still exists in some situations and this raises the question of to what degree a simplified paper test would reduce the test performance at detecting visual problems compared with a more sophisticated computerised method. It can be argued that perhaps a computer screener is necessary to ascertain the correct battery of tests (due to ease of including and excluding tests) that can then be reproduced as a paper based screener. This is an important part of the research described in this thesis and the development of two screening tools; one computerised and the other a rapid flipchart will enable a comparison between the two techniques to be made.

Testing visual acuity with a flipchart is commonly used in children and there are a variety of paper-based acuity tests that are commercially available for children, including the Cambridge Crowding Cards and the LogMAR crowded test (Rabbetts, 2000). Smeeth and colleagues used the Glasgow acuity test (later renamed the LogMAR crowded test) when screening older people (Smeeth *et al.*, 2003c). However, this is rare and paper-based testing is not commonly used in older people.

The section above has outlined how computerised vision screening and flipchart tools can be used in the older population. The section below explores the research design, aims and objectives.

3.3 General research question

The general research question is: can a computerised vision screening tool and a rapid flipchart vision screener be used among the older population to detect (with adequate sensitivity & specificity) correctable visual loss as established by a 'gold standard' eye examination? Furthermore, what battery of screening tests would be most appropriate to incorporate into the screening tools and what venues would be most appropriate to conduct the vision screening?

3.4 General aims

The main aim of the research described in this thesis was to evaluate new screening tools and to evaluate their effectiveness in improving the detection of correctable visual loss in older people. Screening tools are not seen as a method of replacing professional eyecare, but rather as a communication tool to increase public awareness among the elderly of the need for regular eye examinations. If, as the literature suggests, (Evans & Rowlands, 2004f) there is a large number of older people who avoid eyecare services then screening may be a way of re-engaging these people with the eyecare services. The screening itself would act as a safety net for people who have hitherto failed to participate in regular full eye examinations. When the vision screening detects correctable visual impairment then the patient will be given individual personal advice that an eye problem has been detected and they must seek professional care. It seems likely that people who are thus identified will be more likely to seek professional care than if they had not received the specific targeted advice that will result from vision screening.

This last point highlights a hypothesis that was not directly tested in the present research: that individual advice to older people as an outcome of screening will be more effective than, for example, an advertising campaign, in persuading them to seek professional eyecare. It should be noted though that the value of the screening software is not solely contingent on this hypothesis. The screening tools could ultimately be used for a different purpose, either in addition to or in place of their potential direct role in improving the take up of eyecare services in older people. This other role might be to carry out research in a given community to establish the prevalence of undetected visual problems so as to determine whether

further action is necessary. Further action might include publicity campaigns, outreach clinics, or increased funding of community optometric eyecare services.

The present research therefore concentrates on evaluating the sensitivity and specificity of the screening tools at detecting correctable visual problems. This information will provide data on the validity of the screeners which will allow informed decisions about their potential uses.

3.5 Brief overview of research design

Most research can be classified as having a certain research design. Typical examples are cohort studies (one or more groups are followed over time, of which a randomised controlled trial is a specific interventional type), case control study (two populations are compared at a point in time), cross-sectional studies (prevalence surveys), and evaluations of diagnostic tests (which determine the ability of a test to detect a condition). The research described in this thesis is predominantly a diagnostic (screening) test evaluation (see below). Although not the primary goal, some epidemiological data was analysed in what was in essence a cross-sectional survey. In another facet of the research some cohorts of patients were followed over a brief period of time to monitor the effect of interventions on quality of life. This was a small cohort study.

It is important to note that although this is not a diagnostic study, screening can be considered a subcategory of diagnosis (Haynes *et al.*, 2006). Because of the similarities between diagnostic studies and screening studies, the key aspects of research design applied in this study closely resemble those of a diagnostic study.

Haynes and colleagues outline four points that ensure a valid diagnostic study. These points are outlined in Table 3.1 below with comments on how the criteria relate to the present study

Table 3.1 Ensuring a valid diagnostic study (Haynes *et al.*, 2006)

Criteria for a diagnostic study	Comment
Assemble an appropriate spectrum of patients	Patients will all be aged 65 and over living in the South London area where there is likely to be a significant unmet need for eyecare.
Apply both the diagnostic test and reference standard to all of them	The screening tests and the gold standard eye examination will be applied to all participants. This is discussed in more detail below.
Interpreters each blind to each other	A double masked protocol will be adopted. Both the optometrist and the screener will be masked to the results of the other.
Study is repeated in a second, independent set of patients	The study will be repeated on another set of older patients. This is discussed in more detail below.

3.5.1 The need for two studies

External validation for the study can be ensured by conducting a second study involving an independent but similar population (Haynes *et al.*, 2006).The results from the first study will enable the development of a more refined computerised screener. In addition to the computerised screener, the key tests will also be made available in a flipchart format for places where computerised testing is not appropriate. Both these screening tools will be evaluated in the second study in the same way as the initial computerised screener was evaluated in the first study.

3.5.2 The need for a Gold standard

The accuracy of a screening test in detecting the target condition can be evaluated by comparing the results obtained with an established 'Gold Standard' (Haynes *et al.*, 2006). In this study the gold standard is a full eye examination that will be accepted as the definitive determination of whether patients have correctable visual loss.

Harper and Reeves (1999) outline two crucial points surrounding the gold standard for a diagnostic test. The first point is that the gold standard definition of normality should be clearly defined. Methodological standards for the evaluation of diagnostic tests summarised by Harper and Reeves state that all participants should be assigned to receive both diagnostic testing and gold standard verification. However there may be times when the definitive examination is impractical or too invasive to be administered to all participants and as such may only be assigned to those participants who fail the diagnostic test. It is particularly important in these situations that the gold standard definition of normality clarifies this and highlights the possibility of work –up bias (Harper & Reeves, 1999e). Work up- bias is the bias that occurs when the definitive gold standard is conducted only on those participants who fail the diagnostic test. The end result of this is a high sensitivity for diagnosing the disease, but no or insignificant results to rule out the disease. In other words, no specificity may be calculated as there is no control group of negatives (Kelly *et al.*, 1997a). The second point with reference to the gold standard highlighted by Harper and Reeves is that it should be independent of the diagnostic test under evaluation. This means that the diagnostic tests should not be performed as part of the gold standard (Harper & Reeves, 1999f). This is known as incorporation bias and occurs when the test under evaluation is itself used as a gold standard (Kelly *et al.*, 1997b).

In order to avoid the biases discussed above, the study will take into account both the above points and the gold standard eye examination will be applied to all participants in the study. The vision screening tests will be assigned independently of the gold standard.

3.6 Objectives and expected outcomes

The study will result in the development of two vision screening tools for the older population. A computerised vision screener and a rapid flipchart vision screening tool. The objectives and expected outcomes of the study are outlined below**.**

Primary Objective 1: Determine the battery of vision tests and questions for a computerised vision screener that has greatest sensitivity (and specificity) for detecting correctable visual problems in older people.

Primary Objective 2: Determine the battery of vision tests and questions for a rapid flipchart vision screener that has greatest sensitivity (and specificity) for detecting correctable visual problems in older people.

Primary Objective 3: Calculate the sensitivity and specificity of the final version of the computerised vision screener for detecting correctable visual problems in older people.

Primary Objective 4: Calculate the sensitivity and specificity of the final flipchart rapid screener for detecting correctable visual problems in older people.

The effectiveness of the above screening tools will be evaluated and information will also be obtained on the most appropriate venue(s) for screening and on participants' opinion of the screening process. It is expected that the rapid flipchart will be more suited to community based settings where the use of computerised techniques may not be appropriate for example in hospital wards.

It is expected that the research will not only provide information on the most appropriate tests for a vision screener but also provide additional information on issues surrounding access to eye care. Below are secondary objectives and additional observations that hope to be made as a result of the research.

Secondary Objective: Determine whether people whose visual problems are detected with screening do, as a result of the screening, receive treatment of their visual problems and appropriate support. When this does not occur, we will seek to discover the reasons

Additional observation 1: Provide a commentary on the suitability of different venues for screening vision in older people.

Additional observation 2: Comment on the characteristics of older people with poor vision in South London. In particular, make observations on the relationship

between ethnicity and correctable visual loss and also between poverty and correctable visual loss.

It is anticipated that the research will detect correctable visual impairment in approximately one third of participants as suggested by the systematic review by Evans and Rowlands (Evans & Rowlands, 2004g), and these people will obtain a direct and immediate benefit, in terms of correcting visual impairment and in reduced risk of falls and improved quality of life.

At the planning stage of the study it was acknowledged that the research may produce a negative result: it is possible that vision screening in older people is not effective. The following factors that could lead to this conclusion were considered: screening might not be able to detect the relevant visual problems, screening might not be cost effective, or screening might not be successful at encouraging older people with visual problems to engage in eyecare services.

Some of the literature appears to support this point of view, but always without a full analysis of the options for vision screening. For example, a systematic review that reached this conclusion set extremely strict selection criteria (Smeeth & Iliffe, 2000;Smeeth & Iliffe, 1998). This meant that only five trials met the inclusion criteria and all of these used self-reported measures to assess impaired vision. Vision was not assessed at all: only participants' opinions of their vision. Another paper points out that visual acuity assessments "are probably preferable to questions about visual problems" but does not consider in detail screening to assess additional visual functions as well as acuity (Smeeth, 1998). Regardless of whether computerised screening proves to be effective, this approach is a valuable tool for investigating which tests are most useful for vision screening generally in older people.

3.7 Chapter summary

This chapter has outlined the design of the screening tools to be used in the study. The main research question, aims and objectives have also been explored. Key aspects of the research design have been outlined and the next chapter will focus in detail on the methods of conducting the study.

Chapter 4

Methods

4.1 General Methods

4.1.1 Introduction

This thesis describes two studies which were designed to assess the sensitivity, specificity and validity of two new screening tools which have been developed to identify poor vision among the elderly. Both studies followed a double masked randomised design. The sensitivity and specificity of the screeners was determined by comparing the results of the screeners to a gold standard eye examination carried out by an experienced optometrist.

4.1.2 Participants

The inclusion criteria for both studies were that all participants had to be over the age of 65 years and living in South London. This area provides a population with diverse cultural and socio-economic profiles. Older people of all ethnicities and levels of ability were included in the studies. In order to include older people who were not already under the care of an eyecare practitioner, a variety of recruitment campaigns were conducted including leaflet drops, posters, open days, press releases and word of mouth. Local newsagents, churches, community centres', GP practices, care homes were all contacted. Several open days at community centres also enabled the researcher to speak personally to older people and this proved to be the most effective method of recruiting participants. Word of mouth then generated a steady flow of patients at a variety of venues. No exclusion criterion was set and all older people over the age of 65 years were encouraged to participate.

The sample size for the first study was calculated according to the methods described by Jones et al. for screening tests (Jones *et al.*, 2003). The calculations require a stipulation of acceptable sensitivity and specificity and estimate of the prevalence of the target condition (see Table 4.1). The systematic review by Evans and Rowlands suggested that the prevalence of the target conditions is likely to be 30% (Evans & Rowlands, 2004o)

Table 4.1 Assumptions for sample size calculation.

Question	**Assumption**
What is the lowest sensitivity that is acceptable?	95%
What is the lowest specificity that is acceptable?	95%
What do we want the confidence intervals to be?	5%
Likely prevalence of target disorders (cataract or uncorrected refractive error)?	30%

Using these figures it was estimated that a sample size of approximately 250-300 would be required. This estimate of sample size was based on assumptions about prevalence that may not be appropriate for the previously un-researched South London population. It was therefore planned to repeat the sample size calculation approximately halfway through the study, using the real data obtained thus far. At this time (N=150), the prevalence of the target conditions was 52.3% and the revised sample size calculation suggested that 140 participants would be required. To allow for a margin of error, the study was continued until 180 subjects had been tested in Study 1 and 200 subjects in Study 2. Table 4.2 outlines the assumptions for the revised calculation.

Table 4.2 Assumptions for revised sample size calculation

Question	Assumption
What is the lowest sensitivity that is acceptable?	95%
What is the lowest specificity that is acceptable?	95%
What do we want the confidence intervals to be?	5%
Likely prevalence of target disorders (cataract or uncorrected refractive error)?	52.3%

The calculations above use sensitivity and specificity values that were used by Jones et al (2003) to calculate the sample size for a diagnostic test to detect ankle fractures. In hindsight, these values were unrealistically high for vision screening and we could have lowered the level of sensitivity and specificity, which would have reduced the sample size required. However, in research of the type described in the thesis the basic principle is to provide the maximum precision in estimates of sensitivity and specificity by using the largest sample size that is practical given the inevitable constraints imposed by time and finances, which is the overarching principle that was followed.

4.1.3 Venues for conducting research

The screening was carried out in a variety of venues of clinical and "non-clinical" settings in order to a) encourage participation from older people who were not receiving eyecare and who were perhaps fearful of a more clinical environment and b) establish the effectiveness of the screening tools in a typical community setting.

The screening tools were designed to be used in non-clinical environments and the only requirement was a viewing distance of at least 3m and "normal" room lighting. A darkened room of a least 3m in length was required for the gold standard examination. Another major consideration when selecting venues for the study was ease of access for elderly participants.

Several authors have suggested GP surgeries as a possible venue to conduct screening, (Bulpitt *et al.*, 1990;Reinstein *et al.*, 1993;Smeeth, 1998) although

others have expressed doubts (Mangione *et al.*, 1992;Brabyn *et al.*, 2001g). Possible venues have been reviewed in Chapter 2, Table 2.6. A list of potential venues and whether or not these would be suitable for present research is shown in Table 4.3 below.

Table 4.3 Possible venues for vision screening, with comments on their suitability for the present research.

Venue	Conclusions for present research
GP surgery	• Suitable for present research
Surgical & orthopaedic wards	• Suitable for present research
Accident & emergency (A&E) clinics	• These clinics are usually very busy • Patients in these clinics do not have time for a full eye examination • Not suitable for present research • If a flip-chart screener is found to be useful, it could be used here in the future
Outpatient clinics	• Patients in these clinics do not have time for a full eye examination • Not suitable for present research • If a flip-chart screener is found to be useful, it could be used here in the future
Falls clinics	• Patients in these clinics do not have time for a full eye examination • Not suitable for present research • If a flip-chart screener is found to be useful, it could be used here in the future

Residential rehabilitation centres	• Suitable for present research
Community centres	• Suitable for present research
Nursing homes	• Suitable for present research
Individual residences	• Health & Safety issues raised by PCT, so not suitable for present research • If a flip-chart screener is found to be useful, it could be used here in the future by community health care staff

The table above shows that the most appropriate venues are those where participants will be tested either in the place where they are resident permanently (e.g., residential home) or temporarily (e.g., rehabilitation centre) or in a place that is local to them and which they regularly visit (e.g., GP surgery, community centre). The venues used in the present study are outlined in the following section.

4.1.3.2 Venues used for present research

Table 4.4 below shows the venues that were used in the study.

Table 4.4 Venues used in present study

Venue	Study	Comment
The Institute of Optometry	1 and 2	The Institute of Optometry (IoO) is based in South East London and provides optometric care in a clinic based environment. It is open to all members of the public regardless of their visual needs
Tower Hill residential care home	1	This is a large, purpose built care home located in South East London, providing facilities for the nursing, social and personal care of the elderly. A separate unit is provided for the care of those suffering with dementia

		related illnesses. The home has a total capacity of 128 places.
Pulross intermediate healthcare centre	1	This healthcare centre is located in Brixton, South West London. Intermediate Care is an emerging approach to healthcare where primary care is located in the community rather than relying solely on resources in central hospital situations. The centre is a partnership between community health services and local general practitioners. Other service providers such as local hospitals and social services have close links with the Centre. The range of services that the Centre provides includes physiotherapy, occupational therapy and speech therapy. They also have a range of clinics such as falls clinics and post surgery follow up. In addition the Centre has a number of short-stay inpatient wards and individual rooms.
Community based optometric practice	1	A community based optometric practice with a high number of older people from ethnic minorities.
Blairderry Road surgery	2	This GP practice is located in the heart of the Streatham community in South West London.
Woodlawns day centre	2	Woodlawns Day Centre is situated in South West London and is managed by Age Concern Lambeth. The Centre provides activities and facilities for older people of all cultures in Lambeth. Services include a luncheon club, welfare advice, snooker, bingo, bridge, line dancing, hairdressers, day trips, outings and holidays.

4.1.4 Diagnostic criteria for defining target eye disease

The purpose of the gold standard eye examination was to give a true indication of the presence of correctable visual loss. It was important to specify diagnostic criteria for defining the target eye conditions in order to establish when these conditions became clinically significant. The presence of cataract or refractive error may not cause vision loss in the early stages and the diagnostic criteria outlined in this section give a clear indication of when an optometrist may consider correcting this vision loss and when an older person would benefit from intervention.

The diagnostic criteria for the main target conditions are stated below.

4.1.4.1 Cataract

Cataract was defined using the Lens Opacities Classification System III (LOCSIII). This grading system consists of six slit-lamp images for grading nuclear colour (NC) and nuclear opalescence (NO), five retroillumination images for grading cortical cataract (C), and five retroillumination images for grading posterior subcapsular (P) cataract. An illustration of the LOCS III grading scale can be found in Chapter 5 (Figure 5.1).

The diagnostic criteria for cataract used in this study have been used by previous researchers based on the LOCS criteria of LOCS III score of 4 or more for nuclear cataract, and 2 or more for cortical or posterior sub-capsular cataract (Foster *et al.*, 2003a;Saw *et al.*, 2003b). It has been shown that performance at using the LOCS III scale improves with practice (Karbassi *et al.*, 1993a). In view of this practice effect, the LOCS III scale was used by the researcher for 6 months prior to the study in order to gain experience. This criterion was applied monocularly, i.e. the presence of cataract (as defined above) in one eye or both was taken to be significant.

4.1.4.2 Refractive error

Saw and colleagues defined significant uncorrected or under-corrected refractive error as uncorrected myopia, hypermetropia, or astigmatism of at least 1.00D and

an improvement of at least two lines of visual acuity with correction (Saw *et al.*, 2003a). This criterion was modified in the present research because of problems with applying the 1D criterion as well as the 2 line improvement in VA. The three main reasons for modifying the criterion for this study are listed below.

- Some patients attended with spectacles which were in such poor condition (e.g., scratched lenses) that the VA was greatly impaired with the spectacles and these needed changing even though the change in refractive error may have been minimal. It was felt that these people should be included since they were in need of primary eyecare services.

- Focimetry of spectacles was not always possible because a focimeter was not available in some community centres. . An estimate of the prescription was made by hand neutralisation in these cases, but this has relatively low accuracy, especially for varifocals.

- Even if a 1D or more change in refractive error is found, it is debatable whether it is advisable to prescribe such a large change in prescription. Such large changes can be disorientating and could increase the risk of a fall (Cumming *et al.*, 2007).

It was therefore decided to modify the criterion so that any patient whose visual acuity was at least two lines (0.2 LogMAR units) better with subjective refractive findings than presenting visual acuity was defined as having a significant change in prescription. This criterion was applied monocularly: a 2 line improvement in distance acuity in either eye was regarded as significant. It was important to take monocular deficits into consideration for distance because of the risk of falls and driving accidents. The same criterion was used for near vision. However, the criterion was applied binocularly because monocular deficits for near are unlikely to impact on safety in the same way they would for distance. Distance visual acuities were measured using a computerised letter chart (Test chart 2000) and the optotypes were frequently randomised during the eye examinations so it was not possible for participants to memorise the chart.

4.1.4.3 Correctable vision loss

Correctable vision loss is a term used throughout the study to describe the presence of significant cataract or significant gain in acuity through refractive correction. In Table 4.5 below the criteria for correctable visual loss are shown.

Table 4.5 Defining Correctable visual loss

Correctable Vision loss	**Monocular/Binocular**
Significant gain in distance acuity through refractive correction.	The gain in acuity can be monocular or binocular
Significant gain in near acuity through refractive correction	Binocular only. This criterion was introduced when near acuity was being evaluated
Significant cataract	The presence of cataract can be monocular or binocular

4.1.4.4 Macular degeneration

The literature suggests that quite basic tests will be able to detect uncorrected refractive errors and cataract. These are the main target conditions for this study because: (a) they have a very high prevalence, (b) they can readily be cured, and (c) their treatment is of direct and immediate benefit to the public through correcting visual impairment and improving quality of life (Koole *et al.*, 2001b;Crabtree *et al.*, 1999;McGwin, Jr. *et al.*, 2003).

Macular degeneration is a common cause of reduced visual acuity among the elderly. Although this is not readily correctable in most cases, patients with this condition may benefit from ophthalmological investigation, possible treatment and for further support and low vision aids. Additionally, as outlined in Chapter 1 (p.33), new treatments for some forms of macular degeneration recently have been developed. In view of this, macular degeneration was considered as a target condition for the screener. The diagnostic criteria (based on the gold standard eye

examination) used for age-related maculopathy (ARM) was based on the Clinical Age Related Maculopathy Staging System (Seddon *et al.*, 2006a). This is a 5 stage grading system; stage 1 being no drusen and 5 being exudative macular changes.

An abbreviated form of the table is shown below.

Table 4.6 Clinical Age Related Maculopathy Staging System (Seddon *et al.*, 2006b)

Maculopathy grade	**Clinical features**
1	No drusen or <10 small drusen without pigment abnormalities
2	Approximately ≥10 small drusen or <15 intermediate drusen, or pigment abnormalities associated with ARM
3	Approximately ≥15 intermediate drusen or any large drusen
4	Geographic atrophy with involvement of the macular center, or noncentral geographic atrophy at least 350 μm in size
5	Exudative AMD, including nondrusenoid pigment epithelial detachments, serous or hemorrhagic retinal detachments, CNVM with subretinal or sub-RPE haemorrhages or fibrosis, or scars consistent with treatment of AMD

For the purposes of analysing whether visual acuity screening identifies macular changes, the gold standard data was re-coded into; 0-no macular changes and 1-macular changes present. This enabled ROC curves to be drawn and cut-off values to be calculated (this is explained in Chapter 7).

4.1.4.5 Macular degeneration risk of progression.

This category was introduced in study 2 in response to comments from the expert advisory group (see Section 4.1.6) and is based on the risk of macular degeneration progressing to advanced macular degeneration (neovascular disease

or geographic atrophy). A study conducted by Ferris et al (Ferris FL & Age-Related Eye Disease Study (AREDS) Research Group., 2005), indicated that large drusen and any pigmentary changes were particularly predictive of advanced AMD. Using the study by Ferris et al as a guide for the definition of AMD progression, it has been defined as greater than a stage 2 using the Clinical Age Related Maculopathy Staging System.

4.1.4.6 Glaucoma

Visual loss resulting from glaucoma cannot be treated and is not a primary target condition for this study. However vision loss from glaucoma may be prevented through early detection. It is difficult to screen for glaucoma, since all three commonly used glaucoma tests have a low sensitivity and/or specificity in isolation (Ivers *et al.*, 2001d) and using all three tests (Tuck & Crick, 1997b) in screening by non-healthcare professionals is impractical.

However, a simple central visual field test was developed for the computer-based vision screener and its efficacy was assessed in the first study. Participants were advised that this screening test was not an alternative to the glaucoma screening carried out as part of a full eye examination.

The diagnosis of glaucoma in the gold standard is multi-factorial, (Weinreb & Khaw, 2004a;Harper & Reeves, 1999c) and the diagnostic criteria of Foster and colleagues were used in this study (Foster *et al.*, 2002). In terms of glaucoma, the detection abilities of the screening tools were judged by their ability to detect three categories of patients; firstly those patients that had already been diagnosed with glaucoma; secondly, those patients that had been referred for further ophthalmological investigation for possible glaucoma as a result of the gold standard eye examination and finally those patients that the gold standard had identified as needing to be closely monitored for glaucomatous changes.

4.1.4.7 Summary of assumptions made

There are certain assumptions made during this study and these are outlined below:

- There are other ocular diseases that may decrease vision in addition to those mentioned above in Section 4.1.4. However, the literature reviewed in Chapter 2 indicates that the target conditions in this research are the main causes of reduced vision in older people. In this study the screening tools were designed specifically to screen for correctable loss of vision, in particular significant cataract and uncorrected refractive error.

- In the present research, all cataracts are assumed to be a form of correctable vision loss.

- There may be an overlap between those patients that had significant cataracts and those that had uncorrected refractive error.

4.1.5 Ethical considerations

The research followed the tenets of the Helsinki declaration (World Medical Assembly, 1989) for research involving human subjects and conformed to the Department of Health's Research Governance Framework (Department of Health, 2001). The research has been approved by the Institute of Optometry and City University RECs and approved by the NHS LREC. The research was also been approved by the local PCT Research Support Unit.

All participants were given full information about the research, both verbally and in writing, and it was explained that participation was optional and that refusal to participate would not in any way influence their continued medical, optometric, or social care.

Particular care was taken not to alarm or confuse older people. Participants were offered the opportunity of having the researcher speak to a family member or carer about the research, and every participant was given written information, which they were able to discuss with their family or carers. Any queries that potential participants and their family or carers had were fully answered before their consent to participate was sought.

Some older people might avoid eye care services because they are afraid that the outcome of an eye examination might prevent them from continuing to drive. Participants were asked whether this was a factor in order to determine the scale of the problem. Additionally, it is possible that this may have been a reason why some people might have declined to participate in the research. Therefore, when people declined participation they were offered a stamp-addressed envelope containing an anonymous questionnaire. This questionnaire included questions aimed at identifying reasons for non-participation, including fears about being prevented from driving. A record was kept of the number of participants who declined participation so that this could be compared with the number of completed "non-participation questionnaires" that were received.

The tests that were used were all based on standard visual tests that are in widespread clinical use. Participants were allowed to opt out of the research at any time without having to give a reason. Where visual problems were detected, every effort was made to help participants by referring (with consent) for optometric and/or medical investigation and treatment as appropriate. The usual referral pathways were followed. For most conditions, this is for the optometrist to refer the patient to the GP and for the GP to then refer to an ophthalmologist. Exceptions include a few conditions which are considered to be emergencies (e.g., retinal detachment) when the patient is referred directly to an ophthalmologist, who would be contacted first by telephone. The referrals were based on the gold standard eye examination; however the results from the screener were compared to the gold standard eye examination regularly in case the screener had detected a problem that the gold standard had not. In this situation, the participant was referred if necessary.

4.1.6 Expert Advisory Group

This research benefited from the input of an expert advisory group, established at the suggestion of the funding body (The Thomas Pocklington Trust). This group comprised the following multidisciplinary members:

- Dr. Angela McCullagh –Research and development director, Thomas Pocklington Trust
- Anita Lightstone- Head of Eye Health; RNIB
- Prof Ann Taket- Faculty of Health and Social Care, London South Bank University
- Prof Bruce Evans- Director of Research, Institute of Optometry, London
- Prof David Thomson- Department of Optometry and Visual Science, City University, London
- Prof Gill Rowlands -Clinical lead for the Primary Care Research Network-Greater London
- Prof Jennifer Evans- Department of Epidemiology & Population Health, London School of Hygiene & Tropical Medicine

This group met regularly throughout the research, on a total of 4 occasions. The group provided helpful suggestions on all aspects of the research.

4.2 First Study Procedure

The first study was divided in to 4 main sections these are shown in Table 4.7, which also indicated the order in which all the procedures were conducted.

Table 4.7 First study procedure. The tests are described in more detail later on in this chapter

	Tests	**Order**
pre study briefing	consent form, questionnaire on previous eye care, lifestyle questionnaire.	1
vision Screening	Computer Vision Screener (CVS1)	2
	history and symptoms	3

gold standard eye examination	<u>basic refractive tests</u> distance/ Near vision and visual acuities retinoscopy distance subjective refraction and visual acuities near subjective refraction and visual acuities	 4 8 9 12
	<u>binocular vision tests</u> cover test fixation disparity near point of convergence stereoacuity motility	 5, 10, 13 11,14 15 16 6
	pupils	7
	amsler	17
	tonometry	18
	visual field assessment	20
	external eye examination (slit lamp biomicroscopy; see below)	19
	internal eye examination (see below)	21
post study debriefing	prescription and advice issued, together with list of local optometric practices	22

The 4 main parts to the first study will now be looked at in more detail.

4.2.1 Pre study briefing

Each participant was issued with a pack which included a selection of forms and information sheets. Participants were sent the information pack prior to their appointment or were asked to come in earlier so that they had an opportunity to read through the information prior to consenting to take part. Below is a list of all the documents in the information pack. The information was also available in large print and participants were given the opportunity of having the research discussed

with a family or friend. Participants who did not speak English were encouraged to bring a friend or a family member who could help translate during the eye examination and the screening. The study literature would have been translated in to different languages if this was needed, however this situation did not arise.

Copies of all of these are included in the Appendix

1) Participant information pack covering letter
2) Information sheet
3) Information leaflet
4) Consent form
5) Questionnaire on previous eye care
6) Non participation questionnaire

4.2.2 Study 1 Computer Vision Screener (CVS1)

The literature review in Chapter 2 informed the selection of tests that were included in the first version of the computer vision screener. The table below shows the battery of tests that were included in CVS1.

Table 4.8 Battery of tests included in CVS1

Tests included in CVS1	**Test Description**	**Studies indicating that test may be useful in screening**
Symptoms and history	CVS1 contains questions regarding details of the last eye examination, any visual symptoms and details regarding current spectacles. It also contains a section on history and family history of eye conditions.	(Smeeth *et al.*, 2003d) Screening by solely asking questions about vision is inadequate. However the battery of tests in CVS1 will enable screening by asking questions to be evaluated in conjunction with other tests.

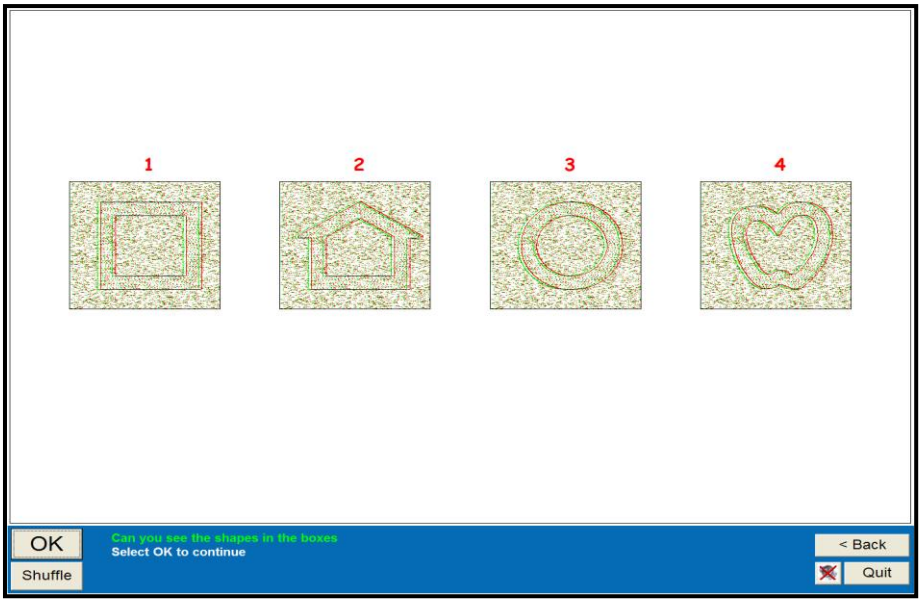
Near acuity	This was tested binocularly with near correction in place. The reading passage was made up of words from the Wilkins Rate of Reading Test (Evans & Wilkins, 2000). The words are arranged in a pseudo-random order, rather than forming a 'story'. The words were made larger until the patient was able to read the middle line of passage without any errors. The size of print ranged from font size 8 to font size 24	(Brabyn *et al.*, 2001h) (Taylor *et al.*, 1997) Although NV acuity may not be a suitable test in isolation it may be useful when combined with other tests.
Visual field test	This was conducted monocularly with habitual near correction in place. The test was based on the Henson multiple stimulus supra threshold programme. The number of points correctly identified was noted. There were a total of 26 points shown over 8 presentations	(Taylor *et al.*, 1997) Nearly three times more people had visual impairment because of VF loss than VA loss.
Fixation disparity	Both these tests were conducted at near with habitual near correction and red green filters. The level of stereoacuity was noted and	(Davison, 1985) It may be possible that decompensated phorias especially vertical phorias as investigated by Davison may be correlated with driving

	the presence of a vertical or horizontal slip was noted.	accidents.
Stereoacuity		(Lord & Dayhew, 2001) Stereopsis was found to be a particularly important visual predictor of falls
High contrast distance VA	The distance acuity tests were conducted monocularly at 3m with habitual distance correction in place. The tests consisted of 4 letters in a box and the number of letters correctly read was noted. The letters were made larger until all letters were correctly seen. The low contrast acuity test was set at 10% contrast. The font size for high contrast acuity ranged from 0.1 LogMAR to 0.5 LogMAR in 0.1 steps. The font size for low contrast acuity ranged from 0.3 LogMAR to 0.7 LogMAR in 0.1 steps.	(Ivers *et al.*, 2001) In isolation Ivers and colleagues showed that measuring acuity had a poor sensitivity & specificity for detecting eye disease. However they did not evaluate the effectiveness of acuity testing when combined with other tests.
Low contrast distance VA		(Lord & Dayhew, 2001) Low contrast VA was found to be one of the best predictors of falls. It was also found that measuring acuity monocularly was important because poor vision in one eye with good vision in the other had a similar risk to poor vision in both eyes.

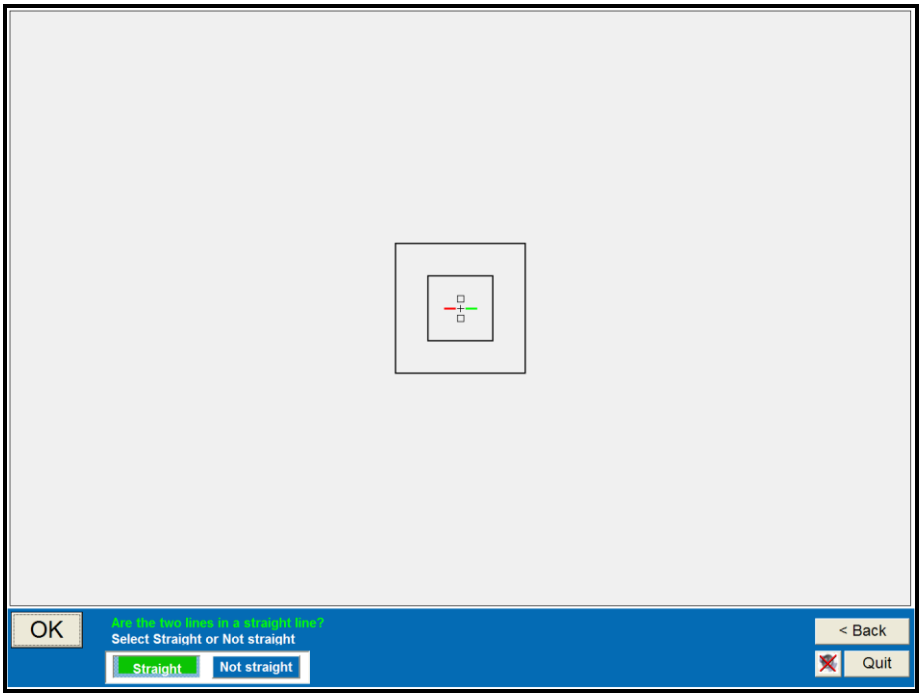
Figure 4.1 below shows the tests that were incorporated into the first version of the computer screener.

(a) Visual field test

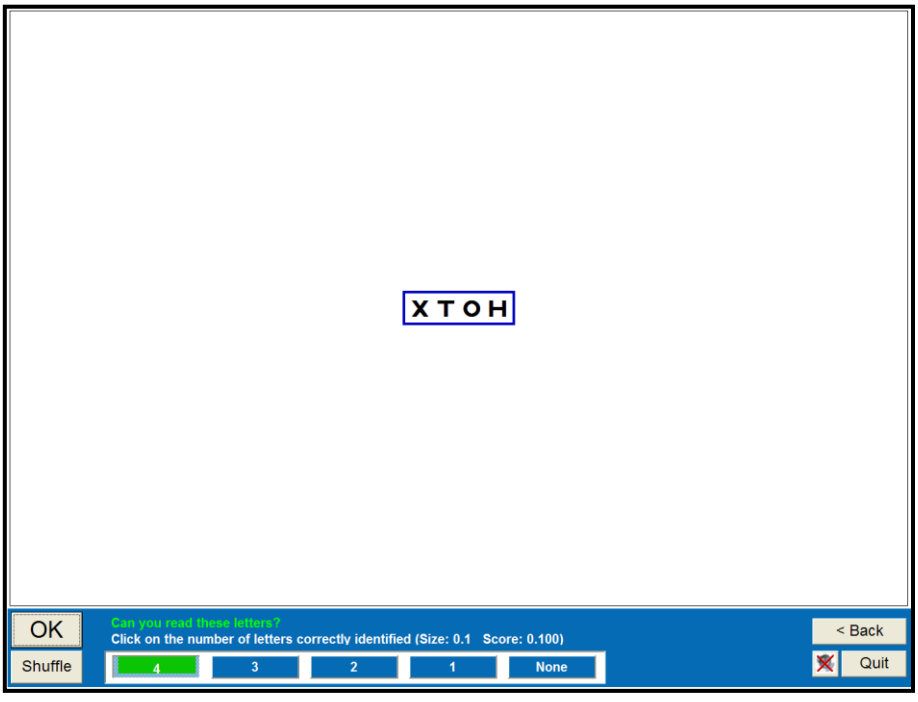
(b) Stereoacuity test



(c) Fixation Disparity



(d) High contrast acuity



(e) Low contrast acuity

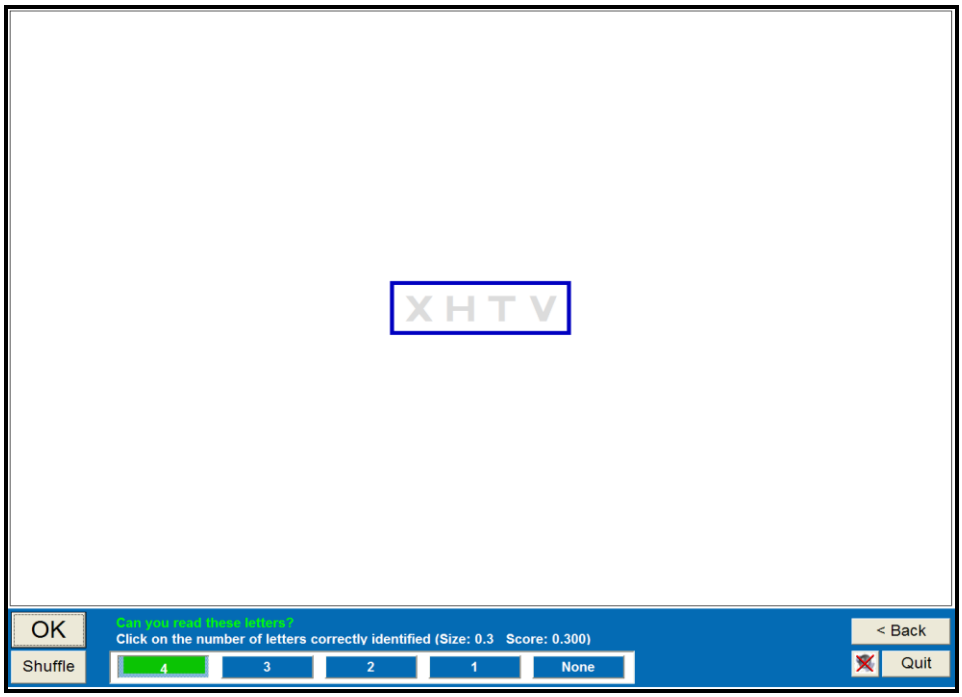


Figure 4.1 Tests incorporated in to CVS1

4.2.3 Gold Standard eye examination

At the time of the eye examination, the results from the vision screening were not known to the research optometrist carrying out the eye examination nor to the patient. The screening was conducted first by a research assistant. The research optometrist was not present in the room when the screening was taking place. There were three research assistants in total working at various times during the study. All three assistants were given training in correctly administering the screening before they screened participants. The gold standard eye examinations were all conducted by the present author after the screening had taken place. This masked protocol was only broken after the record card of the eye examination had been completed. The computer screener took approximately 10 minutes to administer and the flipchart took approximately 5 minutes. The gold standard eye examination took approximately 1 hour. Participants were encouraged to take their time and were offered regular breaks. The tests used in the gold standard are discussed below.

4.2.3.1 History and Symptoms

Participants were asked a number of detailed questions regarding their vision and current spectacles. The areas covered in the history and symptoms are summarised in Table 4.9.

Table 4.9 History and symptoms

Date of last eye examination
Patients' perception of their vision with current spectacles for distance, near, VDU use and driving (if applicable)
Details of current spectacles, type of spectacles, age of spectacles, how many spectacles
Details regarding any particular symptoms that the patient may be having including headaches, flashing lights, floaters, and double vision
History of falls within the last year
Questions regarding general health including high blood pressure, diabetes and glaucoma
Details regarding any medication
Previous ocular history including details of any eye procedures and appointments at the eye hospital.
Family history of eye disease including high blood pressure, diabetes, glaucoma
Details regarding contact lens wear if applicable
History of falls within the last year
Details regarding any particular hobbies and interests

A Standardised quality of life measure was also applied at this stage. The Quality of Life (QoL) questionnaire (Wolffsohn & Cochrane, 2000) is a brief questionnaire (one side of A4) and typically take less than 10 minutes to administer (see Appendix).

The patient's current spectacles were checked to determine what refractive correction was being worn by the patient (focimetry). It was possible to accurately focimeter the current spectacles for patients seen at the Institute of Optometry but this became more difficult as the study extended into community based settings. In these community settings an attempt was made at hand neutralisation in many cases, but this has relatively low accuracy, especially for varifocals.

4.2.3.2 Distance/ near vision and visual acuities

Monocular and binocular distance high contrast visual acuities with and without the patient's habitual spectacles were measured. This was done at a distance of 6m when using the Institute of Optometry clinics and at a distance of 3m (using a laptop) when in community venues. The chart used in all situations was a LogMAR chart on the computerised Test Chart 2000 programme. Distance low contrast acuity was also measured with the patient's habitual correction in place. The same chart was used at the same distance but the contrast was reduced to 10% in order to match the contrast of the low contrast acuity test on the screening tools.

Monocular and binocular near acuity was measured with the patient's habitual correction in place and was measured at the distance at which the patient usually reads and this was noted. The chart that was used was the Institute of Optometry Near Test Card. This card is based on a logarithmic scale and is held at the participant's usual reading distance. Each passage starts with an isolated word on the left hand side of the card which can be used to obtain the participant's near acuity threshold. The patient then reads the paragraph above their threshold on the right hand side of the card. This consists of words from the Wilkins Rate of Reading Test (Evans & Wilkins, 2000). As with the near acuity test on the computer screener, the words are arranged in a pseudo-random order (Figure 4.2).

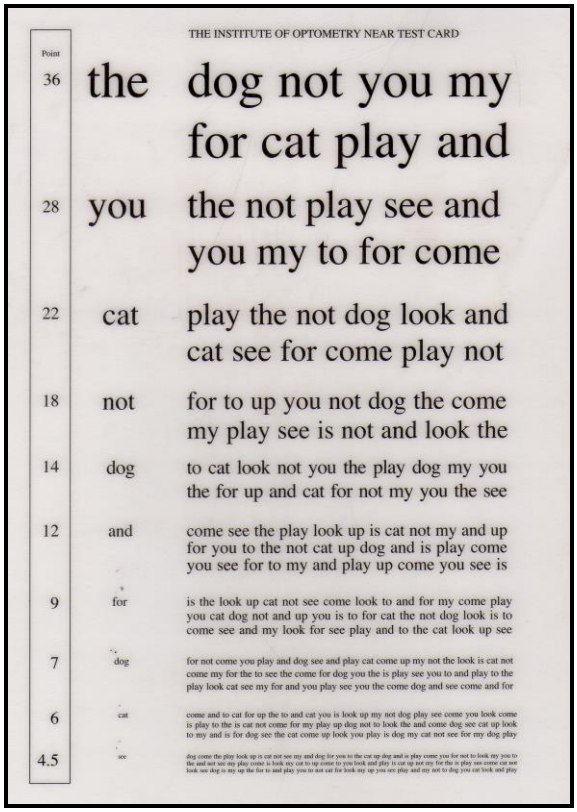


Figure 4.2 The Institute of Optometry Near Test Card

4.2.3.3 Retinoscopy

Retinoscopy is an objective technique for determining the refractive error of the eye by observing the movement of light reflected from the patient's fundus (Henson D, 1995). Lenses of different powers are positioned in front of the eye until 'neutrality' of the reflex is obtained. A trial frame and lenses were used and conventional static distance retinoscopy using a streak retinoscope was employed with the patient fixating on the green rings of the duochrome (Rabbetts, 2000).

4.2.3.4 Distance subjective refraction and visual acuities

A conventional monocular subjective refraction was carried out to determine the refractive error using a trial frame and lenses and corrected monocular and binocular VAs were recorded. A cross cylinder technique was used to measure astigmatism and the refraction was checked with a +1.00 D blur test. The clinical procedure used to obtain the distance subjective refraction including any astigmatic correction has been described in detail by Elliott (Elliott, 1997).

4.2.3.5 Near subjective refraction and visual acuities

The patient's working distance for doing near work determined the starting point for the near addition. The near add was refined by placing plus and minus spheres in front of the initial add. Near visual acuities were also measured according to the procedures outlined previously. The range of clear vision with the add was noted.

4.2.3.6 Cover test

The cover test is a dissociation test in which each eye is covered in turn whilst the patient fixates a specified target at a given fixation distance. The practitioner observes the eye movements, from which the type of binocular anomaly can be diagnosed (Evans, 2002). The procedure and grading system for the cover test is outlined by Evans (Evans, 2002). A unilateral and alternate cover test was conducted for distance and near with the patient's habitual correction and with the optimal correction in place.

4.2.3.7 Aligning prism (associated heterophoria)

When both eyes are fixating at one point which is seen in binocular single vision, the eyes can be slightly misaligned without causing double vision. This misalignment is called fixation disparity (Evans, 2002). Although the tests used in this study did not measure the degree of fixation disparity; that is the amount by which the eye is actually deviated, the test measured the amount of aligning prism (associated phoria). This is the minimum strength of prismatic lens required to neutralise the fixation disparity (Evans, 2002).

The aligning prism for distance and near was determined with the optimal refractive correction in place. The Mallett fixation disparity unit was used to measure the aligning prism at near and when the study was being conducted at the Institute of Optometry, the Mallett fixation disparity test for distance was used. When the study was based at community venues, a distance Mallett fixation disparity test was not available and so the fixation disparity test on Test Chart 2000 was used. This follows the same principles as the Mallett test, but uses red/green filters instead of

polarised filters. The procedure used for the measurement of aligning prism is that described by Evans (Evans, 2002).

4.2.3.8 Near point of convergence

The near point of convergence (NPC) is the nearest point where the lines of sight intersect when the eyes converge to the maximum. This point is usually 8-10cm from the spectacle plane (Millodot, 2000).

This test was conducted with the patient's optimal near refractive correction in place and the patient was instructed to look at a single letter at near, one size larger than their near threshold acuity. The target was moved towards the patient and they were asked to report when the letter appeared double (break point). The target was then withdrawn until recovery occurred. The break and recovery NPC points were recorded in centimetres (to nearest 1cm) from the corneal plane. The break point was recorded first followed by the recovery point.

4.2.3.9 Stereoacuity

Stereoacuity is a measure of stereopsis which is the awareness of the relative distance of objects from the observer by means of binocular vision and based on retinal disparity. Stereoacuity represents the ability to detect the smallest difference in depth between two objects (Millodot, 2000). There are a number of stereoacuity tests available and the test used in this study was the Randot stereo test.

Two subtests of the Randot stereo test were used to facilitate the testing of individuals at different levels. As outlined by the manufacturer's manual, the first subtest consisted of large homogenous areas containing simple forms at two levels of gross disparity, with each set having one blank to act as control. The patients wore polarised analysers and were asked to identify the forms within the boxes at a distance of 40cm .The patients were given the time they needed without feeling rushed. The level of stereopsis measured in this subtest is 500 and 250 seconds of arc.

The second subtest consists of 10 sets of 3 circles of which only one circle of each set has crossed disparity, which, when seen binocularly, should appear to stand forward from the other two. The level of stereopsis of the last circle to be chosen correctly is recorded. If one is missed, the preceding line is tested again to determine whether the subject can achieve this level of stereopsis or whether they were just guessing. The score on this variation ranged from 400 to 20 seconds of arc.

4.2.3.10 Motility

This test is designed to assess the integrity of the extraocular muscles and their associated neural pathways. The patient was asked to fixate a penlight, which was moved in eight meridians (following a star pattern) whilst keeping his or her head still (Millodot, 2000).

The test was carried out binocularly in 8 directions of gaze at a distance of 50 cm as outlined by Elliott (Elliott, 1997). It was noted if the patient was experiencing any pain, discomfort or double vision. The results were recorded using the acronym S.A.F.E (see Table 4.10 below).

Table 4.10 Recording Motility

Recording Motility	**Comment**
Smooth	if jerky, grade as 1 (minimal), 2 (definite but mild, 3 (moderate), 4 (markedly jerky, unusual), 5 very jerky, highly unusual
Accurate	
Full	degrees of restriction was noted in degrees
Extensive	

For a patient with strabismus, normal motility can be recorded as ‘No incomitancy detected’.

4.2.3.11 Pupils

The size and shape of the pupils were noted and with the room lighting reduced, a pen torch was used to examine the direct and consensual reflexes. The light was directed towards each eye from the side and the presence of direct and consensual reflexes were noted and whether or not the response was equal in each eye. The pupils in older patients are often small and this can make assessing pupil reactions difficult.

The afferent pupil pathway was also tested in every case but was particularly important where the vision in one eye was reduced as an afferent pupillary defect may indicate a causative lesion, typically an optic nerve lesion or severe retinal disease. An afferent defect may also be present when the eyes have equal acuities, as it often precedes the reduction in acuity caused by certain conditions such as optic neuritis. The afferent pupil pathway was evaluated using the swinging flashlight test where each eye is illuminated in turn. The affected eye will show pupil dilation despite being illuminated. The procedure used and the notation used to record the pupil reactions have been described by Elliott (Elliott, 1997).

4.2.3.12 Amsler

The Amsler chart is designed to detect abnormalities in the central visual field. The chart consists of a white grid of 5mm squares on a black background with a central fixation dot. When fixated at a distance of 30cm, the entire chart subtends an angle of 20 degrees (Millodot, 2000). The test is carried out monocularly with the patient's best corrected near prescription in place. The patient was asked to look directly at the central spot with the uncovered eye and to mark out any black spots, distortion of lines or blurred areas on grid. The number of small squares within the area delineated by the patient was counted and scotoma and metamorphopsia score was graded numerically as outlined by Verma and colleagues (Verma *et al.*, 2004).

4.2.3.13 Tonometry

Tonometry was an important part of the gold standard eye examination because it was used as part of a battery of tests (including visual field examination and optic nerve head examination) to screen for glaucoma, The Perkins Tonometer is a portable contact tonometer based on the same principle as a Goldmann Tonometer (Henson D, 1995) and it was used as recommended by Elliott (Elliott, 1997). Contact tonometry requires the instillation of a topical anaesthetic (Benoxinate hydrochloride 0.4%) and Fluorescein Sodium Chloride. When the study was based in the community, the Perkins tonometer was the only method of assessing intraocular pressure. However, at the Institute of Optometry other methods of non-contact tonometry were also available. These other methods were only used for those patients who were not willing to have drops administered for contact tonometry.

4.2.3.14 Visual Field assessment

Two types of visual field instruments were used in the gold standard eye examination. When based at the Institute of Optometry the Humphrey Visual Field Analyser (HFA) was used. When based in the community, a Frequency Doubling Technology instrument (FDT) was used because this is compact enough to be transported to the venues.

The FDT is a method of testing the visual field based on the frequency doubling illusion and thus assessing the functional integrity of the large diameter magnocellular retinal ganglion cells which are very susceptible to early glaucomatous damage (Litwak A B, 2000). This is a self-contained computerised perimeter in which the stimulus display consists of a low spatial frequency sinusoidal grating which flickers in a counterphase fashion. The grating is presented in many locations throughout the visual field and the patient's task is to detect the stimulus by identifying the quadrant in which it is present (Millodot, 2000). FDT perimetry compares well with conventional visual field testing for the detection of glaucoma,(Allen *et al.*, 2002a;Tatemichi *et al.*, 2002a) but is less

effective at detecting rarer visual field defects from neurological causes (Fong *et al.*, 2003b).

The FDT is portable and ideal for a community- based setting because it is independent of room illumination and independent of refractive error up to a certain degree as stated in the manufacturer's manual. This is because the contrast grating is affected little by defocus therefore the stimuli should be relatively resistant to blur (Delgado *et al.*, 2002). It is also suggested that pupil size has no effect on the outcome of the test and this made it particularly appropriate for the current study as the effect of the dilating drops did not impact the visual field results.

An N-30 threshold test was carried out on all patients. 19 test locations were examined and the visual field eccentricity tested extends 30 degrees nasally to 20 degrees temporally. The central test location is circular and has a diameter of 10 degrees. The remaining 18 locations cover squares of 10 degrees by 10 degrees.

The HFA (model 750) used at the Institute of Optometry is a computerised perimeter. It uses 31.5 apostilb background illumination (10.0 cd/m^2) and a stimulus size III (with the capability of changing size from I to V). During the test, the intensity of the stimulus changes depending on the patient's response. However, the stimulus size remains the same throughout the test (Dersu & Wiggins, 2006a).

A SITA fast threshold strategy was used (24-2 SITA Fast) which has been shown to produce repeatable thresholds in a short test duration. Threshold values are constantly calculated throughout the test at the same points. If results are too different, those points are tested again. The test strategy used incorporates the Glaucoma Hemifield Test (GHT) and this compares points on the upper field to corresponding points on the lower one. It is based on the idea that the sensitivity of the field should be similar in both hemifields. It describes the field as normal, borderline or outside normal limits. When the GHT reads "outside normal limits" it is stating that the difference in the upper and lower sets of points would not be found in 99% of patients without glaucoma. "Borderline" means the difference

detected would not be found in 97% of patients without glaucoma (Dersu & Wiggins, 2006b).

4.2.3.15 External eye examination

The external eye was examined using a slit lamp biomicroscope. The structures observed are listed below in Table 4.11 together with the grading scales that were used to aid investigation.

Table 4.11 Structures examined and grading scales used for external eye examination

Structure	**Grading scale**
Blepharitis	Each of these conditions was graded from 0 (normal) to 4 (severe) using the Efron grading scale (Efron, 1998)
Meibomian Gland dysfunction	
Conjunctival redness	
Limbal redness	
Pingueculae/Pterygium	This was graded using photographs from a contact lens management handbook (Anderson *et al.*, 2002)
Cornea	The presence of any corneal abnormality was noted
Anterior Chamber angle	The angle was graded from 0 to 4 using the Van Herick technique (Van Herick W. *et al.*, 1969a)
Anterior Chamber cells/flare	This was graded according to the scale outlined by Kanski (Kanski, 1999)

The depth of the anterior chamber was assessed by grading the angle between the posterior cornea and the anterior iris. This was measured using an optic section at an angle of 60 degrees at the limbal edge. This method is known as the Van

Herrick Technique and includes 5 ratios where 0 indicates a closed angle and 4 indicates an angle that is wide open. This test allows some prediction of the risk of angle closure glaucoma and as such is important prior to the installation of any mydriatic drugs (Elliott, 1997).

At this stage in the routine, one drop of tropicamide hydrochloride 0.5% was instilled in to each eye. Tropicamide is an antimuscarinic and causes pupillary dilation within 20 minutes of instillation so that internal eye examination could take place.

4.2.3.16 Internal eye examination

The internal eye was assessed using a combination of direct and indirect ophthalmoscopy. The structures investigated and the grading scales used are included in Table 4.12 below.

Table 4.12 Structures examined and grading scales used for internal eye examination

Structure	Grading Scale
Lens	The LOCS III grading scale was used in the assessment of the lens for the presence of any age related lens opacities as explained earlier in this chapter. The grading scale is a series of colour slit lamp and retro illumination photographs that are used as standards for grading the opacities. The pupil was at least 6mm in diameter when dilated for the grading technique to be conducted. A slit beam (0.2mm in width) at an angle of 45 degrees to the line of vision was used in order to grade nuclear cataract. The beam height was just tall enough to overlap the pupil margin. In order to grade cortical or posterior sub capsular cataract the height and width of the slit beam was reduced. The slit beam was positioned to enter the pupillary space at either the 3 or 9 o'clock position
Vitreous	Any abnormalities of the vitreous were noted, including vitreous floaters and signs of synchisis and syneresis as explained in Chapter 1

Optic Disc	The cup to disc ratio was graded using the Pearson Optometric Grading Scale (Pearson R M, 2003b). Disc features were evaluated with specific reference to glaucoma as this is a common condition prevalent in the older population. An optic nerve head evaluation checklist was used as a guideline. The checklist included the assessment of clinical features such as the presence of acquired pits, disc haemorrhages, peripapillary atrophy, neural retinal rim colour, notches and thinning (Litwak A B, 2000).
Retinal vessels	Retinal vasculature was graded using the Pearson Optometric Grading Scale. The grading scale evaluates the vessels in term of AV ratio, arterial reflex and tortuosity (Pearson R M, 2003c). It is known that these features are important in the detection of hypertension.
Background	The background was assessed for common age related conditions such as diabetes and hypertensive retinopathy, these have been explained in Chapter 1. The presence of any other abnormal features was noted.
Macular	The degree of macular degeneration present was also noted using a staging system (Seddon *et al.*, 2006c). Any other abnormalities were noted.

4.2.4 Post study debriefing

Where visual problems were detected, every effort was made to help participants by referring (with consent) for optometric and/or medical investigation and treatment as appropriate. The usual referral pathways were followed and these have been outlined earlier in the chapter. For most conditions, the usual procedure is for the optometrist to refer the patient to the GP and for the GP to then refer to an ophthalmologist. If the condition is an ocular emergency then the patient is referred directly to an ophthalmologist. A prescription was issued to each participant at the end of the eye examination stating whether there had been a change. Advice was given on the type of spectacles needed and what they should be used for. Further information was given on their eligibility for free NHS glasses and the provision of these by local optical practices in the South London area.

Investigation into the provision of NHS eyecare in South London was conducted as a preliminary study and is described in Chapter 5.

When the eye examination was being conducted the practitioner was not aware of the results from the screener so that a masked design was kept. Once the eye examination was completed the results from the screener were made available to the optometrist so that if a problem was detected on screening that the optometrist was unaware of during the eye examination, then the patient would have been referred or re-examined as appropriate.

The participants were also asked to complete a short questionnaire to evaluate the screening procedure. This and the other documents given to the patient at the end of the examination are included in the Appendix.

4.3 Second Study

The aim of the first study was to investigate the sensitivity and specificity of the first version of the computerised vision screener (CVS1) for identifying correctable visual loss. The results enabled cut-off values for each of the tests to be established that indicated the value above which further investigation was indicated (i.e. referral to an optometrist). As well as considering individual tests, we sought to investigate combinations of tests, with the aim of deriving a suitable battery of tests that could be incorporated into the revised computerised vision screener (CVS2) and a flipchart screener. The main aim of study 2 was to evaluate the refined vision screener on a different population of older people and also to assess the effectiveness of the screening tools in a more community-based environment.

The procedure for study 2 was exactly the same that for the first study except both the flipchart screener and the revised vision screener were administered. Both systems were used to test a further 200 elderly people. These participants were seen in a variety of settings as described in Table 4.4. Participants were also given a full eye examination as in the first study. The only test that was omitted from the gold standard was stereo acuity, because this was not found to be useful in the first

study (see Chapter 7). Both the optometrist and the screener were masked to each other's results.

When uncorrected refractive errors, significant cataract, or other ocular or systemic pathology were detected, the participant was referred as appropriate. The same diagnostic criteria were used as outlined for the first study. As in the first study, participants were followed-up to discover the outcome. Standardised quality of life measures were applied at the eye examination and at follow-up as outlined for study 1.

The sensitivity and specificity of both the revised computerised screener and the flip-chart rapid screener for identifying the target conditions were calculated. The secondary outcomes of Study 2 were to determine the sensitivity and specificity of the screening tests for detecting other visual conditions, such as glaucoma and age-related macular disease and to investigate the effect of vision screening on quality of life.

4.3.1 Refined computer vision screener

Two tests in CVS1 were found to be of little value for detecting the target conditions (Chapter 7) and were not included in CVS2. The table below summarises the screening tests incorporated in the three screening instruments.

Table 4.13 Tests incorporated into screening tools. All the tests listed in the first column were used in CVS1.

Test	CVS2	Rapid flipchart screener
Symptoms and history	Yes	Yes
Near acuity	Yes	Yes
Visual field test	Yes	No
Stereoacuity	No	No
Fixation disparity	No	No
High contrast distance acuity	Yes	Yes
Low contrast distance acuity	Yes	Yes

4.3.2 The rapid flipchart screener

Analyses of the results with CVS1 (Chapter 7) enabled the key tests to be made available in a flipchart format. The flipchart is a cost effective simple method of screening that may be suitable for places where computerised testing is not appropriate. This was a more a rapid screening tool and was evaluated in the same way as the refined computerised screener. The rationale behind the present research was to evaluate the flip-chart screener under conditions similar to those in which it may ultimately be used and therefore special lighting was not used, other than the best that could be provided in the available setting. For example, in the Woodlawns community centre the room lights were turned on and the window curtains kept open.

The table below shows which tests were used in the flipchart screener. The visual field test that was included in the computer vision screener could not be implemented in a flip-chart format.

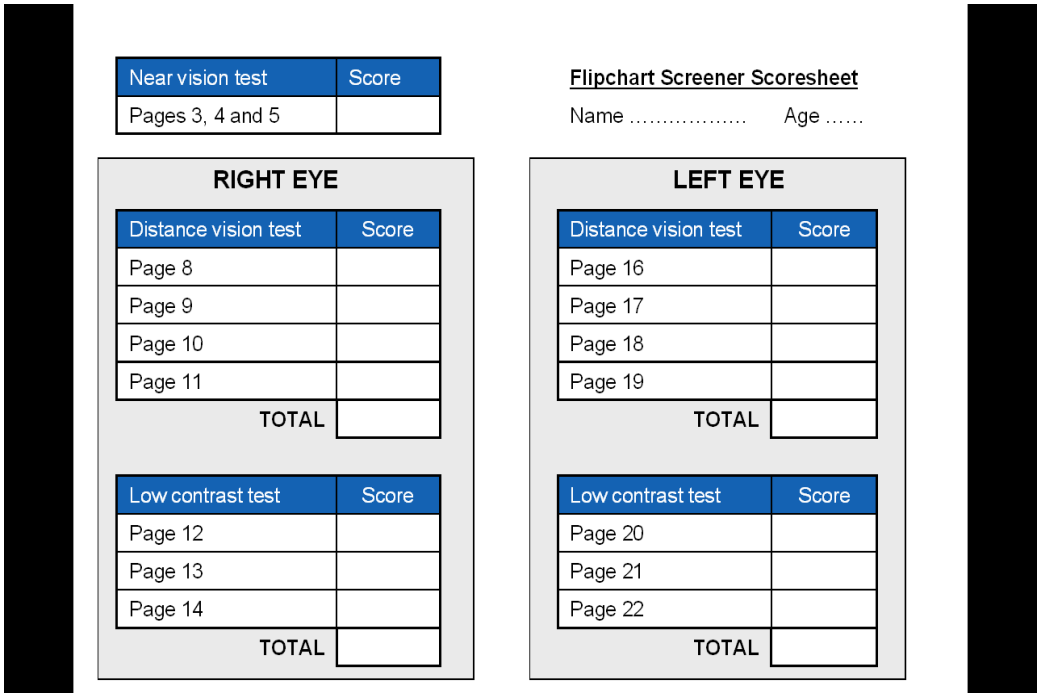
Table 4.14 Tests included in Rapid Flipchart Screener

Tests Included	Monocular or Binocular	Font size
Presenting near visual acuity	Binocular	N7, N9, N12
Presenting distance visual acuity	Monocular	Logmar 0.2,0.3,0.4,0.5
Presenting low contrast acuity	Monocular	Logmar 0.4, 0.5, 0.6

The size of the letters chosen was based on the cut-off values derived in the first version of the computer screener.

4.3.2.1 Scoring system for rapid flipchart screener

The computerised screening tool had an automated scoring system that passed or failed the participant depending on the outcome of the tests and which stored the results for subsequent analysis. For the rapid flipchart screener, the three tests each had a simple scoring system resulting in a final number at the end of the screening procedure. The goal of developing this scoring system was to have clear and simple step-by-step instructions printed on the flipchart screener so that it could ultimately be used by lay personnel (e.g., care assistants). This scoring system will now be explained and images of the flipchart screener below show how clear the instructions are. The figure below shows the score sheet that was completed for each patient to determine their overall score for the flipchart screener.



Near vision test	Score
Pages 3, 4 and 5	

Flipchart Screener Scoresheet

Name ..... Age .....

RIGHT EYE

Distance vision test	Score
Page 8	
Page 9	
Page 10	
Page 11	
TOTAL	

Low contrast test	Score
Page 12	
Page 13	
Page 14	
TOTAL	

LEFT EYE

Distance vision test	Score
Page 16	
Page 17	
Page 18	
Page 19	
TOTAL	

Low contrast test	Score
Page 20	
Page 21	
Page 22	
TOTAL	

Figure 4.3 Score sheet for rapid flipchart screener

4.3.2.2 Scoring near acuity

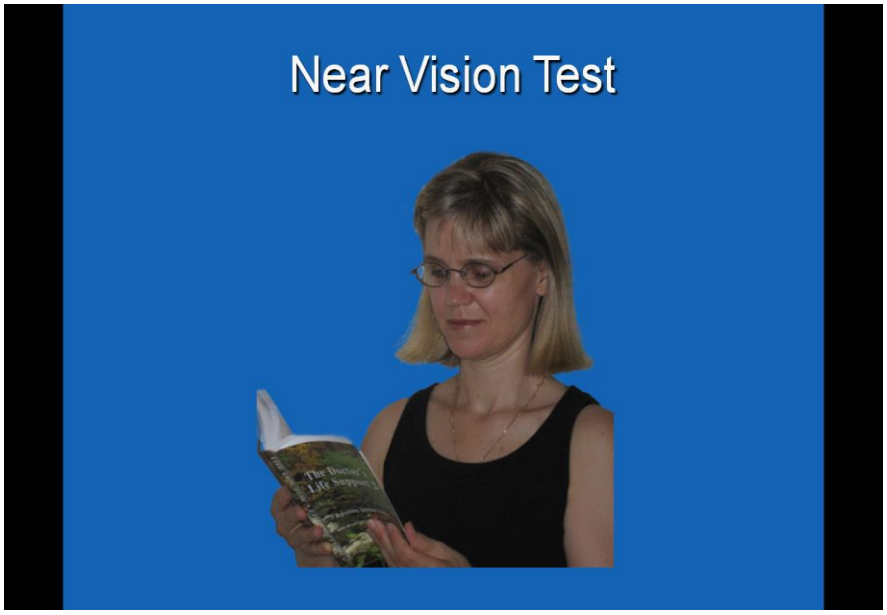
Participants were invited to hold the flip-chart screener at a normal reading distance and view the paragraph of text printed on the page. The paragraph was constructed from the same simple words employed by the Wilkins Rate of Reading test in order to avoid contextural cues. The text on the first page was printed in Arial font in 7 point size and participants were asked whether they could read the text easily. If the answer was “yes”, the test was repeated for the other eye. If the answer was “no”, the participant was shown the next page which was printed in 9 point text. This process was repeated for increasing font sizes until the ceiling of 12 point size was reached. A simple numeric scoring system was developed to describe the endpoint of the test (see Table 4.15).

Table 4.15 Scoring near acuity on the rapid flipchart screener

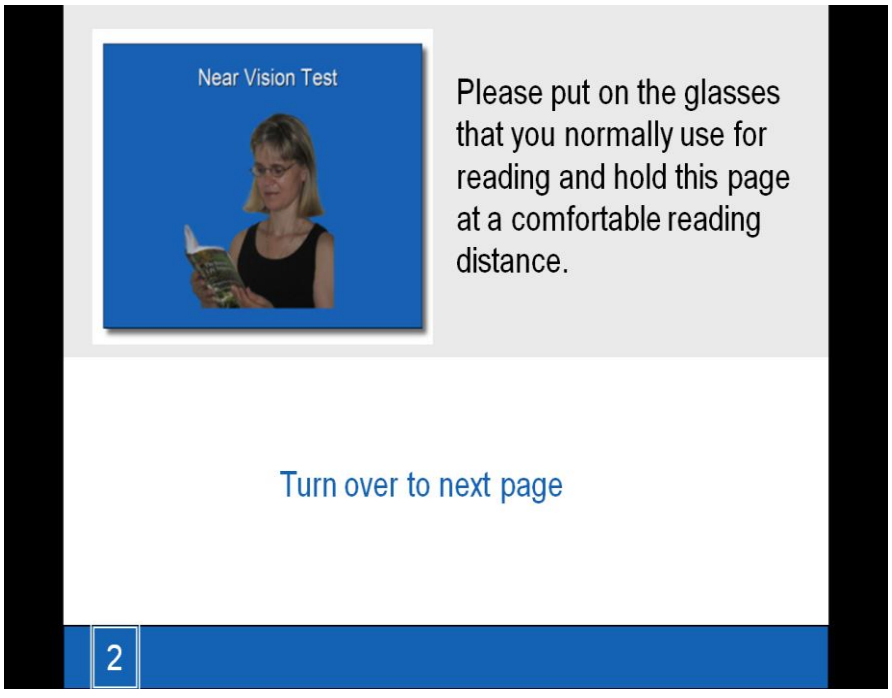
page	Font Size	Patient response	Score	Next Action
3	N7	Easy	1	End of near acuity screening, begin distance acuity screening
	N7	Not easy		Move on to larger size near text.
4	N9	Easy	2	End of near acuity screening, begin distance acuity screening
	N9	Not easy		Move on to larger size near text.
5	N12	Easy	3	End of near acuity screening, begin distance acuity screening
	N12	Not easy	4	End of near acuity screening, begin distance acuity screening

Figure 4.4 below shows a few pages from the flipchart screener that relates to the testing of near vision and illustrates more clearly how the instructions are incorporated in to the screener. Illustrations a) and b) are shown to the participant in turn and this is accompanied by instructions for the person that is administering the screening (b and d).

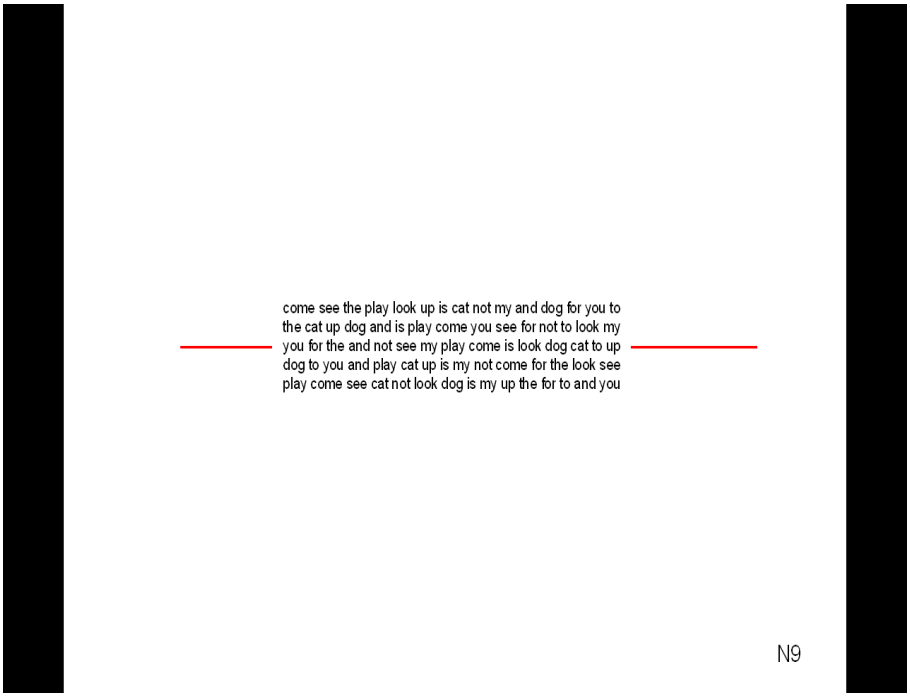
a)


Near Vision Test

b)


Near Vision Test
Please put on the glasses that you normally use for reading and hold this page at a comfortable reading distance.
Turn over to next page
2

c)



d)

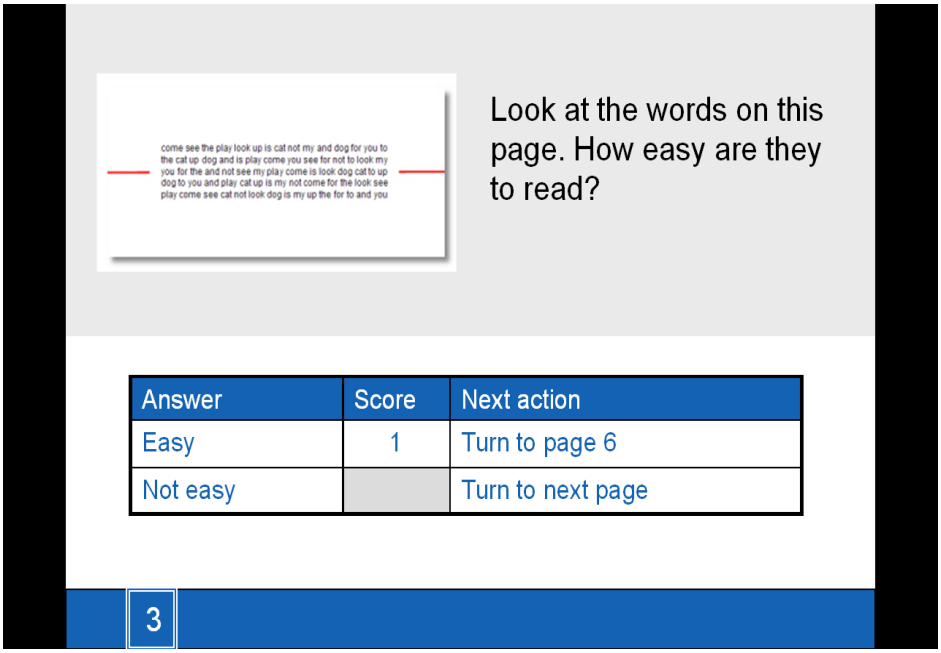


Figure 4.4 Testing of near acuity with flipchart screener

4.3.3.2.2 Scoring distance acuity

Distance visual acuity is measured using the flip-chart screener by asking the patient to read four letters surrounded by a crowding rectangle from a distance of 4 metres. The letters are in a Bailey-Lovie format and have a contrast of close to 1. On the first page the letter size equate to LogMAR 0.2 and the screener records the number of letters correctly identified. If all letters on this page are correctly identified the screener moves straight on to repeat the test with the other eye. If one or more letters are read incorrectly, the next page of letters is shown which equates to 0.3 LogMAR. This procedure is repeated until all four letters are correctly identified or the ceiling of 0.5 LogMAR is reached. A simplified scoring method is used to keep a tally of the number of letters read which is used to work out the final LogMAR score (see Table 4.16)

Table 4.16 Scoring distance visual acuity on the rapid flipchart screener. Four optotypes were present on each page.

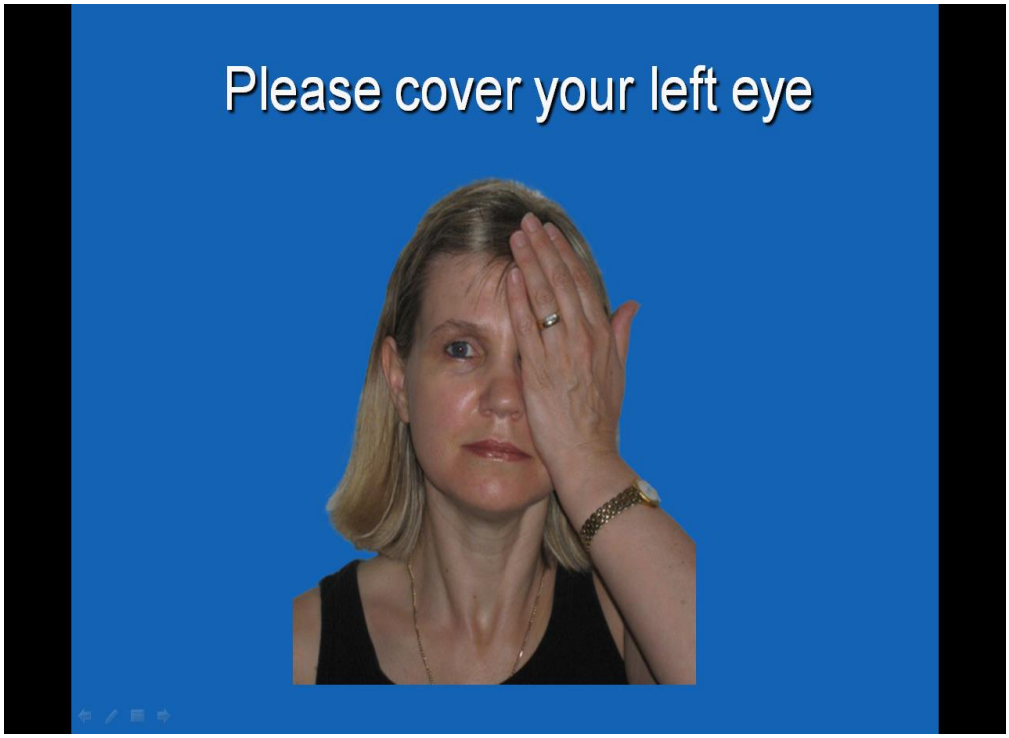
page	LogMAR Size	Patient response	Score	Next Action
8	0.2	4 correct	0	End of test, begin low contrast testing
		3 correct	1	Move on 0.3 logmar
		2 correct	2	Move on to 0.3 logmar
		1 correct	3	Move on to 0.3 logmar
		None correct	4	Move on to 0.3 logmar
9	0.3	4 correct	0	End of test, begin low contrast testing
		3 correct	1	Move on to 0.4 logmar
		2 correct	2	Move on to 0.4 logmar
		1 correct	3	Move on to 0.4 logmar

		None correct	4	Move on to 0.4 logmar
10	0.4	4 correct	0	End of test, begin low contrast testing
		3 correct	1	Move on to 0.5 logmar
		2 correct	2	Move on to 0.5 logmar
		1 correct	3	Move on to 0.5 logmar
		None correct	4	Move on to 0.5 logmar
11	0.5	4 correct	0	End of test, begin low contrast testing
		3 correct	1	End of test, begin low contrast testing
		2 correct	2	End of test, begin low contrast testing
		1 correct	3	End of test, begin low contrast testing
		None correct	4	End of test, begin low contrast testing

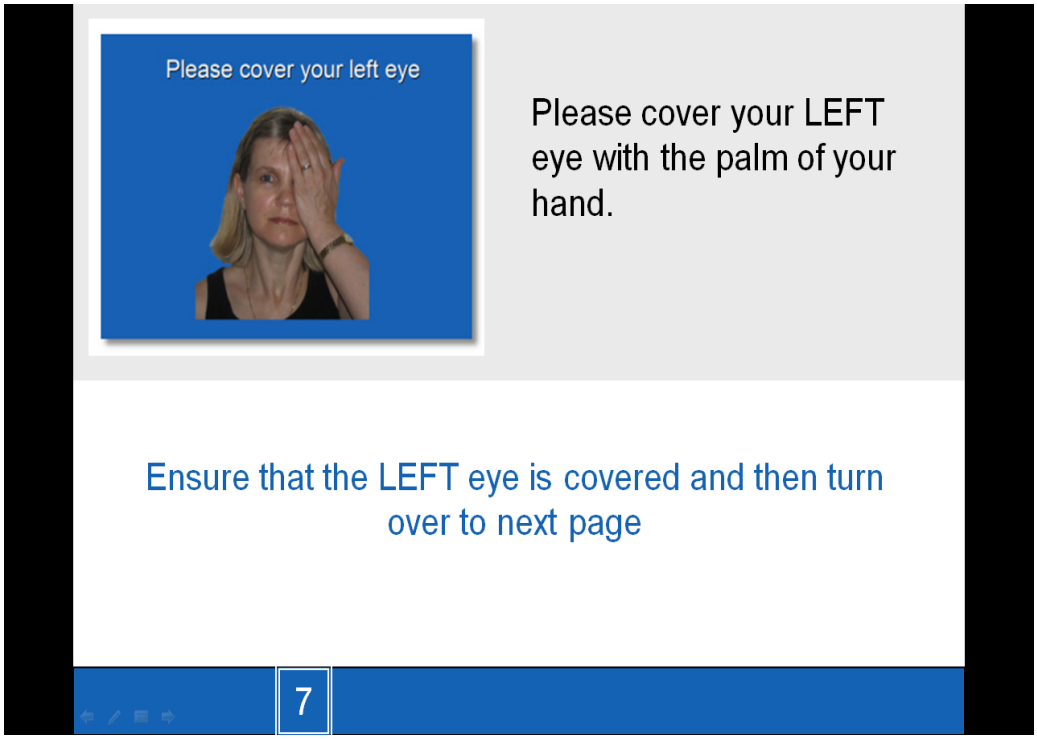
The scoring system for low contrast visual acuity is the same as that for high contrast acuity. However, with low contrast acuity the LogMAR ranges were 0.4 to 0.6. The contrast of the low contrast charts was 10%.

Figure 4.5 below shows the first few pages for the testing of high contrast acuity together with the instructions for the person administering the screening. Unlike the figure, in the present research an eye patch was used to occlude the eye not being tested.

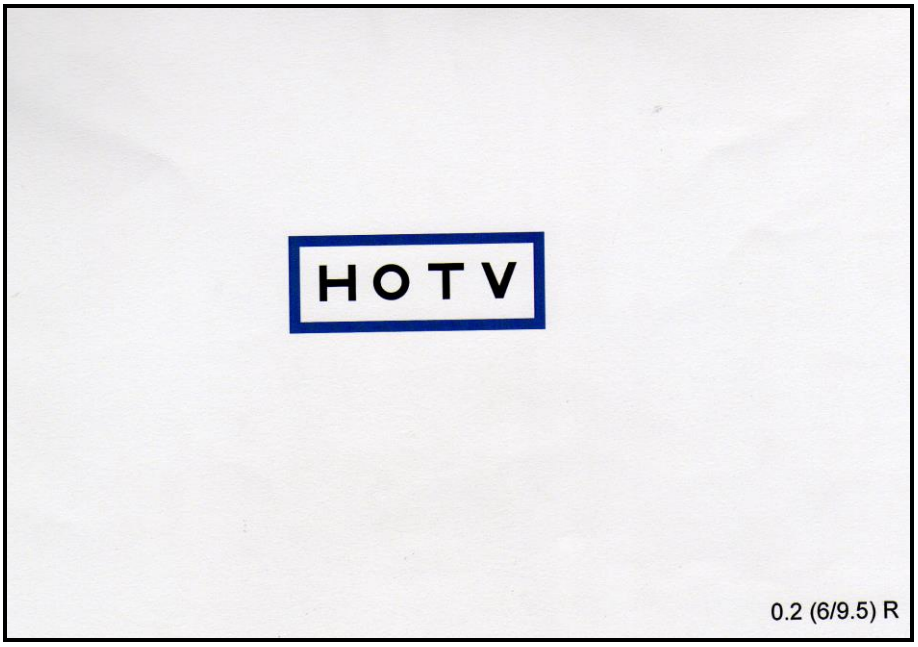
(a)


Please cover your left eye

(b)


Please cover your left eye
Please cover your LEFT eye with the palm of your hand.
Ensure that the LEFT eye is covered and then turn over to next page
7

(c)



(d)

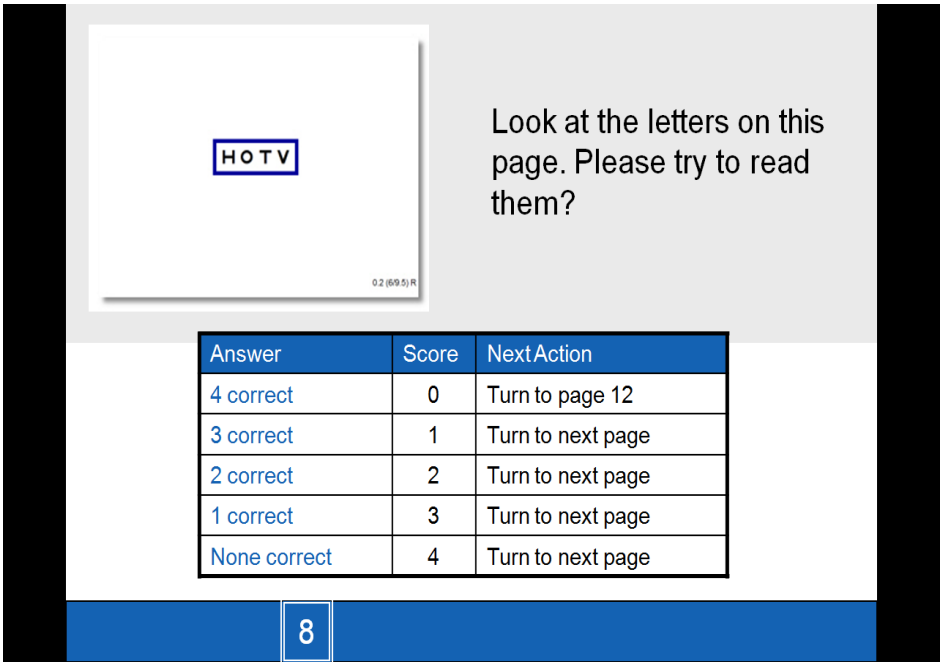


Figure 4.5 Testing of high contrast distance acuity with flipchart screener

4.4 Chapter summary

This chapter has concentrated on the methods of the main study outlining the computer screening tests used and the gold standard eye examination. The tests used in the flipchart screener have also been described. Before the results of this main study are presented, the next chapter will give details of two preliminary studies that were conducted. The first preliminary study investigated the provision of NHS eyecare in South London and the second study was a supplementary study incorporated into Study 1 which involved investigating the grading of cataract with the LOCS III grading system.

Chapter 5

Provision of NHS primary eyecare in South London

The previous chapter outlined the procedure for the main study. Two smaller studies that were conducted in parallel to the main study will be described in the next two chapters. Both studies provided important information that was used to inform the design of Study 1 and were necessary to the development of Study 2. The first study described in this chapter was designed to assess the provision of NHS eyecare in South London. The second supplementary study (Chapter 6) focussed on the grading of cataract using the LOCS III grading system with two types of instruments.

5.1 Background

A brief overview of the eyecare services available to older people in the UK was provided in Chapter 1. It was noted that although eyecare is available for older people, between 20 and 50% of older people do not avail themselves of the services and as a result have undetected reduced vision (Evans & Rowlands, 2004k). In the majority of cases the reduced vision could be corrected with spectacles or cataract surgery.

Anxiety about the cost associated with eyecare seems to be a major factor in deterring older people from seeking eyecare (Conway & McLaughlan, 2007). This is perhaps surprising because, in the UK, the NHS funds a basic 'sight test' for people aged 60 and over by primary eyecare practitioners (usually community optometrists). The fact that this state-funded sight test is not available to most adults under the age of 60 years, and that government policies on this have been inconsistent over the last 20 years, might explain why some older people seem unaware of the availability of state-funded eyecare. This recent history throws light

on the effect of cost on the take-up of primary eyecare services and will now briefly be reviewed.

Between 1958 and 1989 all citizens of the UK were eligible for a “free” sight test paid for by the NHS and the take up was relatively high. In 1989, eligibility for an NHS sight test was restricted to children, students and those on low incomes or at high risk of eye disease. This removal of universal NHS funded sight tests resulted in a considerable reduction in the number of people receiving community eyecare (Conway & McLaughlan, 2007) and this had a knock-on effect on the number of referrals to the hospital eye service. For example, the numbers of patients being identified as requiring treatment or follow up for glaucoma declined by nearly one fifth (Laidlaw *et al.*, 1994). Pressure from the public and lobbying from various professional bodies and other organisations eventually led to the reintroduction of sight tests funded by the NHS for all people over the age of 60 years in 1999. This decision had an immediate effect on the number of older people seeking eyecare. Between 1999 and 2000, 5,434 million people over the age of 60 had an eye test funded by the NHS in England and Wales, an increase of 34 per cent on the previous year for this age group (Department of Health, 2006). However, concerns about the take-up of eye tests among older people remain as it is estimated that about 4.2 million older people (or 43% of those aged over 60 years) do not have eye examinations at the recommended frequency (RNIB, 2008).

Although some optometrists are seeking to enhance the services they offer by charging a supplementary fee for additional tests (e.g., fundus photography), this is still rare and patients would still be able to obtain the basic NHS sight test free of charge (Association of Optometrists, 2003).

A recent survey commissioned by the Eyecare Trust and the Central (LOC) Fund revealed that fear of cost seems to be a major barrier to many older people caring for their eyes, as 30% of those surveyed believed it would 'cost a lot of money' (Eyecare Trust, 2007). The main fear that older people seem to have concerning the costs of a visit to eyecare practitioners does not relate to the examination (because older people are entitled to NHS funded eye examinations) but rather the cost of spectacles (Conway & McLaughlan, 2007). This is perhaps surprising

because people on low income are entitled to an NHS Optical Voucher which can, depending on level of income, be used to fully or partially offset the cost of spectacles. Specifically, people on Pension Credit are eligible for an NHS Optical Voucher (GOS 3 form; described below) and nearly half of all people receiving a state pension are eligible for Pension Credit (Age concern, 2005). Even if older patients are not eligible for pension credit, they may still be entitled to an NHS voucher if they make a low income scheme claim by completing an HC1 form. This is aimed at those on a low income but whose income exceeds the amount that would entitle them to receive Pension Credit. The claim may result in either an HC2 certificate which entitles the person to the maximum NHS voucher value or a HC3 certificate which entitles the person to limited help toward the cost of glasses.

The NHS voucher scheme was introduced in July 1986. Free NHS spectacles were replaced by means-tested NHS optical vouchers which could be put towards the cost of spectacles. The voucher scheme gives eligible patients flexibility over which glasses or lenses to choose. Patients are able to take the voucher to the provider of their choice (although, as noted below, this practice is discouraged by the College of Optometrists because it is associated with an increased risk of consumer complaints). The scheme also gives patients flexibility to top up the voucher value (if they wish) to obtain more expensive frames of their choice. However, patients may be deterred from using vouchers at certain practices because they do not stock a range of spectacles within the voucher value (Government Response to the Health Committee's Report on NHS Charges, 2006c). This report will be returned to in the discussion. In the discussion below, the term voucher-value spectacles (VVS) is used to describe spectacles where the cost **is** fully covered by the voucher, i.e. spectacles that are free of charge for eligible patients.

Under the National Health Service (General Ophthalmic Services) Regulations 1968, ‘opticians’ are required to display a notice showing the services available under the NHS General Ophthalmic Services and listing which patients are entitled to a free NHS sight test and/or an optical voucher towards the cost of glasses or contact lenses (Government Response to the Health Committee's Report on NHS

Charges, 2006b). The regulations at present do not compel practices to provide VVS. The NHS Optical Voucher has been criticised in the optical press as making it uneconomic to provide VVS (Optician, 1986a). Having searched PubMed and DoH databases, no data was found on the proportion of optical practices that provide VVS. If this proportion was known then it could be monitored over time to determine whether the availability of VVS is changing. One of the objectives of this preliminary research was to provide an indication of the proportion of optical practices which provide VVS spectacles. Frame choice is important when selecting spectacles and so the number of frames available for VVS was also investigated.

5.2 Methods

A questionnaire (see Appendix) and a covering letter were sent to two different populations of optometrists. The first population included all optical practices in South London which were identified by searching the Opticians Register (General Optical Council, 2005). This population was chosen so that a list of eyecare practices in South London which provided VVS could be produced and given to participants after the gold standard eye examination as part of the main study.

For a second, more national sample of optometrists the UK, the optometry e-mail discussion list was used. This is a forum, hosted by Manchester University, which included at the time of the survey 303 members and is used to discuss clinical and other issues relating to optometry. The questionnaire in the Appendix was sent to all members of the list.

5.3 Statistical analyses

For continuous variables, if the data appeared to be non-normally distributed (determined by comparison of mean and median and by inspection of frequency distributions) then non-parametric statistics were used. Where means or medians are cited, the 95% confidence limits are given in parentheses. The confidence limits were calculated for parametric data from the mean and standard deviation while for non-parametric data percentile rankings were used.

5.4 Results

In the South London sample, 65 questionnaires were sent out and 53 responses were received (response rate 82%). There were 22 responses from the 303 members of the UK optometry e-mail discussion list (response rate 7%: see Discussion), giving a combined sample size of 75.

All respondents provided NHS sight tests. For patients eligible for an NHS Voucher, complete spectacles were provided at no additional charge by 59% of the respondents (70% of the South London sample and 32% of the e-mail sample).

Of those who supplied VVS, the number of frames that were provided for patients to choose from ranged from 1 to 100, with a median of 16.5 (0-100). In the South London sample, the median was 20 (0-100) and in the e-mail sample the median was 10 (3.3-19.1).

Practices that did not provide VVS were asked if the voucher at least covered the cost of the lenses. 13% of the practices surveyed were in this category and of these the minimum cost of a frame ranged from £5 to £65, with a mean of £25.

5.5 Discussion

Using the combined data from both sample groups, just over half of practices reported that they could provide spectacles whose cost is fully covered by the NHS Optical Voucher. However, this proportion was markedly different for the two sample groups. The reason for this difference will now be considered.

There was a low participation rate in the e-mail sample (22 of 303). Many members of the UK optometry e-mail discussion list do not routinely contribute to the discussions, but merely “listen” to a minority of members who make frequent contributions. It is therefore not surprising that only a minority of members participated. It seems possible that practitioners who invest time in participating in this list may tend to be particularly progressive in terms of developing their clinical skills. What impact this may have, if any, on the NHS services that they provide is unclear. It is apparent from an inspection of the respondents to the survey that their

locations are scattered throughout the UK, and it is thought that their practices are likely to provide eyecare to a broad spread of socio-economic groups.

In contrast, the South London region (Southwark, Lambeth and Lewisham) covered by the first sample includes a disproportionate number of areas associated with deprivation and poverty. A report titled, 'London divided. Income inequality and poverty in the capital' (Livingstone K, 2002) indicates that deprivation in London appears to be concentrated in the eastern and southern parts of inner London, with areas such as Lambeth and Southwark featuring strongly among the most deprived. It is likely that in areas where there is a higher than average proportion of people on low income, there will be a greater demand for VVS and patients are more likely to 'shop around' for a practice that will provide these.

Nonetheless, even in South London nearly a third of the practices that responded to the survey do not provide VVS. The response rate in this area was high (82%), so it is likely that this figure is fairly accurate. The next section in this chapter will now consider the effect of this on patients on low income who may have their eyes examined at a practice where no VVS are available.

5.5.1 The impact of the unavailability of spectacles fully funded by the NHS

As noted above, patients can take their NHS Optical Voucher from the practice at which it was prescribed and 'shop around' to find a practice that will provide VVS. This is undesirable since there is an increase risk of spectacle non-tolerance and intractable consumer complaints if the spectacles are dispensed at a practice that is different to the practice at which they were prescribed (Optical Consumer Complaints Service, 2006). This is why the College of Optometrists, a public benefit body, recommends in advice to the public: 'The prescribing and dispensing of spectacles are very closely linked and it would be in your best interests to have your spectacles dispensed where you have your eyes examined' (College of Optometrists, 2005).

Even if patients are not aware of this recommendation, it is usually more convenient for patients to obtain their spectacles from the practice at which they were prescribed. If the patient cannot afford the spectacles at this practice then the

patient may decide not to have new spectacles, even when clinically necessary. This is particularly likely for older patients who may have mobility problems and are therefore less likely to take their prescription to another practice. Alternatively, patients may decide to have spectacles where they are prescribed, but are left with costs that cause them financial difficulties. This is likely to deter them from seeking eyecare in the future. Even when a practice does provide VVS, the results from the survey show that the range of frames is usually rather limited. Although the median number of frames available in our combined sample is 16.5, a proportion of these will be children's frames. As such, only a small number of frames would be suitable for older people.

Earlier in this chapter it was noted that a recent government report recommended that the optometry contract should be amended to require all eyecare practices providing General Ophthalmic Services (GOS) to provide a range of VVS (Government Response to the Health Committee's Report on NHS Charges, 2006a). Such a requirement could be counter-productive if the value of the vouchers remains uneconomic because it could force practices to withdraw from providing NHS services. Since market forces apply to encourage optical practices to provide VVS, perhaps a more appropriate policy to increase the availability of VVS would be to increase the value of the voucher to an economically viable level (Optician, 1986b).

Previous research and reviews have demonstrated high levels of unmet visual needs amongst older people (Reidy *et al.*, 1998d) which impact of quality of life (Evans & Rowlands, 2004l). Many of these problems could be resolved by an optometric examination and the provision of suitable spectacles (Jessa *et al.*, 2007). Unmet visual need is more common amongst those already disadvantaged through socio-economic deprivation (Reidy *et al.*, 1998c) and those from minority ethnic groups (Lindesay *et al.*, 1997). The survey indicates that sub-optimal availability of, and patient awareness of, VVS may exacerbate the prevalence of this unmet visual need. Better understanding by the public of the availability of free eye tests and 'free' spectacles, combined with better availability of VVS, is likely to

improve the visual welfare and quality of life of a significant proportion of elderly people.

5.5.2 Limitations of the research

It is acknowledged that the sample size for this preliminary study is modest; it would be interesting to carry out a national survey to establish a more accurate estimate and to analyse geographical variations.

Another limitation of this study was that it was questionnaire–based and subject to a number of biases. For the South London survey, respondents were told that the primary purpose of the survey was to generate a list of practices that could be given to people who were found to be eligible for an NHS Optical Voucher in the main study. Therefore, some respondents may have been inclined to exaggerate the provision of VVS at their practice.

It is also possible that some respondents included frames that are available, but which are not necessarily on display nor offered routinely to eligible patients as VVS. This is particularly likely in some of the more commercial practices where dispensing staff are paid on a commission basis. It would be interesting to research this using a 'standardised patient' methodology (Shah *et al.*, 2007) that has recently been applied to optometry (Shah et al., in preparation).

Even when VVS are available to people who are on low income, this will only be relevant if the patient meets the NHS eligibility criteria. In most cases, this means that the patient has to be receiving Pension Credit. As explained earlier there is another route to eligibility, through filling in an HC1 form, but this is a very detailed form and it is possible that the complexity of the HC1 form acts as a deterrent to many patients. New research from Age Concern shows that 6 out of 10 lower income pensioners are deterred from claiming benefits by the complex system, with almost half finding means-testing too intrusive and 48% being discouraged by the complicated forms (Age concern, 2007b). A recent press release by Age Concern indicates that a third of those entitled to claim pension credit are still not receiving this. Despite significant increases to the cost of living for pensioners in recent years, up to £2.5 billion is left unclaimed each year (Age concern, 2007a)

The limitations of the research that are described above would mostly result in an overestimation of the uptake of VVS. In other words, the best estimate is that about half or less of older people with low income are able to readily obtain VVS. It is likely that this is one of the barriers that result in so many older people in the UK having poor vision simply through lack of appropriate spectacles.

The results of this preliminary study provided the information necessary to develop a list of all the practices in the South London area that provided spectacles whose cost was fully covered by the NHS. This list was given to all eligible participants at the end of the study together with a copy of their spectacle prescription as outlined in Chapter 4. A copy of the documents given to participants after the study is enclosed in the Appendix.

Chapter 6

Comparison of cataract grading performed with a standard and portable slit-lamp biomicroscope

6.1 Background

Cataract is defined as a partial or complete loss of transparency of the crystalline lens substance or its capsule (Millodot, 2000). Although cataract can occur at any age, it is primarily an age-related condition. The prevalence of cataract in developed countries is 35% of those aged 65+ (Martinez *et al.*, 1982b) increasing to 46% of those aged over 75 years (Gibson *et al.*, 1985).

Because the onset of the condition is gradual, the diagnostic criteria are important. Cataract can be described by its observed clinical characteristics or by its effect on vision. There are problems with judging the severity of cataract from the effect on vision. For example, cataract typically impairs low contrast visual acuity to a much greater degree than high contrast visual acuity (Elliott & Whitaker, 1992), yet relatively few clinics regularly measure low contrast acuity (Evans & Rowlands, 2004h). Also, some forms of cataract (e.g., posterior sub-capsular cataract) have a much greater effect on vision when the pupil is constricted, as in daylight, than in a typical consulting room. Therefore, studies seeking to assess the prevalence of cataracts require a reliable and repeatable classification system.

A number of systems have been developed to classify and grade cataracts but the most widely used (Pearson R M, 2003d) is the Lens Opacities Classification System (LOCS III) scale developed by Chylack and colleagues (Chylack, Jr. *et al.*, 1993c). Initially, the LOCS used black and white photographs for the classification

of cortical and posterior sub-capsular cataracts and a coloured photograph for the classification of nuclear colour and opalescence. This system subsequently evolved into LOCS II and LOCS III in which each type of cataract is illustrated with colour photographs. The figure below shows the LOCS III grading system developed by Chylack and colleagues (Chylack, Jr. *et al.*, 1993e).

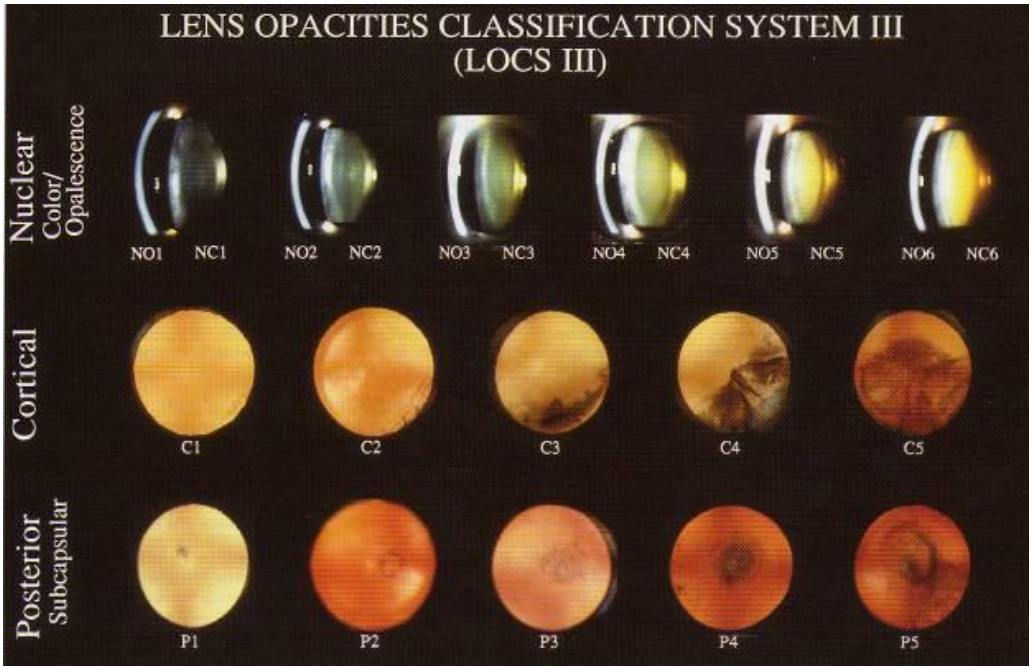


Figure 6.1The Lens Opacity Classification System III

Reproduced with permission from: Chylack LT, Jr., Wolfe JK, Singer DM, Leske MC, Bullimore MA, Bailey IL, Friend J, McCarthy D, & Wu SY; The Lens Opacities Classification System III. The Longitudinal Study of Cataract Study Group. *Arch Ophthalmol* 111, 831-836; Copyright © (1993) American Medical Association. All rights reserved.

The LOCS III scale has been validated and used in many research studies (Chylack, Jr. *et al.*, 1993b;Karbassi *et al.*, 1993b;Balaram *et al.*, 2000b;Hall *et al.*, 1997b;Davison & Chylack, 2003) but is rarely used during routine eye examinations.

An informal survey via an e-mail discussion list that is subscribed to by 300 UK optometrists was carried out. Only three optometrists reported grading cataract. One had used LOCS III in a research study but in clinical practice just classified as

cortical, nuclear, or poster sub-capsular. Another described a local scheme used in West Kent where all cataracts are graded as 0-4, but the meaning of the grades is “left to the optometrist’s discretion”. The final practice used the grading system recommended by Pearson (Pearson R M, 2003a), which is a version of the LOCS III which has been simplified for optometric practice.

It is perhaps surprising that formal cataract grading scales are only infrequently used in optometric practice. There are more than 8,500 practising optometrists in the UK who carry out approximately 17 million eye examinations each year, of which 28% are of patients aged 65 years or over (Department of Health, 2004). Based on these figures and those of Martinez et al (Martinez *et al.*, 1982a) it is possible to estimate that UK optometrists examine about 2 million patients with cataract each year. Optometrists are responsible for the majority of referrals for cataract surgery in the UK and have the necessary skills to investigate the clinical and functional needs of these patients, both before and after surgery (Association of Optometrists, 2005). The optometrist’s role in these cases is to determine whether the cataract is at a stage that requires referral for surgery and, if not, then to decide on an appropriate re-examination interval taking account of the type and rate of change of cataract. When early stages of cataract are detected it is important for the optometrist to monitor the rate of change of the cataract, which would be facilitated by using a grading scale.

This raises the question of why the most widely used cataract grading scale, the LOCS III, is not routinely used in optometric practice. It is felt that there are two main limitations of the LOCS III scale which may restrict its use in a primary care setting. First, the system has been developed for use with a table-mounted slit lamp biomicroscope and second, it requires pupillary dilation. Furthermore, the appearance of a cataract is poorly correlated to its effect on visual function and the decision to operate or not is quite rightly based on perceived visual function.

A table-mounted slit-lamp is not ideal for examining the elderly, particularly those who are wheelchair users or who suffer from arthritis. It is also not suitable for domiciliary visits. The introduction of portable slit-lamp biomicroscopes potentially

overcomes both of these issues. However, the performance of portable slit-lamps in the context of grading has not been investigated.

The purpose of this study was to investigate whether the type and severity of cataract can be graded reliably in community settings using a hand-held slit lamp biomicroscope. The data reported here were gathered as part of Study 1 in order to establish if the hand-held slit lamp could be used in Study 2 which was far more community-based.

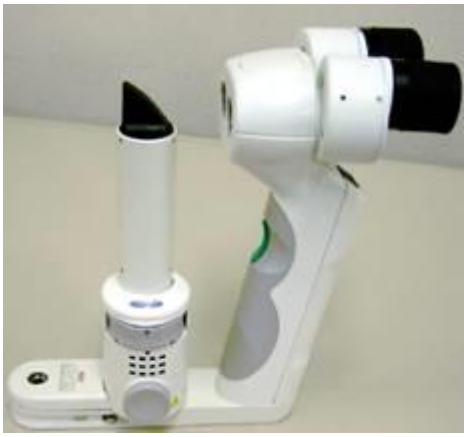


Figure 6.2 Kowa SL-15 portable slit lamp biomicroscope

6.2 Methods

6.2.1 Training

This study required two observers and the author was assisted by a colleague, Mitesh Amin. The researchers were both familiar with the literature on the LOCS III grading system. Before the research started they attended several training sessions in which they carried out LOCS III cataract grading using both instruments on about 15 patients and compared gradings. Where there were discrepancies between their gradings they re-assessed the patient together and compared the patient again with the LOCS III grading photographs to reach a consensus. The training patients had various degrees and types of cataracts. In addition to developing expertise with the LOCS III system, a secondary purpose of this training was to determine the step size that was to be used in the research.

Both researchers determined that the minimum step size that they could discern was 0.5 of a grade, for all sub-types of lens opacities (see Discussion).

6.2.2 Participants

Participants were aged 65 years and over who were recruited for Study 1 of the main screening research (see Chapter 4). Some participants were seen in community optometric clinics; others were recruited and examined in community settings as discussed in Chapter 4. The research was widely publicised (e.g., social clubs, GP surgeries, libraries) in the hope of attracting older people who might otherwise not be participating in eyecare services. Altogether, 116 patients participated in the cataract grading comparative study. The selection criteria were as described in Chapter 4. The reasons why the number of participants in the cataract grading study was less than the total number in Study 1 was that a) the cataract grading study finished a little before the end of Study 1, b) patients who had already received bilateral cataract surgery were excluded and c) patients who declined pupillary dilation (e.g., because they were driving) were excluded.

6.2.3 Procedure

A full explanation of the nature and purpose of the study was given to all patients and accompanying family members/carers both verbally and in writing before commencing any testing. Questions were invited and answered and patients were only included in the research if they provided informed consent. The research conformed to the tenets of the Declaration of Helsinki and was approved by relevant Research Ethics Committees.

Participants had their anterior chamber angle depth assessed by Van Herick's technique (Van Herick W. *et al.*, 1969b), so that patients with narrow angles at risk of closed angle glaucoma could be excluded. Two patients were excluded for this reason (these cases were referred for an ophthalmological opinion on the risk of closed angle glaucoma). Patients also had their intraocular pressures measured before and after dilation by the tonometry methods described in Chapter 4. The pressure rose in one case by about 5mmHg after dilation, but this person was monitored over three hours and the pressures returned to normal. This patient was

already under care in the Hospital Eye Service, but was given information and warned about the risk of closed-angle glaucoma. Pupils were dilated using Tropicamide as outlined in Chapter 4 and the cataract grading was carried out between 15-40 minutes later. Cataract grading took place in a darkened room with 'room lights out' as recommended by Chylack (personal communication, 2005).

Patients were allocated consecutively into four groups: A,B,C,D. Members of each group were tested with both the table-top (TT) and the portable (P) slit-lamp biomicroscopes by the two researchers (MA and ZJ in Table 6.1). As Table 6.1 indicates, some (randomly selected) participants were tested with both researchers using the table-top slit lamp biomicroscope (group A), some with both researchers using the portable slit lamp biomicroscope (group C), and some with one researcher using each instrument (groups B and D). The testing of participants in groups C and D by ZJ involved both instruments, since the protocol for the vision screening study (to be reported elsewhere) stated that the table-top instrument had to be used for the cataract grading data in this project. However, the participants in groups C and D were tested by ZJ first with the portable instrument and the gradings thus obtained were recorded before the table-top instrument was used. ZJ was therefore unaware of the table-top instrument results when she carried out the grading with the portable instrument; both researchers were masked to each other's results throughout the research. Both researchers were present at all testing sessions.

Table 6.1 Testing details illustrating counterbalanced design. TT, table-top; P, portable slit lamp biomicroscope.

Group	Researcher ZJ	Researcher MA
A	TT	TT
B	TT	P
C	P (TT)	P
D	P (TT)	TT

Some participants were invited to return for test-retest comparisons. These participants included those patients who were requested to return for clinical reasons (e.g., repeat visual fields or tonometry) and both researchers repeated the

gradings that they initially carried out (i.e., using the same grouping in Table 6.1 as at the initial examination). When carrying out these repeat gradings, the researchers did not look back at their initial gradings, which were not recollected in any case.

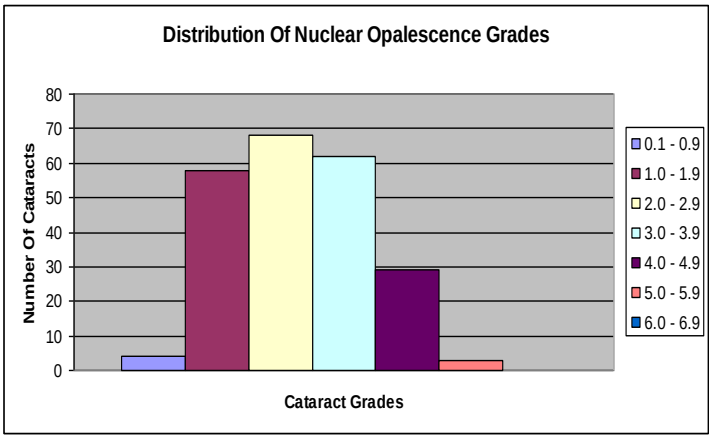
6.3 Results

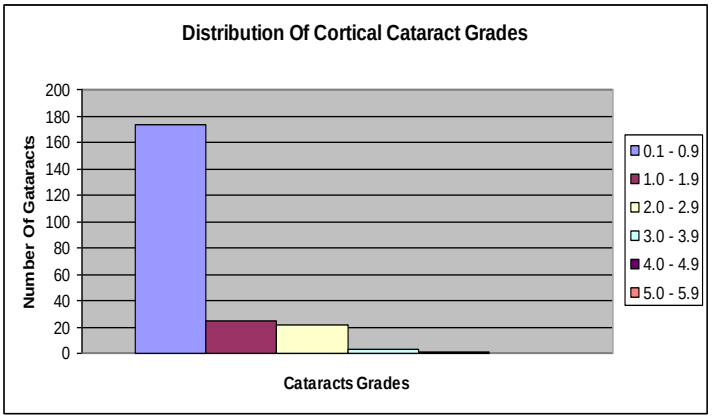
6.3.1 Initial Analyses

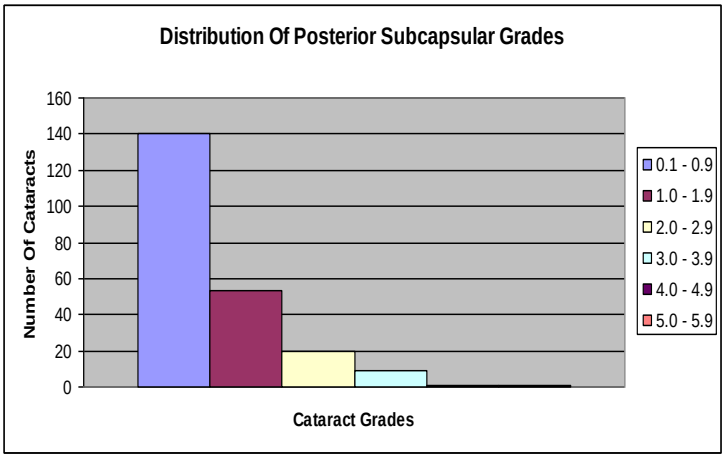
Frequency distributions were plotted to assess the nature of the results obtained. The results for nuclear colour were not used since this is less important in the diagnosis of cataract. Compared with other types of cataract, nuclear sclerosis has a lesser effect on visual function (Stifter et al., 2005; Casson and James, 2006) and previous studies using LOCS III seem to have placed less emphasis on nuclear colour than on nuclear opalescence (Hall et al., 1999; Oishi et al., 2006). Figure 6.3 shows the distributions of the gradings for the various characteristics used in the LOCS III system obtained using (a) the table-top slit-lamp and (b) the portable slit-lamp .The graphs show that the distribution of nuclear opalescence grades approximates a normal distribution, but those for cortical and posterior subcapsular grades do not (Figure 6.3). Non-parametric methods are therefore used in the rest of this section.

Figure 6.3 Frequency distributions of cataract grading

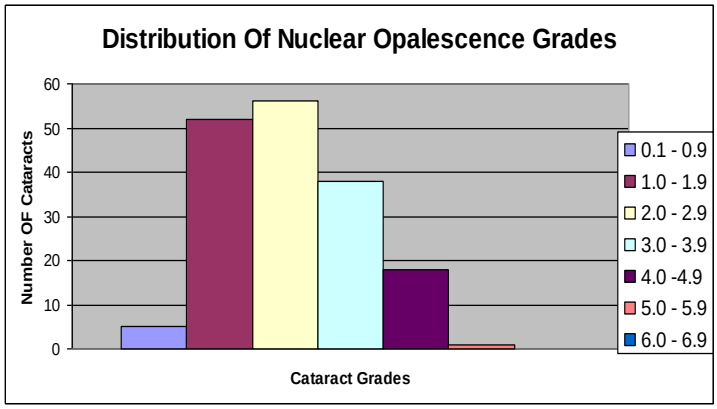
a) table-top slit-lamp biomicroscope

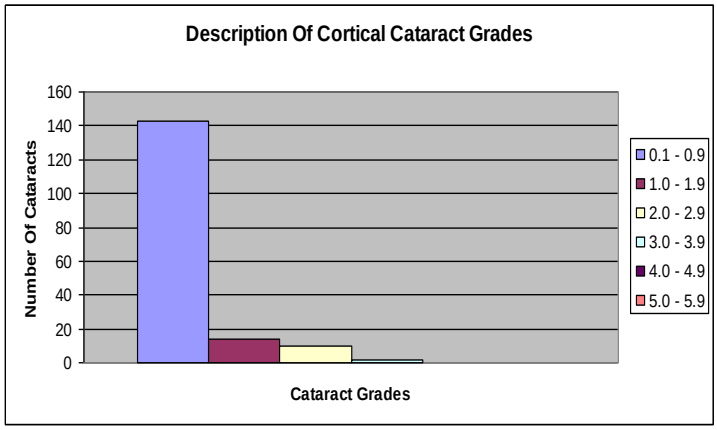


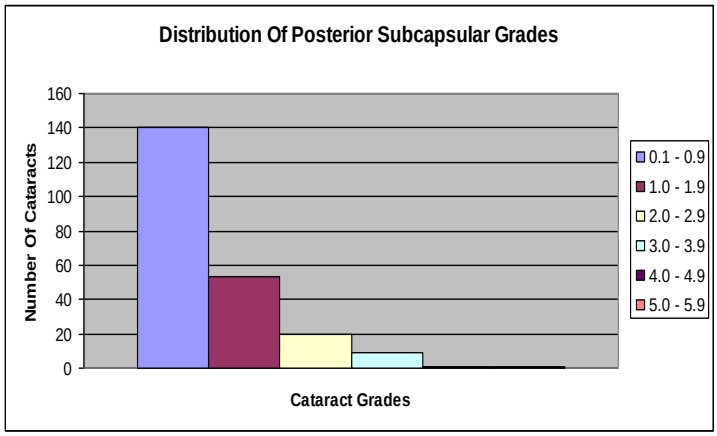




(b) Portable slit-lamp biomicroscope





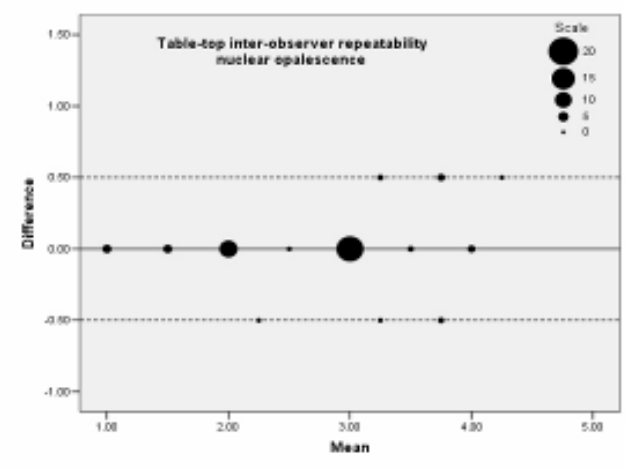


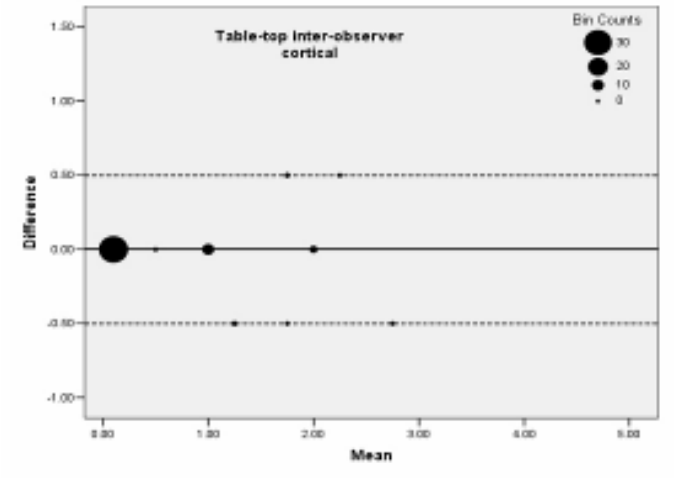
6.3.2 Inter-observer agreement

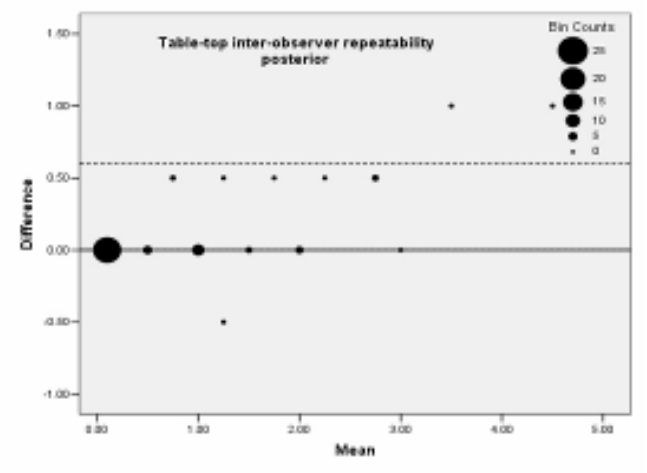
Inter-observer agreement was assessed for the gradings obtained with each instrument. These are illustrated using the non-parametric method of Bland and Altman (1999) for the three main cataract types in Figure 6.4. In every case, the median difference between the two observers was zero. The graphs (below) demonstrate that the 95% limits of agreement are within ±0.50 grades for all cases, except for the table-top instrument grading of posterior lens opacities where the 95% percentile is 0.6 of a grade.

Figure 6.4 Bland and Altman (difference v mean) plots for inter-observer agreement

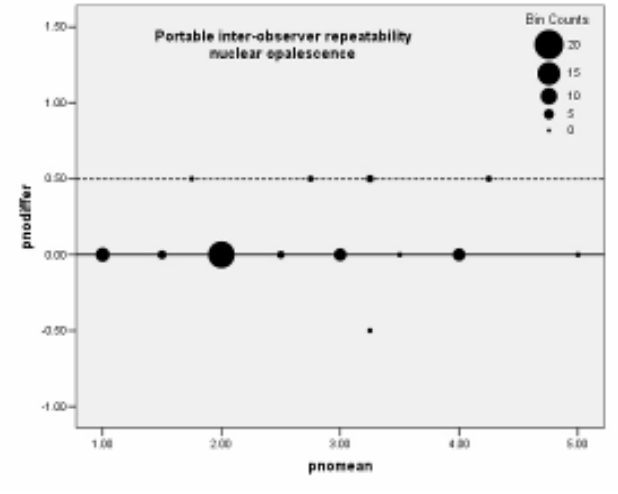
(a) Inter-observer agreement for table top slit-lamp cataract grading

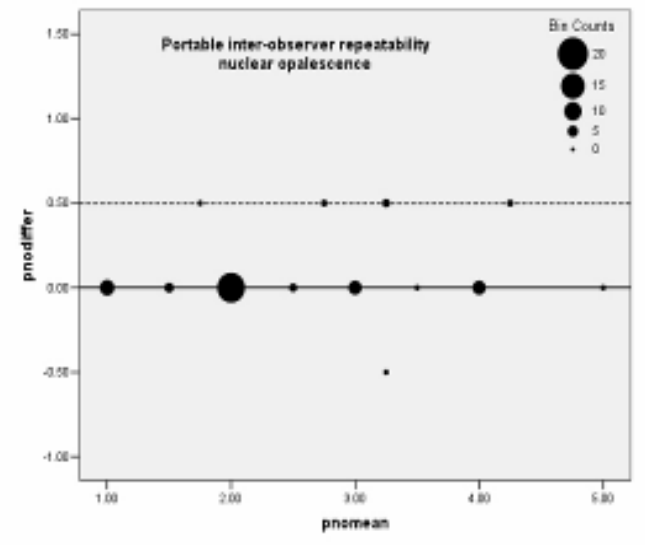


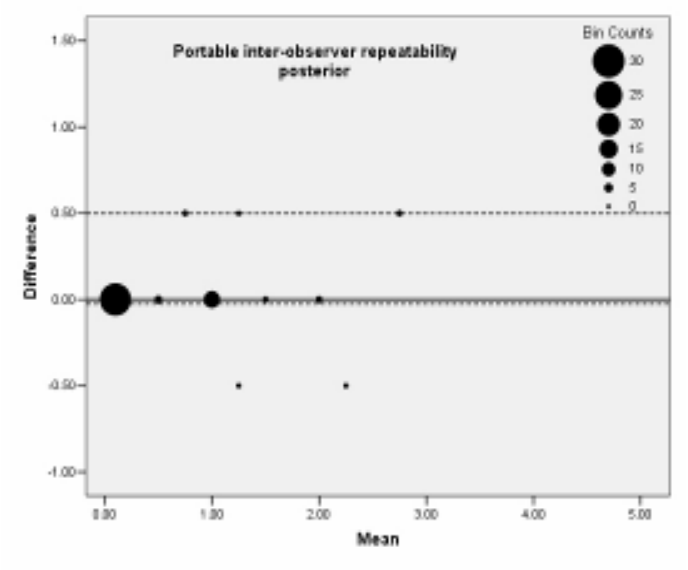




(b) Inter-observer agreement for portable slit-lamp cataract grading



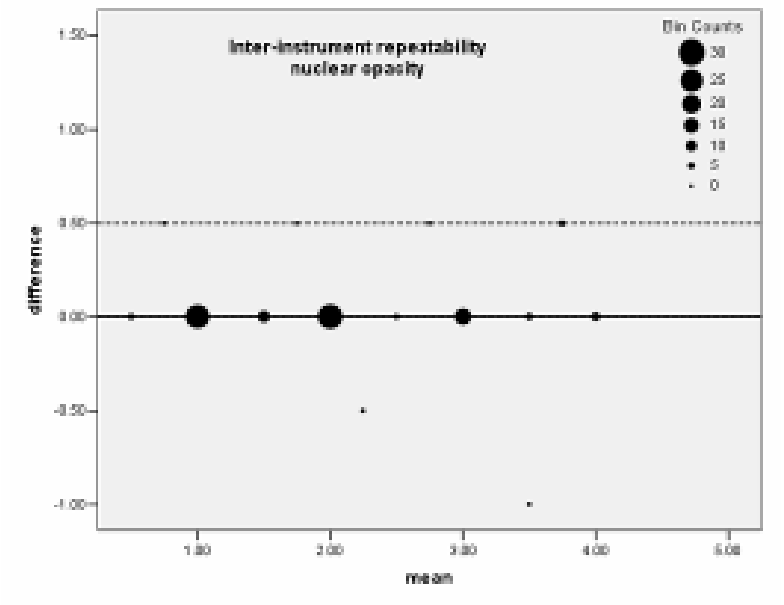


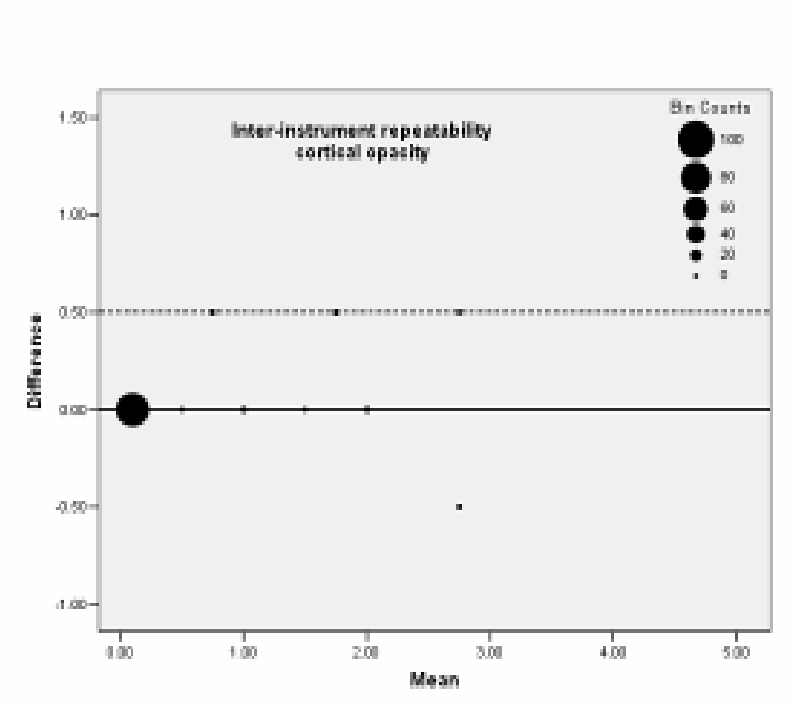


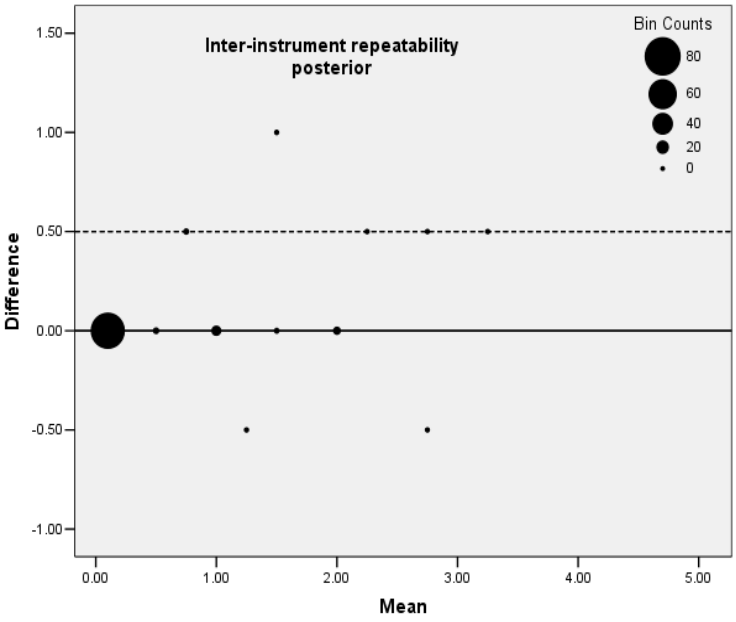
6.3.3 Inter-instrument agreement

In view of the good agreement of the gradings for the two observers, the data were pooled to estimate the inter-instrument repeatability. For all three types of cataract, the 95th percentile was 0.5 and the median and 5th percentile of the difference was zero, as illustrated on the graphs below. In other words, there is no lower line on these graphs because the lower is coincident with the middle line at 0.00.

Figure 6.5 Bland and Altman (difference v mean) plots for inter-instrument agreement




Inter-instrument repeatability
cortical opacity
Bin Counts
100
80
60
40
20
0
1.50
1.00
0.50
0.00
-0.50
-1.00
Difference
0.00
1.00
2.00
3.00
4.00
5.00
Mean


Inter-instrument repeatability
posterior
Bin Counts
80
60
40
20
0
1.50
1.00
0.50
0.00
-0.50
-1.00
Difference
0.00
1.00
2.00
3.00
4.00
5.00
Mean

6.4 Further analyses

A Wilcoxon signed ranks test was carried out as a non-parametric alternative to the paired t-test. The null hypothesis assumed was that the median difference between the pairs of observations is zero. The results of the tests are shown in Table 6.2 below:

Table 6.2Wilcoxon signed rank test

	Nuclear Opalescence	**Cortical**	**Posterior Subcapsular**
Table Top Vs Table Top Slit Lamp	P =0.2482 (52)	P=0.7455 (12)	P=0.0080 (61)
Table Top Vs Hand held Slit lamp	P =0.8497 (35)	P= 0.0578 (44)	P=0.0833 (36)

In view of multiple comparisons, a Bonferroni correction was made which modified the usual p-value for significance of 0.05 to 0.008. From the results obtained, it can be seen that inter-instrument grading showed no significant difference in cataract grading for the 3 subtypes of cataract. Indeed, the only comparison that approached significance was for the inter-observer comparison of posterior subcapsular cataract. This, together with the graphs above, would seem to indicate that inter-instrument repeatability is at least as good as inter-observer repeatability.

The intraclass correlation (ICC) was calculated as an index of reliability. It assesses the ratio of between-groups variances to the total variance. The ICC was calculated to assess inter-observer and inter-instrument grading reliability for nuclear opalescence. It was not appropriate for the other lens opacity types because these were not normally distributed. For nuclear opalescence, inter-observer reliability was high with an ICC coefficient of 0.97 with 95% confidence limits of 0.95-0.98. Inter-instrument reliability also showed a high level of reliability between the instruments with a calculated ICC of 0.98 (95% CI 0.97-0.99).

6.5 Discussion

The results show that the inter-observer agreement is good: Figure 6.4 shows that the 95% limits of agreement were within ±0.50 grades in the majority of cases. The results also show that the inter-instrument repeatability is good, with the graphs showing that for all three types of cataract, the median and 5th percentile of the difference was zero, and the 95th percentile was 0.5. Indeed, the variability between using two instruments is less than the variability between the two observers using the table-top instrument.

A limitation of this study is that finer step sizes were not used. The original paper on the LOCS III recommended a decimal scale (Chylack, Jr. *et al.*, 1993d). Since then, most studies that have used the LOCS III have used a decimal scale (Strouthidis *et al.*, 2005b;Stifter *et al.*, 2005;Stifter *et al.*, 2006;Nirmalan *et al.*, 2006;Karbassi *et al.*, 1993c;Husain *et al.*, 2005;Hall *et al.*, 1999;Hall *et al.*, 1997a;Davison, 2005;Casson & James, 2006;Balaram *et al.*, 2000a) although three studies have used an integer scale (Oishi *et al.*, 2006;Strouthidis *et al.*, 2005a;Lim *et al.*, 2006).

Although from a theoretical perspective finer step sizes are better than coarser step sizes, from a practical point of view the step sizes in a grading scale need to reflect the accuracy with which clinicians are able to make judgements. This was established during the training phase in the present study. It is felt that more research would be useful to investigate whether finer grading scales could be used with the LOCS III system, and whether this would influence the inter-instrument repeatability.

6.6 Conclusions

The results indicate that cataract grading using a portable slit lamp biomicroscope is in good agreement with grading performed using a table-mounted slit lamp and the repeatability is comparable. Indeed, the inter-instrument repeatability is very similar to the inter-observer repeatability.

This chapter has shown that the portable slit lamp biomicroscope can be used as part of the main study in community venues to grade cataract according to the LOCS III grading system. The next chapter will focus on various conventions in statistical analyses before the results from the main study are presented

Chapter 7

General descriptive data and conventions in statistical analysis for detection of target conditions

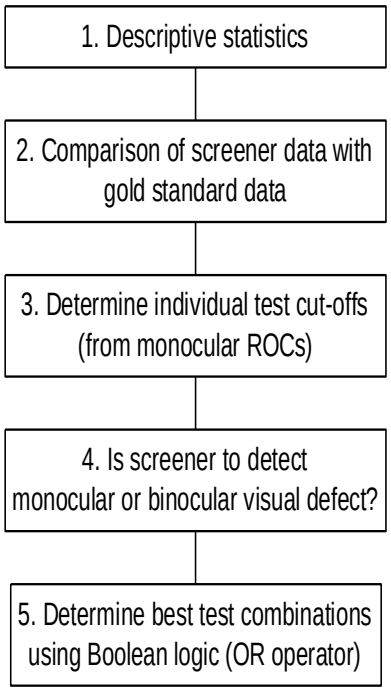


Figure 7.1. Overview of analyses.

Figure 7.1 provides an overview of the statistical analyses applied to the data obtained in the two main studies. This chapter will cover stages 1 and 2 in Figure 7.1, and will outline the approach taken in stages 3-5 in subsequent chapters.

7.1 General descriptive data

There are two aspects of the data that are reported in this thesis: firstly, the distribution of the data obtained for each test will be described; secondly, the ability of the screening instruments to detect the target conditions will be analysed. The screening instruments in Study 2 differed from those in Study 1, so the ability of the instruments to detect the target conditions has to be considered separately for each study.

Although a different cohort of participants was used in Study 1 and Study 2, the selection criteria were identical and it therefore seems likely that both populations can be pooled for the purpose of describing the outcome of the various tests. As a precaution, the key variables (e.g., age, target condition prevalence) in the two populations will be compared statistically to check that the samples are equivalent.

7.1.1 Is it appropriate to pool the samples from both studies for the general descriptive data?

Table 7.1 gives an overview of the study populations in the two studies. It can be seen that in most respects the samples were very similar and the equivalence of the two samples was tested to confirm whether it was appropriate to pool the samples for the descriptive analyses. The age of both samples was not significantly different (t-test, $p=0.31$). Although there were statistically significantly more females in Study 2 than Study 1 (chi-squared test, $p=0.0026$), this did not impact on the prevalence of the target conditions which did not differ significantly in the two samples (Chi-squared tests, $p>0.05$). In view of this, the two samples were pooled to give a sample size of 380 for the descriptive data described below.

Table 7.1 Key statistics from Study 1 and Study 2

	STUDY 1	**STUDY 2**	**Comparison test**
Total number of participants	180	200	
Gender	46% male.	31% male.	Chi-squared test, p=0.0026
Proportion seen in community	12% were seen in the community (22 patients from Pulross Intermediate Care centre). 14 patients (7%) were seen at a community based optometric practice. 144 patients were seen at the Institute of Optometry	31.5% were seen in the community (22 patients from Blaiderry Road GP surgery and 41 from Woodlawns day centre) 137 patients were seen at the Institute of Optometry	
Age	The average age was 77 yrs The median age was 76 yrs. The range was 67-99yrs	The average age was 77 yrs; The median age was 76 yrs. The range was 65-94 yrs	t-test p=0.31
Presenting eye wear	10% presented to the eye examination with no spectacles. 46.6% had multifocal spectacles 23.9% had distance spectacles 38.3% had near spectacles	14.5% presented to the eye examination with no spectacles 44.5% had multifocal spectacles 22.5% had distance spectacles 31.5% had near spectacles.	
Prevalence of significant cataract	31.7%	30.7%	Chi-squared test, p=0.8336
Prevalence of significant uncorrected refractive error	39.4%	30%	Chi-squared test, p=0.0542
Prevalence of correctable visual loss	58.3%	51%	

Prevalence of significant macular degeneration	28.9%	22.5%	Chi-squared test, p=0.1531

In the first part of this section, the optometric characteristics of the combined sample are described. In most cases, these descriptive data are based on the results from the gold standard eye examinations. An exception is symptoms and history, where the highly standardised method of obtaining these data with the screener gives a discrete, well-defined dataset. In the second part of this section, the results of some of the core tests in the computerised screener (e.g., visual acuity) are compared with equivalent tests in the gold standard eye examination.

The research was publicised by communicating with potential participants individually and by word of mouth. This meant that participants who were interested took more information and almost always ended up participating in the research. It was difficult to target those patients who were not keen to take part in the research to fill out the non-participation questionnaire and very few non-participation questionnaires were completed, so it was not possible to analyse the data from these.

7.1.2 Last eye examination, patient history and symptoms

The figure below shows that 20% of participants from the combined sample had either never had an eye examination or had not had an eye examination for at least two years. The Code of Ethics from the College of Optometrists gives guidelines on professional conduct and gives advice regarding the re-examination intervals that are considered good practice for defined categories of patients. The recommended minimum re- examination intervals for those aged between16 and 70 years is 2 years. For patients aged 70 and over the recommended interval is 1 year and this also applies to those patients who are diabetic and those who are over 40 years old with an immediate family history of glaucoma or with ocular hypertension (College of Optometrists, 2008). Figure 7.2 indicates that 20% of the combined sample had either never had an eye examination or had not had one in the last two years. The distribution of ages of the combined sample can be seen in Figure 7.3

and shows that approximately 84% of participants were aged 70 years and over and as such were entitled to an NHS sight test annually.

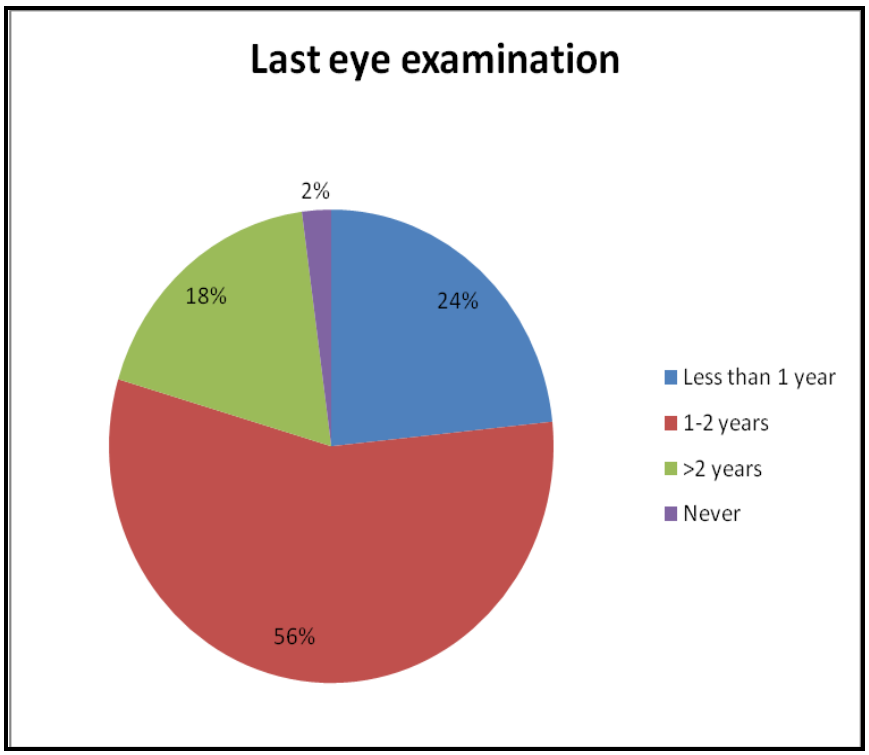


Figure 7.2 Last eye examination

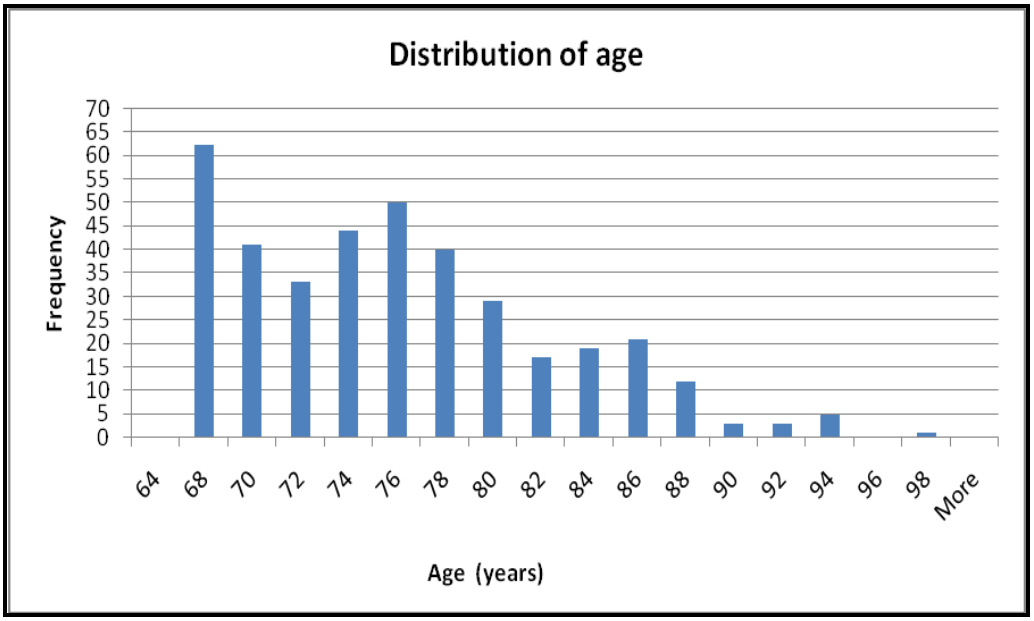


Figure 7.3 Distribution of age in the combined sample.

The data from the screener also provided interesting information regarding reported problems that participants had with their vision and also whether they had a history of eye conditions that would warrant monitoring. Figure 7.4 below shows that approximately 43% of the patients seen reported problems with their distance vision or their near vision or both.

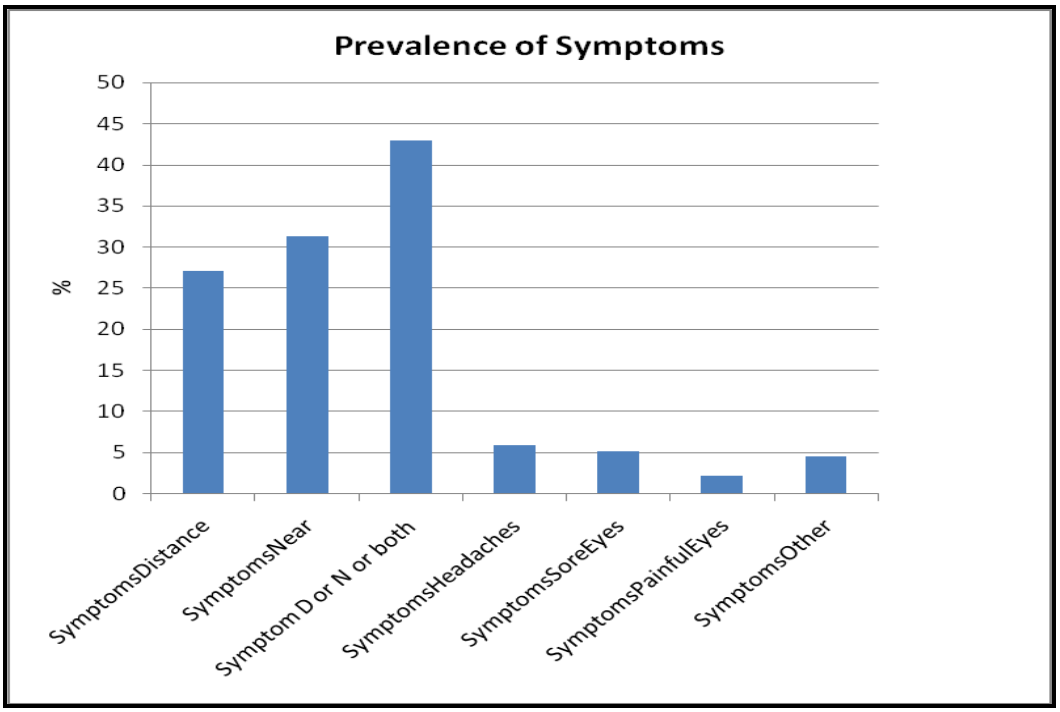


Figure 7.4 Prevalence of symptoms

The figure below shows that a number of patients had a positive history of eye conditions that may result in reduced in vision.

Figure 7.5 shows that approximately 14% of patients seen had a history of macular degeneration, glaucoma or diabetes and approximately 23% had a history of cataracts.

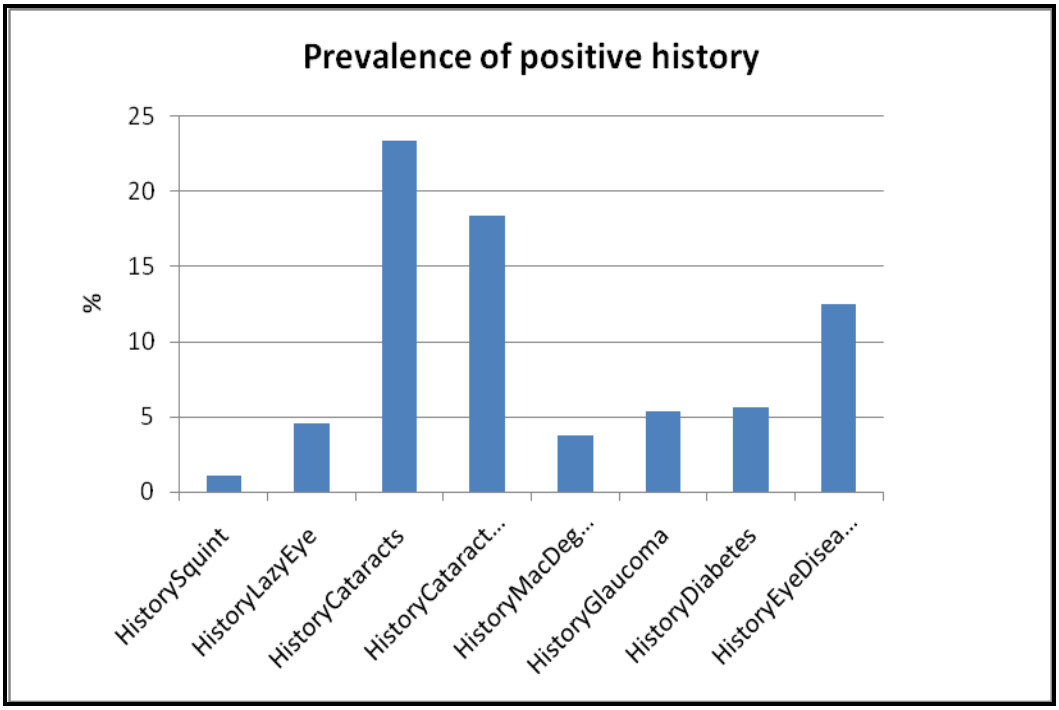


Figure 7.5 Prevalence of positive history. The fourth category refers to a history of cataract surgery

7.1.3 Distribution of cataract

Cataract was defined using the Lens Opacities Classification System III (LOCSIII), described in Chapter 4. The diagnostic criteria for cataract used in this study have been used by previous researchers based on the LOCS criteria of LOCS III score of 4 or more for nuclear cataract, and 2 or more for cortical or posterior sub-capsular cataract (Foster *et al.*, 2003b;Saw *et al.*, 2003c). Figure 7.6 shows the distribution of cataract type for the right eye and the left eye using the combined sample. It can be seen that there is virtually no difference between the two eyes.

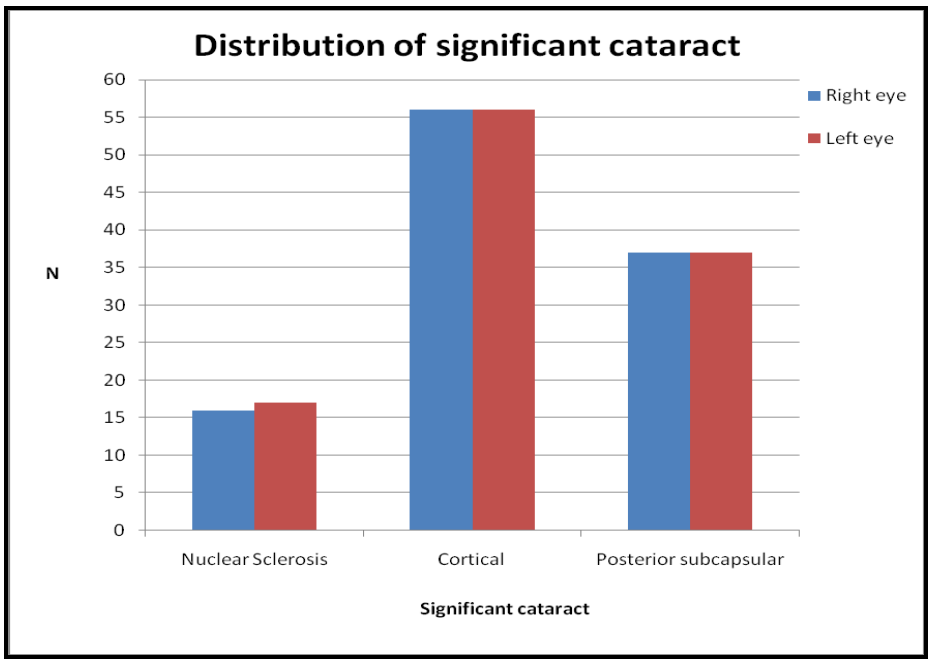


Figure 7.6 Distribution of significant cataract

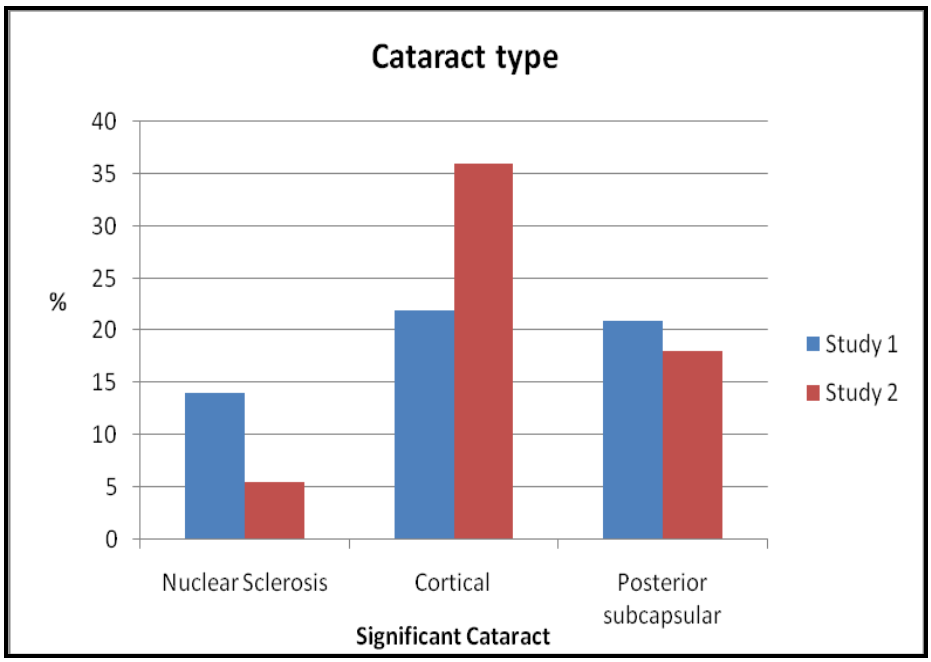


Figure 7.7 Cataract type

Figure 7.7 above shows that the levels of significant posterior subcapsular are very similar in both studies. The levels of significant cortical lens opacities are greater in Study 2 than Study 1 and the levels of significant nuclear sclerosis are greater in Study 1 than Study 2. The possible reasons for this are explored in Chapter 12.

7.1.4 Clinical data from the gold standard eye examination

The table below contains information that was extracted from the gold standard eye examination. The two studies have been combined to give an overall sample of 380 patients. Table 7.2 contains descriptive data from several tests in the gold standard eye examination.

Table 7.2 Descriptive data from gold standard eye examination

	Comment
Heterophoria	46% of participants (174 patients) had a heterophoria either for distance or near or both. The median distance deviation was zero (range 15Δ exophoria to 6Δ esophoria) and the median near deviation was also zero (range 15Δ exophoria to 5Δ esophoria)
Heterotropia	3% of participants (11 patients) had a heterotropia either for distance, near or both.
Prismatic correction required	3% of participants (11 patients) required prismatic correction for distance, near or both.
Amsler grid distortion	5% of participants from the combined sample had some distortion in one or both eyes on the Amsler grid
Amsler grid scotoma	Less than 1% (3 patients) of participants had a scotoma on the Amsler grid test
Anisocoria	2% of participants from the combined sample had anisocoria and less than 1% (3 patients) had an afferent pupillary defect
Convergence	The average (and median) near point of convergence measurement from the combined sample was 8cm

	(range 4cm to 12cm)
Stereoacuity	In Study 1, stereoacuity was measured using the Randot stereo test as described in Chapter 4. The total number of patients that had their stereoacuity measured was 172 and the results obtained ranged from 20 seconds of arc to 1000 seconds of arc with a median stereocuity of 70 seconds of arc.

Study 1 and 2 have been combined for the analysis of the subjective refraction in the gold standard eye examination. The three graphs below show the distributions of the spherical refractive error, cylindrical refractive error and cylindrical axes.

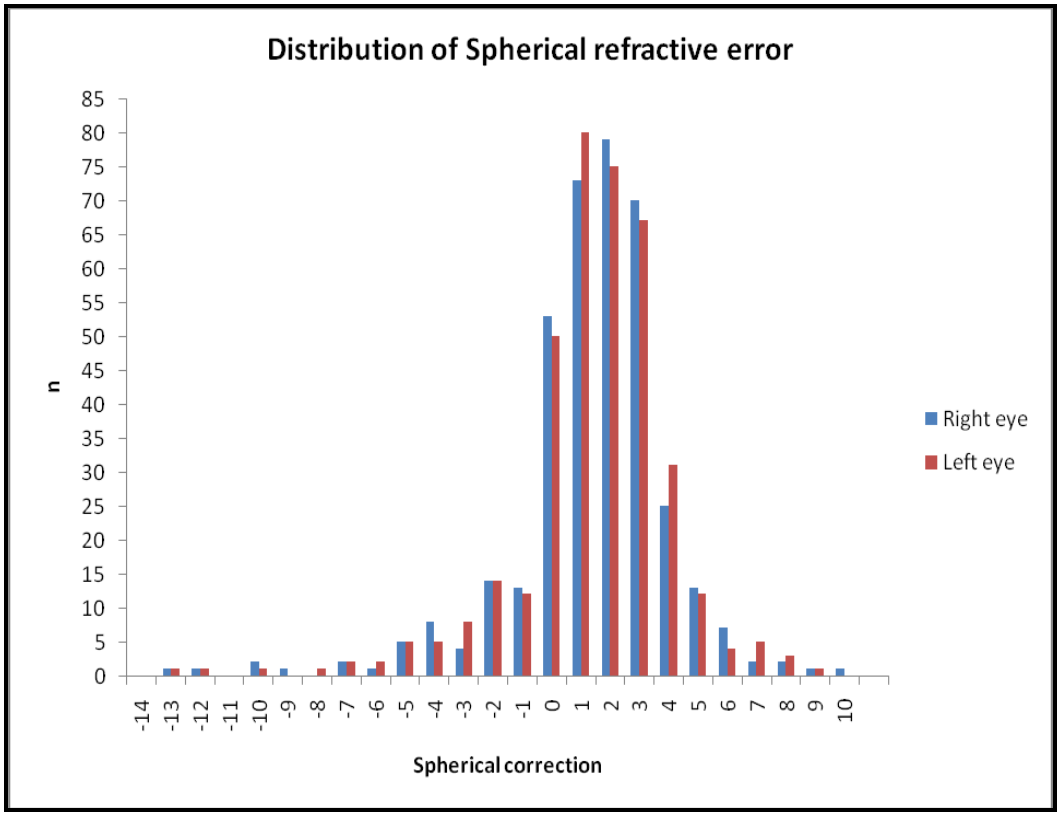


Figure 7.8 Distribution of spherical refractive error. The bins include data from the values stated +/- 0.49.

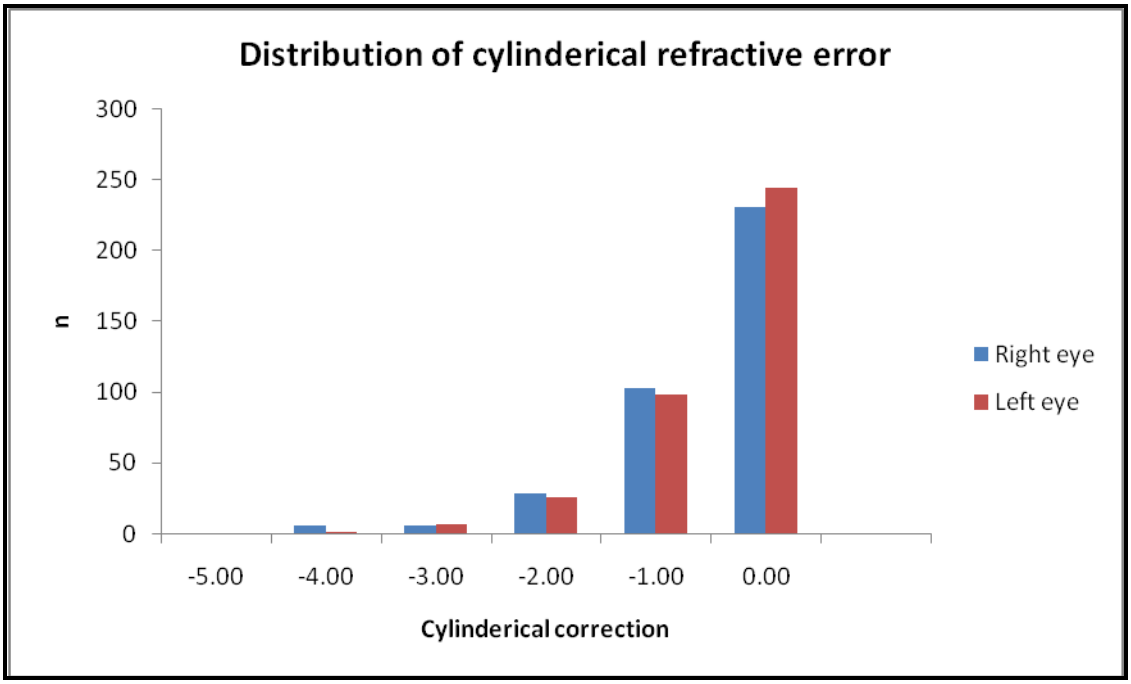


Figure 7.9 Distribution of cylindrical refractive error, measured in negative cylinder notation in 0.25DC steps. The 0.00 bin includes spherical, 0.25DC, 0.50DC, 0.75DC; -1.00 includes -1.00, -1.25, -1.50, -1.75; etc.

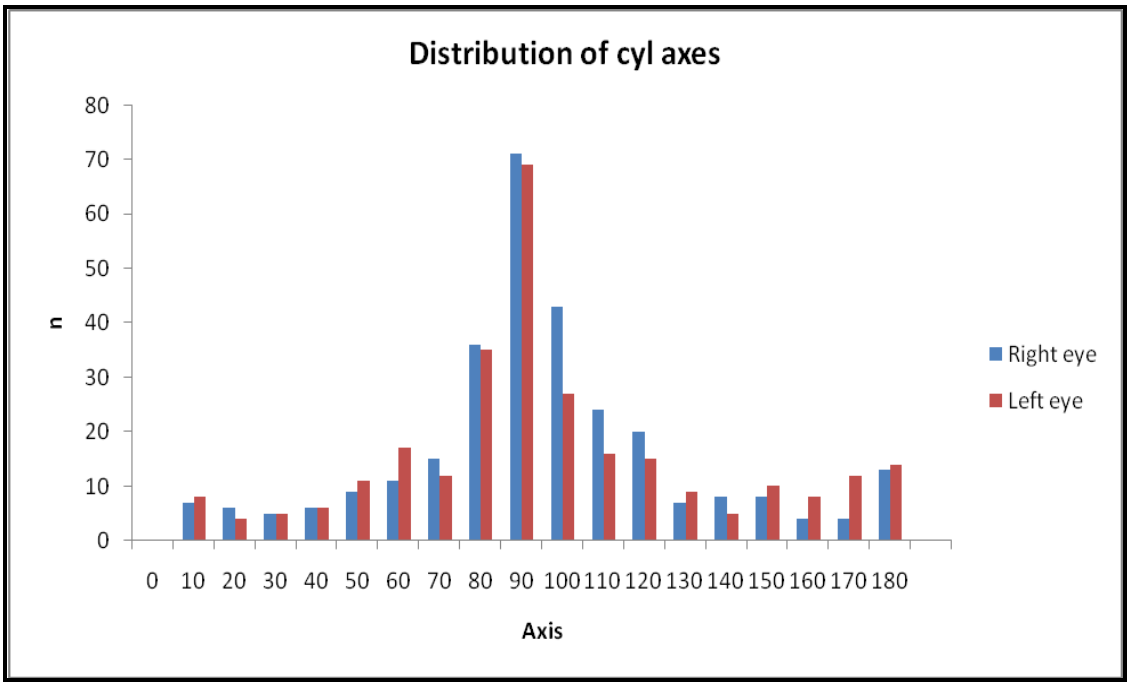


Figure 7.10 Distribution of cyl axis

7.1.5 Overall analysis of visual acuity

High contrast acuity

The methods for measuring visual acuity have been discussed in Chapter 4. The graphs below show the frequency distributions of the presenting visual acuities achieved from the screener and from the gold standard eye examination.

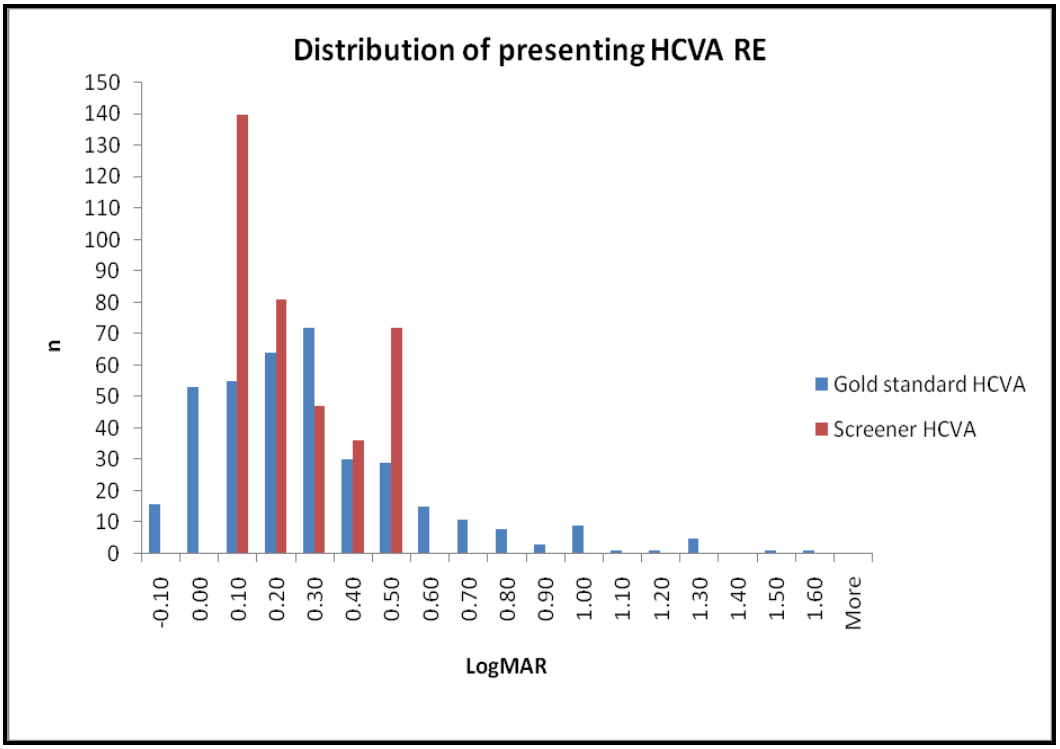


Figure 7.11 Distribution of presenting HCVA in RE. The gold standard test measurement range is -0.10 to >1.60; the screener test measurement range was 0.10 to 0.50.

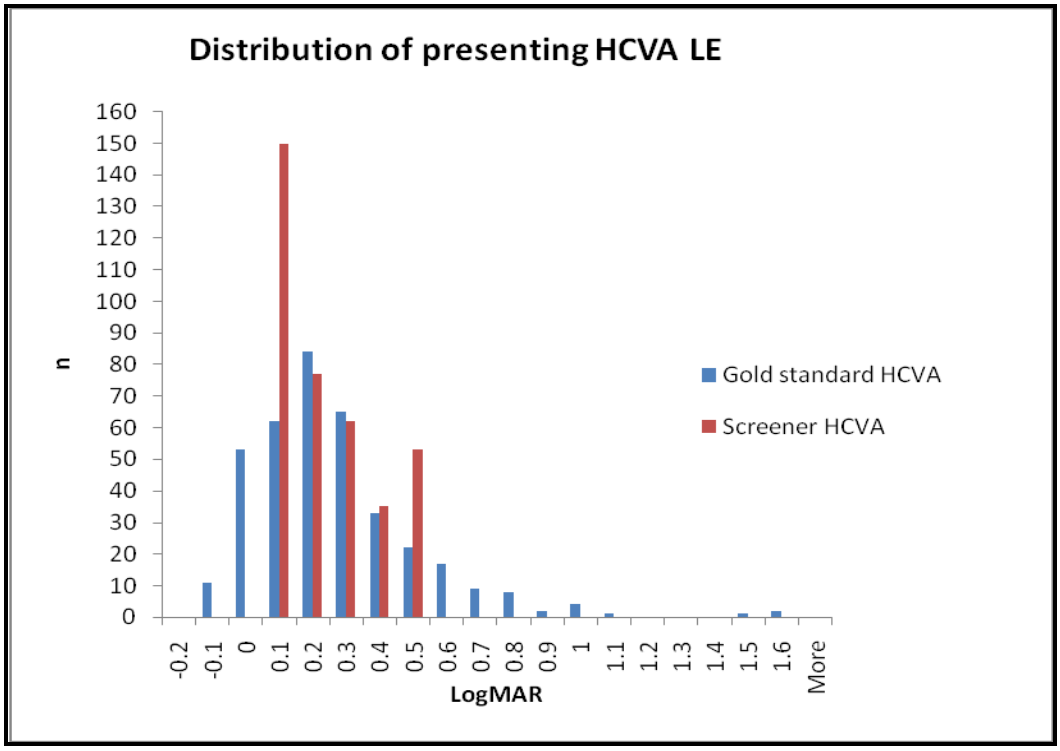


Figure 7.12 Distribution of presenting HCVA in LE. The gold standard test measurement range is -0.10 to >1.60; the screener test measurement range was 0.10 to 0.50.

Figure 7.11 and Figure 7.12 show the distributions of high contrast visual acuities measured in the gold standard eye examination and with the computerised vision screener. The graphs reveal the upper and lower limits of the measurement range of the screener. The figures below show the association between the acuity achieved in the gold standard eye examination and the acuity achieved with the screener. The scatter graphs in Figure 7.13 and Figure 7.14 will be influenced by the measurement range of the screener test (0.10 to 0.50), as illustrated in Figure 7.11 and Figure 7.12. To give an accurate estimate of the inter-test agreement between the high contrast visual acuity tests of the screener and the gold standard test, Bland and Altman graphs (Bland and Altman, 1986) were plotted based on the central range of data, for which the two tests are comparable (data points that for the gold standard lay between 0.20 and 0.40). These are shown for the right and left eyes in Figure 7.15 and Figure 7.16.

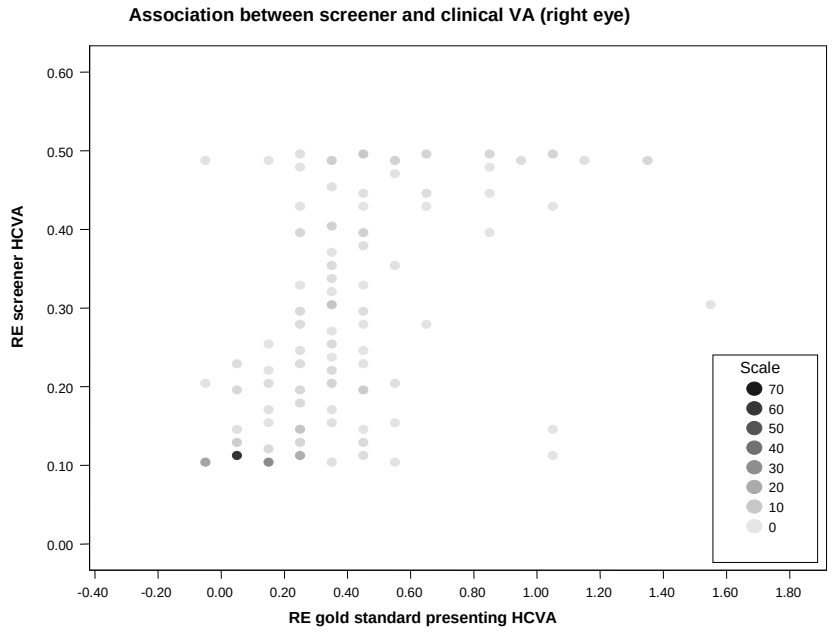


Figure 7.13 Association between screener and clinical VA (right eye). The association is confounded by the upper limit (0.5 LogMAR) and lower limit (0.1 LogMAR) of the screener for measuring HCVA.

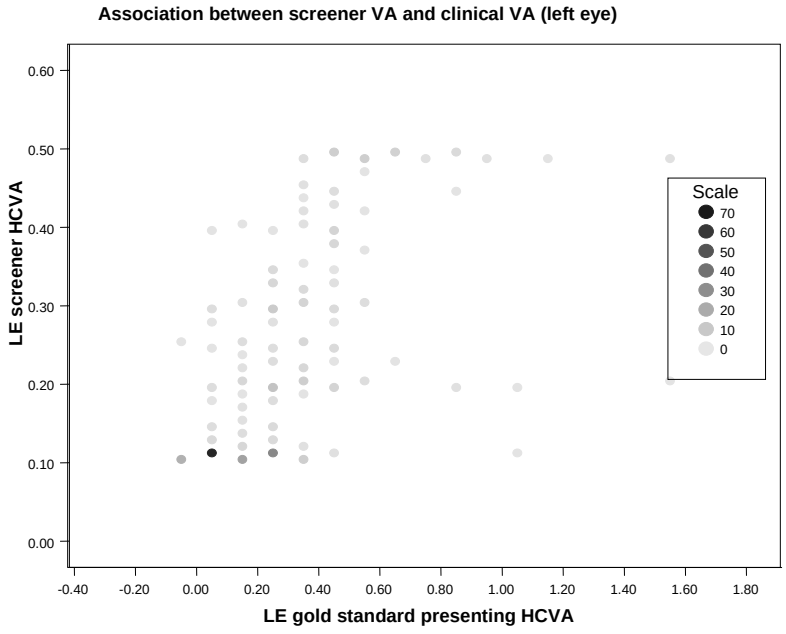


Figure 7.14 Association between screener and clinical VA (left eye). The association is confounded by the upper limit (0.5 LogMAR) and lower limit (0.1 LogMAR) of the screener for measuring HCVA.

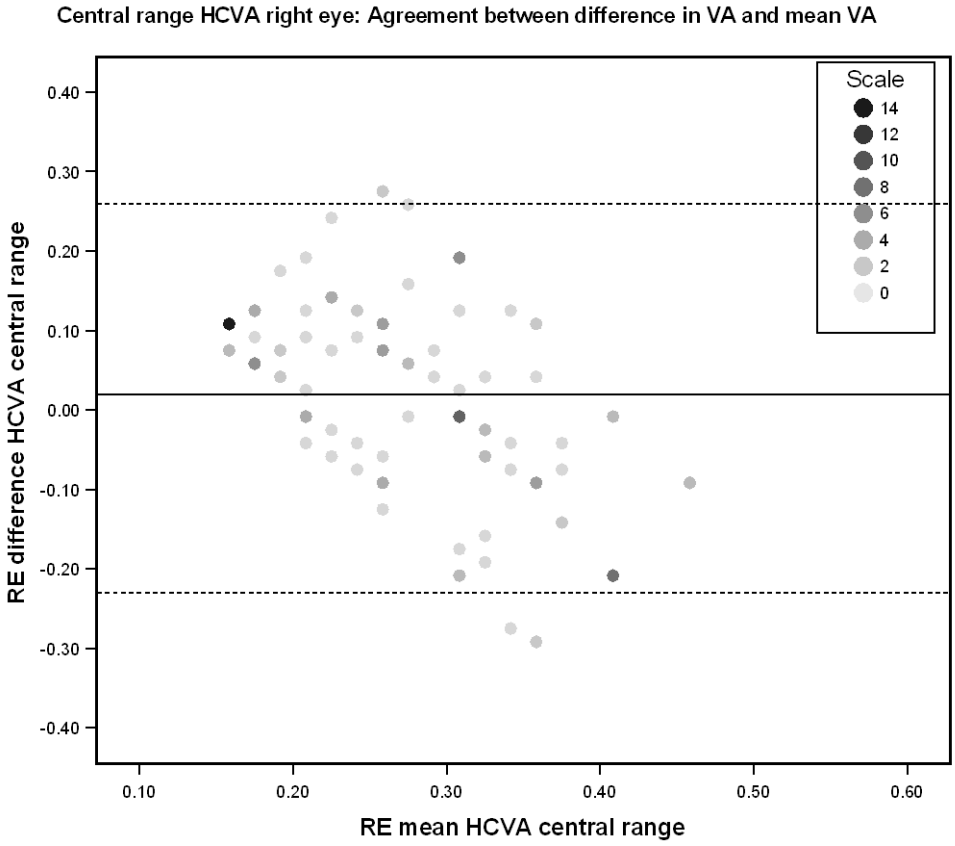


Figure 7.15 Bland and Altman plot of the difference in VA v mean VA in right eye, for gold standard and screener high contrast VA. The central range of data used excludes those with a gold standard acuity of less than 0.2 LogMAR and greater than 0.4 LogMAR (N=143). The mean difference (solid horizontal line) is 0.018 and the standard deviation is 0.12. The upper and lower dashed lines represent + and – 2 standard deviations from the mean (0.26 and -0.23).

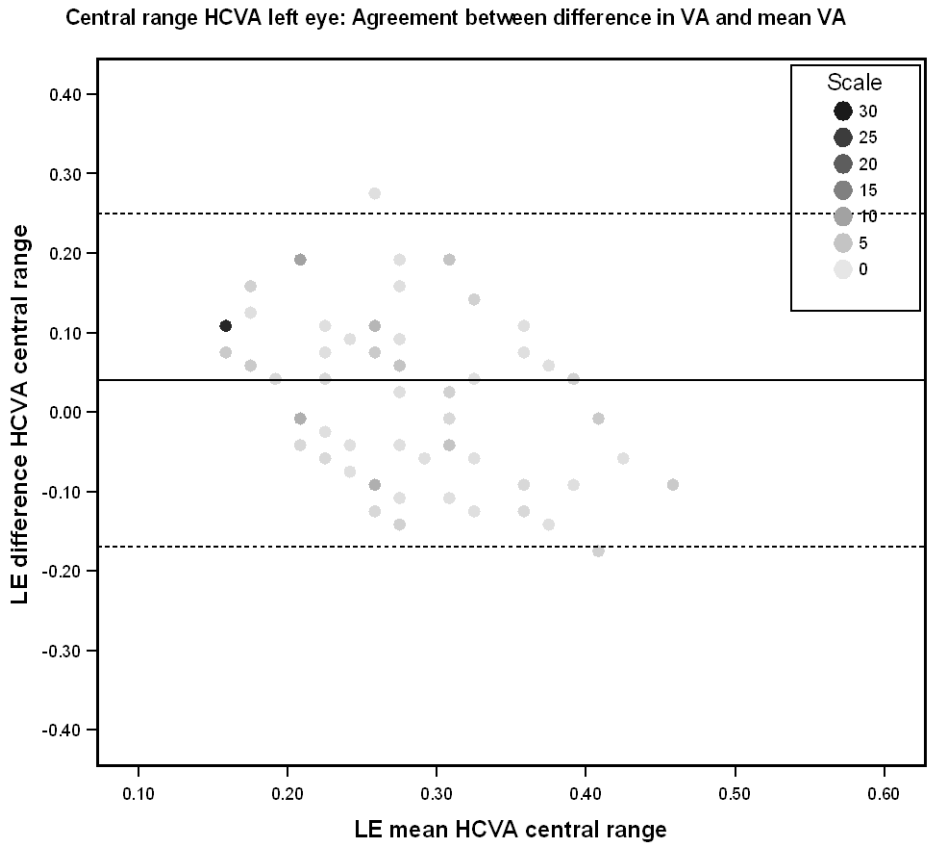


Figure 7.16 Bland and Altman plot of the difference in VA v mean VA in right eye, for gold standard and screener high contrast VA. The central range of data used excludes those with a gold standard acuity of less than 0.2 LogMAR and greater than 0.4 LogMAR (N=155). The mean difference (solid horizontal line) is 0.039 and the standard deviation is 0.10. The upper and lower dashed lines represent + and – 2 standard deviations from the mean (0.25 and -0.17).

The horizontal reference lines in Figure 7.15 and Figure 7.16 show the key variables for the inter-test repeatability of high contrast visual acuity. The mean difference between the two measurement methods is 0.018 for the right eye and 0.039 for the left eye and the 95% limits are approximately two lines for each method.

Low contrast acuity

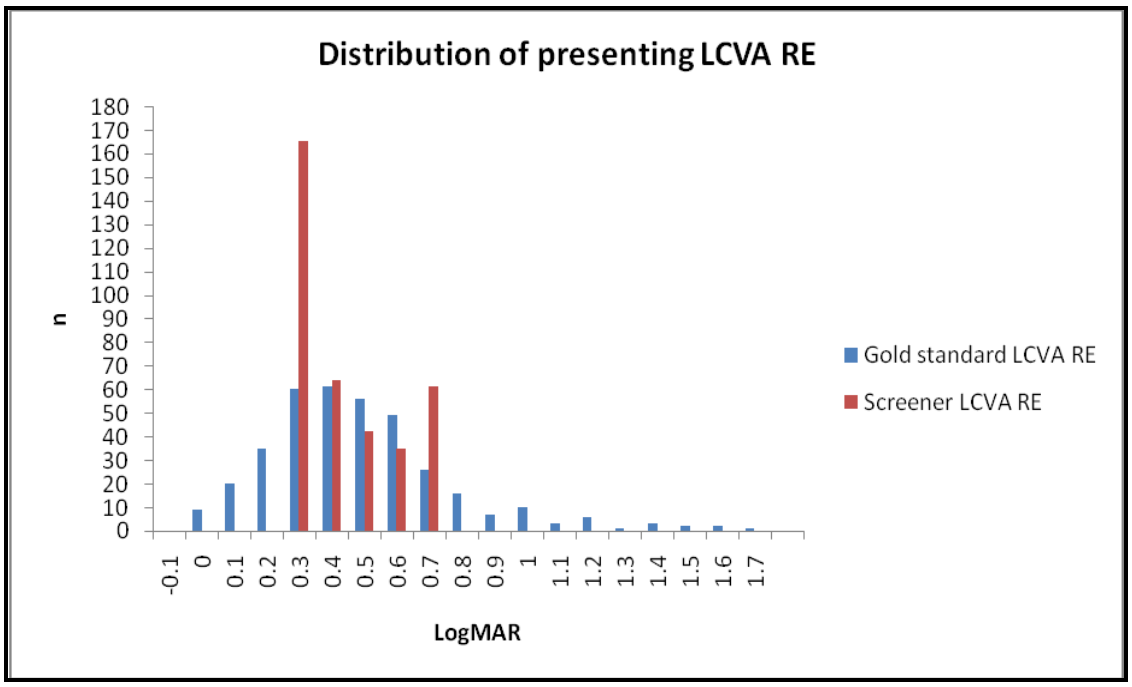


Figure 7.17 Distribution of presenting LCVA in RE. The gold standard test measurement range is -0.10 to >1.60; the screener test measurement range was 0.30 to 0.70.

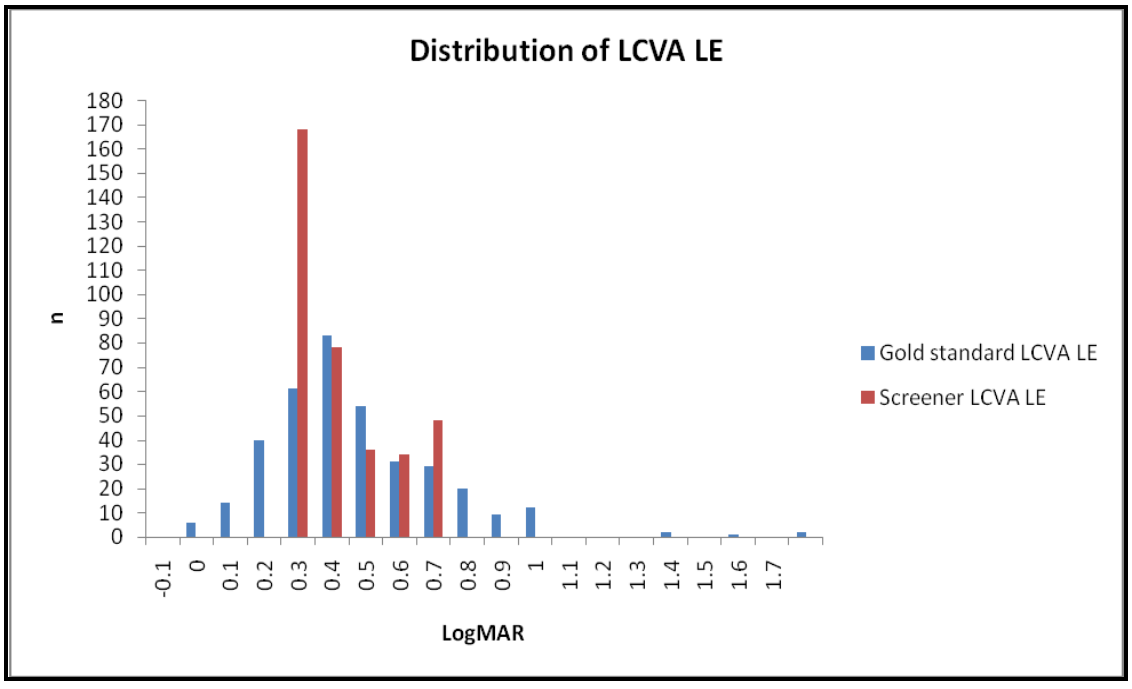


Figure 7.18 Distribution of presenting LCVA in LE. The gold standard test measurement range is -0.10 to >1.60; the screener test measurement range was 0.30 to 0.70.

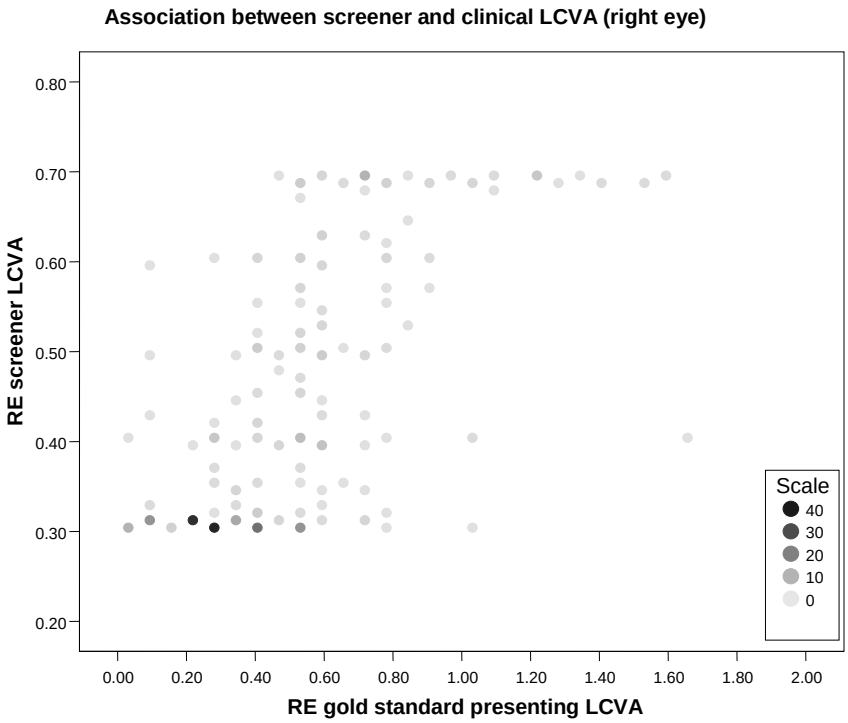


Figure 7.19 Association between screener and clinical LCVA (right eye). The association is confounded by the upper limit (0.7 LogMAR) and lower limit (0.3 LogMAR) of the screener for measuring LCVA.

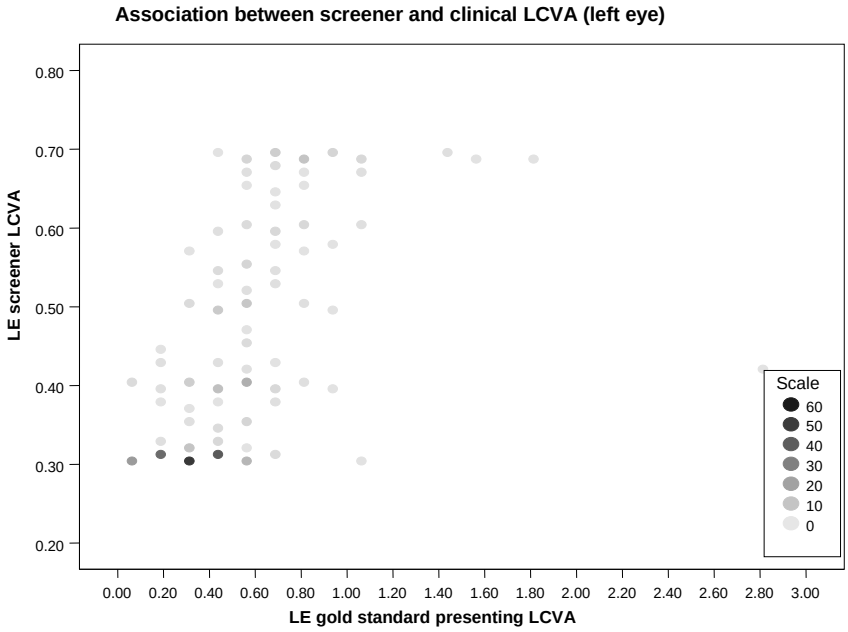


Figure 7.20 Association between screener and clinical LCVA (left eye). The association is confounded by the upper limit (0.7 LogMAR) and lower limit (0.3 LogMAR) of the screener for measuring LCVA.

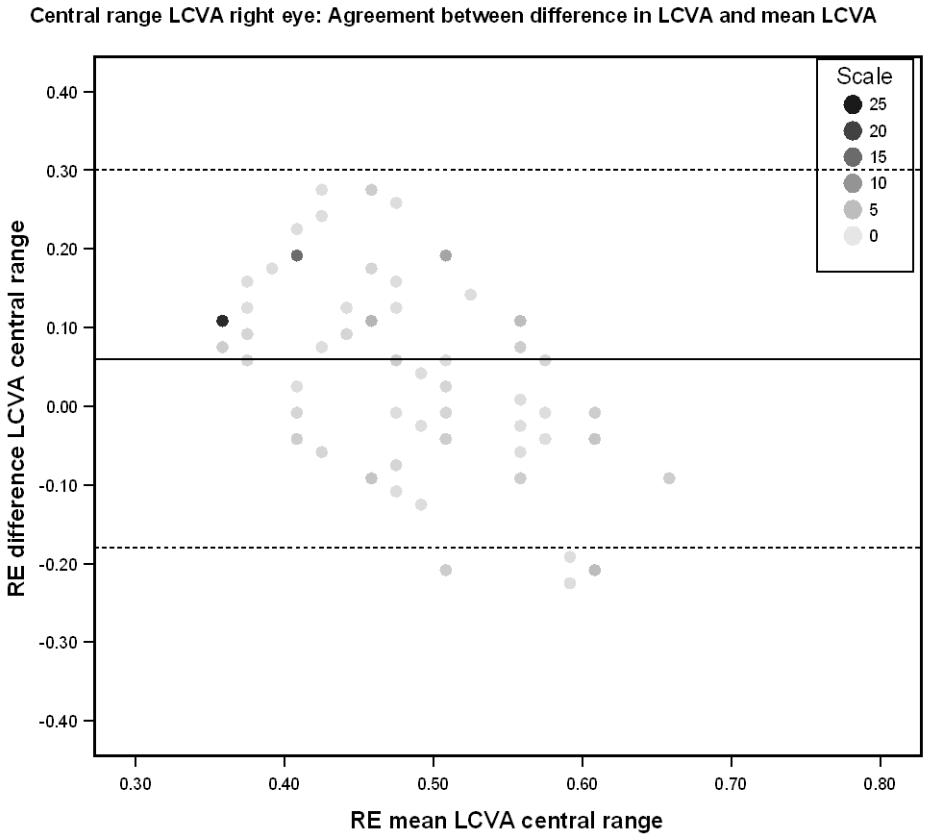


Figure 7.21 Bland and Altman plot of the difference in LCVA v mean LCVA in right eye for gold standard and screener high contrast VA. The central range of data used excludes those with a gold standard presenting low contrast acuity of less than 0.4 LogMAR and greater than 0.6 LogMAR (N=146). The mean difference (solid horizontal line) is 0.060 and the standard deviation is 0.12. The upper and lower dashed lines represent + and – 2 standard deviations from the mean (0.30 and -0.18).

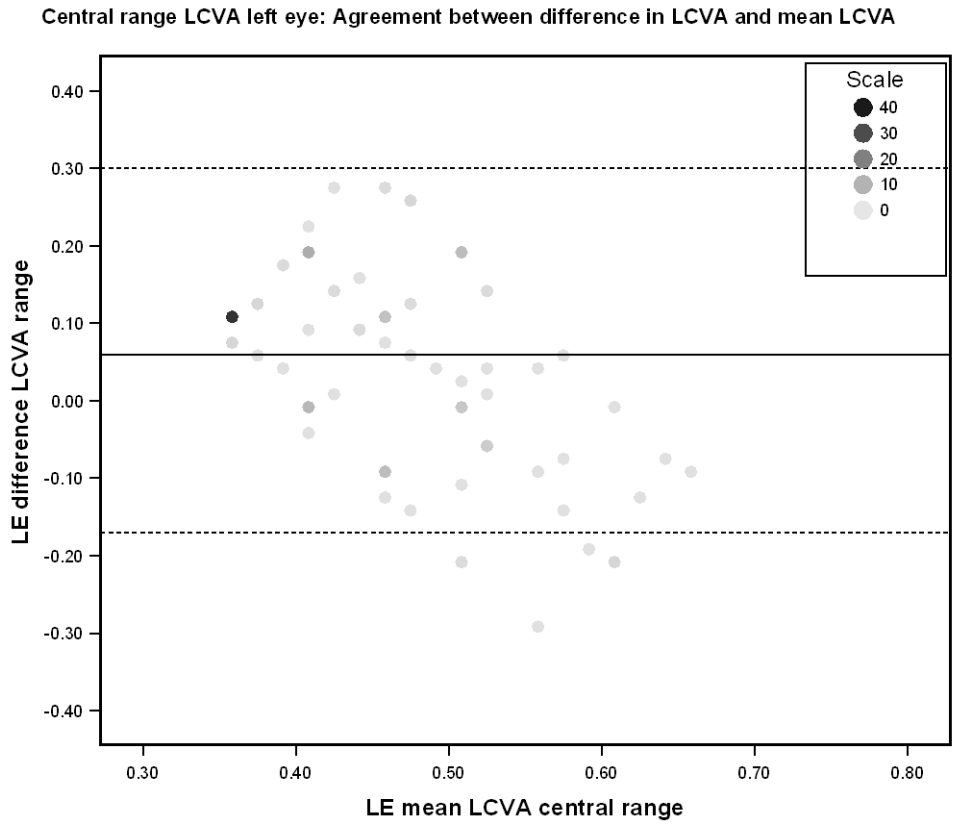


Figure 7.22 Bland and Altman plot of the difference in LCVA v mean LCVA in left eye for gold standard and screener high contrast VA. The central range of data used excludes those with a gold standard presenting low contrast acuity of less than 0.4 LogMAR and greater than 0.6 LogMAR. (N=143) The mean difference (solid horizontal line) is 0.063 and the standard deviation is 0.12. The upper and lower dashed lines represent + and – 2 standard deviations from the mean (0.30 and -0.17).

7.2 Conventions for statistical analysis of ability of screening instruments to detect target conditions

There are a various statistical conventions that can be used in the analysis of results from diagnostic studies and this chapter summarises the key aspects that were considered when analysing the results from Study 1 and Study 2. Different approaches were taken in the analyses of the two studies and the main reason for this was because the two studies had different objectives. The main goal of the first study was to determine which tests would be useful to incorporate in the refined vision screener. The second study focused on which combinations of tests would be useful in the detection of correctable visual loss. Therefore, in the analysis of Study 2 a greater emphasis was placed on combining tests.

7.2.1 Statistical analyses of multi eye data

One of the difficulties when analysing results from ophthalmic research is that each participant contributes two data points, one from each eye. Measurements from the two eyes of a single subject are usually positively correlated. This is because a multitude of factors, including environmental and genetic factors, have an impact on the probability of a finding occurring in both eyes. Therefore, pooling the data from each eye of participants doubles the sample size but results in an overestimation of the precision of statistical estimates. In accordance with best practice (Ray and O'Day, 1985; Murdoch et al., 1998) and the approaches used in other studies of vision screening (Ivers *et al.*, 2001a;Woods *et al.*, 1998b), it was decided to perform statistical analysis to determine the best cut-off points on the left eye data only. The left eye was selected since clinical convention is to test this eye second, so that the right eye can be considered as a "practice eye". In later stages of the analyses, where test combinations are being evaluated to determine the overall ability of the screener to detect the target conditions in either eye, then the data for each eye is used as appropriate (see Section 7.6).

7.2.2 Key Statistics

A number of statistics can be used to describe the outcome of a screening / diagnostic test including sensitivity, specificity and predictive values. These are defined in Table 7.3 below.

Table 7.3 Summary of evaluation of screening test.

(PV, predictive value)		**Gold standard (full eye examination)**	
		Positive	**Negative**
Screening test Result	**Test positive**	TP (true positive)	FP (false positive)
	Test negative	FN (false negative)	TN (true negative)
Sensitivity = TP/TP+FN Specificity = TN/FP+TN +ve PV = TP/TP+FP -ve PV = TN/FN+TN			

The sensitivity of a test is a measure of the accuracy of the test for detecting individuals affected by the target condition while specificity is a measure of the

accuracy of the test in detecting patients who **do not** have the target condition. Calculations of the sensitivity and the specificity of the tests for detecting the target conditions were used throughout the analyses of both studies, particularly to determine the cut-off values for the tests.

However, in order to determine the sensitivity and specificity of a test, all participants must be assessed by the screening test and the Gold Standard test, as happened in the present research. In practice, this information is seldom available in an established screening programme because those that pass the screening are not re-assessed. In these circumstances, the probability that the condition is present when the test is positive (positive predictive value) or that the condition is absent when the test is negative (negative predictive value) can be calculated (Garb, 1996).

These key statistics were used in the evaluation of the screening tests. Another key statistic that was used was ‘area under the curve’ which was derived from the ROC curves. ROC curves formed an important part of the analyses and will now be discussed.

7.3 Importance of ROC curves in evaluating screening tests

In order to determine the “effectiveness” of the various screening tools that have been developed, it was necessary to establish that they were failing the appropriate patients (i.e. those that have significant correctable visual loss, according to the gold standard) and passing the appropriate patients (i.e. those whose vision was within acceptable standards according to the gold standard). In order to do this, the first step was to establish cut-off values (pass/ fail criteria) for the screening tests (i.e., the value above which the patient ought to be referred for an eye examination). ROC curves provide a useful method for establishing an optimum cut-off value.

ROC curves are generated by plotting sensitivity against (1-specificity) for a range of different pass/fail criteria. The pass/fail criterion which gives the optimum sensitivity and specificity can then be determined. Haynes and colleagues explain

the properties of ROC curves and these are summarised in Table 7.4 (Haynes *et al.*, 2006). An example of an ROC curve can be seen in Figure 7.23

Table 7.4 Properties of ROC curves

It illustrates the performance of a dichotomous diagnostic test when different cut off points are selected to distinguish "normal" from "abnormal" results. The effect of using different cut off values on the ROC curve will be discussed below.
It demonstrates the fact that any increase in sensitivity will be accompanied by a decrease in specificity, and vice versa.
The closer the curve gets to the upper left corner of the graph, the better the overall accuracy of the test.
The closer the curve comes to the 45-degree diagonal of the ROC space, the less accurate the test.
The area under the curve provides an overall measure of a test's accuracy. This property is useful when trying to decide which of two competing tests for the same target disorder is the better one. This will be explained in more detail later in this section

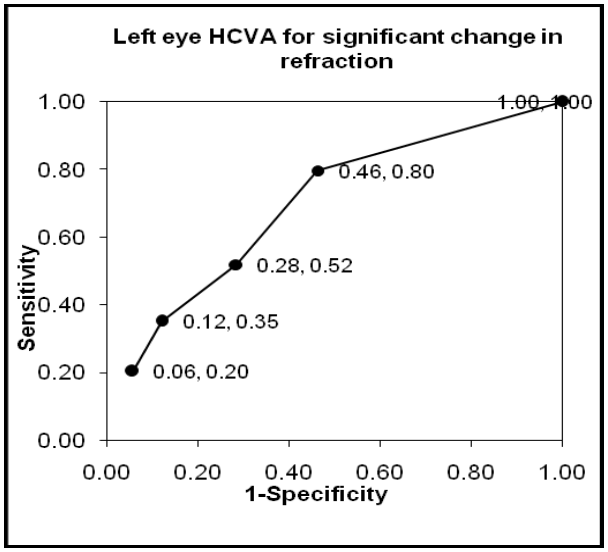


Figure 7.23 Example of an ROC curve showing the suitability of various cut off values of high contrast visual acuity (HCVA) for determining significant gain in acuity through refractive correction. The data labels indicate the X and Y co-ordinates

7.3.1 The effect of changing cut off values on ROC Curves

A perfect screening test would have a sensitivity and specificity of 1.00 and the ROC graph would pass through the top left corner of the graph. A screening test with no discriminative ability would produce a line with unit gradient passing from (0,0) to (1,1). In practice, most screening tests lie between these extremes and the extent that the curve deviates from the 45° diagonal line provides a visual

indication of the effectiveness of the test. The optimum cut-off value depends on the nature of the screening and the relative importance of false negatives and false positives. Cut off values can be manipulated to increase or decrease the sensitivity depending on whether it is more important for the test to be sensitive or specific (Garb, 1996). In this way the best compromise between sensitivity and specificity can be achieved.

7.3.2 Area under the curve (AUC)

The Area under the Curve (AUC) is frequently used to provide a single index of the effectiveness of a screening tool (Hanley & McNeil, 1982). This area is equal to the probability that a random person with the disease has a higher value of the measurement than a random person without the disease. The area is 1 for a perfect test and 0.5 for an uninformative test (Altman, 2007f).

Calculating the area under the curve can be done in 3 ways (Hanley & McNeil, 1983d); the first is using the slope and the intercept of the ROC curve. The second method is the Trapezoidal method, this non parametric method corresponds to Wilcoxon statistics (Lee & Rosner, 2001). The third method utilizes the maximum likelihood estimation technique, and is a method that is more accessible than the others (Hanley & McNeil, 1983). The non parametric method of calculation tends to systematically underestimate the area compared to the maximum likelihood technique (Hanley & McNeil, 1983;Centor & Schwartz, 1985). However, these differences are generally small, particularly with ROC curves derived from five or more cut-off points. Results of the significance of differences between two ROC curves will be similar, regardless of which method is used, as long as the same estimation technique is used on the two curves and as long as the two ROC curves being compared are of similar shape (Centor & Schwartz, 1985).

There are various computer programs that assist in the calculation of the area under the ROC curve. A paper published in 2003, comparing 8 such programs including SPSS and Analyse-it (both these programs were available for the analyses of the present research) concluded that although the programs may have used different calculations, they produced equivalent results (areas under the

curves and their characteristics) (Stephan *et al.*, 2003). SPSS uses a non parametric approach based on the trapezoidal algorithm outlined by Hanley (Hanley & McNeil, 1983) and is the statistical package that has been used to calculate the AUC in the present study.

7.4 Combining tests

One of the main objectives of the research was to determine the most appropriate test or battery of tests to detect correctable visual loss. Most previous studies have relied on the outcome of single tests (Ivers *et al.*, 2001) arguing that combining the results of more than one test would make the test too difficult to administer. However, with the advent of the computerised screener, it has become feasible to build in a more complex analysis of multiple results without affecting its ease of use.

Bayesian theory suggests that given two unrelated measures, which can each discriminate disease, discriminability is increased by using both tests. A positive result with both tests (an AND criterion) would indicate a greater likelihood of the presence of disease. Clinicians intuitively use this approach in their reasoning when making a diagnosis. However, by combining the tests in this way, there is a reduced chance of a patient failing the screening test (as in order to fail, the patient would have to fail all parts of the test combination). This would have the effect of reducing the sensitivity although increasing the specificity of the test. As the different components of our screening computer program assess different aspects of visual function, it was thought inappropriate to combine tests using AND (i.e., the requirement that the individual has to fail all tests in the combination.

Of the two relevant Boolean operators (AND and OR), the OR term would seem most appropriate for the present research. For example, uncorrected refractive error might cause blur at distance or near and it would therefore seem appropriate to combine the distance and near screening visual acuity tests using an OR criterion. Similarly, high contrast visual acuity is likely to detect uncorrected refractive errors, but low contrast visual acuity might be better at detecting cataract.

Therefore, combining the screener high contrast and low contrast acuity results using an OR criterion would seem more appropriate.

7.5 Either eye or both eyes

One occasion where an OR operator might be more relevant than an AND operator is in the decision about whether to base the analyses on one eye or both eyes. This is a fundamental decision which affects the rest of the analyses. Valid arguments can be made for either using the AND operator or the OR operator. If a person has a marked visual impairment in both eyes then they are likely to have greater problems in everyday life than a person who has visual impairment in only one eye. For example, the legal requirements for a normal driving license allow a person with reduced or no vision in one eye to drive, but not if the poor vision is in both eyes. From this perspective, it could be argued that analyses of the monocular data should be done using an AND operator: a person only 'fails' a test if they have poor vision in both eyes, not just if they have poor vision in one eye.

However, there are also very good arguments for using an OR operator in this context. A growing body of research in recent years has emphasised the importance of having two good eyes. Much of this has been related to cataract surgery and, to quote from a recent paper (Hoffmeister *et al.*, 2007): 'Several studies have demonstrated the benefit of second-eye surgery especially in stereopsis and in patient-reported visual disability'. The reason for this is easy to understand in terms of the effect on stereoacuity, which requires good monocular input and which is important in the prevention of falls (Lord & Dayhew, 2001). An additional reason why it may be important to have good vision in each eye is if binocular visual acuity could be impaired by reduced vision in one eye. This relates to binocular summation and the literature on binocular summation will now be briefly reviewed.

7.6 Binocular summation

Binocular summation, defined as an increase in the binocular response compared with the monocular, occurs when the sensitivities of the two eyes are equal or similar so that two eyes produce a better sensitivity than one (Pardhan *et al.*,

1990). However, when the image in one eye is degraded, the binocular response decreases until, with increased degradation, the binocular sensitivity falls below the monocular (Pardhan *et al.*, 1990). This binocular inhibition is also apparent with monocular glare sources (Pardhan *et al.*, 1990;Pardhan & Gilchrist, 1990). In unilateral cataract, binocular inhibition is more marked at high than at low spatial frequencies (Pardhan & Gilchrist, 1991).

For vernier acuity, binocular sensitivity is better than monocular when the targets are of low contrast, but the binocular advantage disappears when high contrast targets are used, apparently as a result of saturation (Banton & Levi, 1991). A similar effect has been reported in patients with unilateral cataract using letter charts (Pardhan, 1993). Normal subjects showed binocular summation but cataractous patients showed no summation at high contrast and binocular inhibition with low contrast charts (Pardhan, 1993).

Binocular summation also occurs in motion detection (Hess *et al.*, 2007). Binocular summation is reduced in older subjects, for central high spatial frequency (Gagnon & Kline, 2003) stimuli and for peripheral (Pardhan & Whitaker, 2003) stimuli.

The relevance of these findings to unilateral cataract is not just theoretical; it has been shown that second eye cataract surgery improves binocular summation as well as stereoacuity (Laidlaw & Harrad, 1993).

These results have a number of implications for the studies described in this thesis. First, it cannot be assumed that the binocular performance for a given test will always be the same or slightly better than the best monocular performance. In some cases, a degraded monocular image (e.g., from cataract or uncorrected refractive error) might render the binocular percept worse than the monocular. This effect is likely to be most marked for low contrast and detailed targets.

In summary, binocular visual acuity can be impaired by reduced vision in one eye and this is especially true for low contrast stimuli. This adds weight to the argument that vision screening instruments should detect reduced visual acuity in either eye, using a right OR left criterion. Another goal of the research was to develop vision

screening tests for detecting visual problems that the patient might be unaware of, which would particularly include a monocular deficit. It was therefore decided that the analyses should concentrate on combining monocular data using an OR criterion

The computerised screener and the flipchart screener measure distance high and low contrast visual acuity monocularly. These tests will therefore detect significant monocular deficits and therefore it was argued that within the context of screening, a single binocular measurement of near acuity would be sufficient.

7.6.1 Limitations of using Boolean operators

Although the OR operator seems most appropriate for clinical tests, symptoms are less straightforward: they are by definition subjective and can be non-specific. For example, patients might complain of blurred near vision simply because their lighting is poor. Indeed symptoms are so common amongst elderly patients that using the presence of any symptom as a basis of a screening fail would result in the majority of patients being referred. It seems more sensible to use an AND operator for symptoms: a person with symptoms would only fail the screener if they also had an abnormal test result on one of the screener vision tests. But since we would like to detect participants who are unaware of their visual problem, it would not make sense to apply this logic in reverse: to only fail a person with an abnormal vision test result if they also have symptoms. This is a disadvantage of using simple pass/fail criteria with Boolean logic.

Another disadvantage is that using simple pass/fail (binary) criteria for the vision tests does not take account of borderline results. For example, a person who just failed the low contrast acuity result but easily passed high contrast distance and near acuity might not necessarily be more impaired than a person who only just passed all three tests. Yet the first person would fail and the second would pass. An alternative approach would be to develop a test algorithm, where test results could be combined in a more sophisticated way. For example, the test and symptom results could be scored, using scoring systems that were weighted according to the clinical significance and diagnostic power of each test, and

summated to determine whether the person passed or failed (Thomson & Evans, 1999). The weighting in this algorithm approach should be based on the diagnostic power of each individual test, and the first priority of the analyses below is to determine this. There is scope for future research in this area to investigate if an algorithm can be developed which performs better than a simple combination of test results using Boolean operators. Further ideas for future research are discussed in Chapter 12.

7.7 A note on confidence intervals (CIs)

Sensitivity and specificity are the most commonly cited indices of the effectiveness of screening. However, these merely describe the effectiveness in relation to the sample screened rather than the wider population. The likelihood that the values provide a good estimate for the wider population can be gauged by calculating the confidence intervals. In other words, the confidence interval around an estimate provides the range of values that is believed to encompass the actual ("true") population value (Medina & Zurakowski, 2003a) or "the main purpose of confidence intervals is to indicate the im(precision) of the sample study estimates as population values" (Altman, 2007e). Wider confidence intervals indicate lesser precision, while narrower ones indicate better precision (Medina & Zurakowski, 2003b). The width depends essentially on three factors. First, the sample size: larger sample sizes will give more precise results with narrower confidence intervals. Wide confidence intervals emphasize the unreliability of conclusions based on small samples. Second, the variability of characteristics being studied: the less variable it is (between subjects, within subjects, from measurement error and from other sources) the more precise the sample estimate and the narrower the confidence interval. Third, the degree of confidence required: if greater or lesser confidence is required different intervals can be constructed. Greater confidence that the population difference is within a confidence interval is obtained with wider intervals (Altman, 2007).

If one repeatedly obtained samples from the population and constructed CIs for each sample, then one would expect a certain percentage of the CIs to include the value of the true population and a certain percentage of them not to include that

value. For example, with a 95% CI, the level of certainty is 95% of such CIs obtained in repeated sampling including the true parameter value and only 5% of the CIs not including the true parameter value (Medina & Zurakowski, 2003c).

7.7.1 Methods of calculating confidence intervals for proportions

The traditional methods of calculating confidence intervals are based on the standard approach of taking a multiple of the standard error either side of the sample proportion (Altman, 2007). Although these methods perform quite well in many cases, they have certain deficiencies and are not valid when zeros or small numbers are involved (Newcombe, 1998;Newcombe, 1998). Traditional methods of calculating confidence intervals should not be used for very low observed proportions, such as the prevalence of a disease or very high ones, such as the sensitivity or specificity of a good diagnostic test (Altman, 2007). Alternative methods (Newcombe, 1998;Newcombe, 1998;Wilson, 1926) are available that although not as simple or intuitive, give much better results across all circumstances (Altman, 2007). The recommended method used to calculate a confidence interval for a proportion is the Wilson score method without continuity correction (Newcombe, 1998). This is the method used to calculate confidence intervals throughout the study.

This chapter has focused on descriptive statistics, comparisons of the screener data with gold standard data (stages 1 and 2 in Figure 7.1), and conventions in statistical analyses that can be used when evaluating data from screening tests (an outline of stages 3-5 in Figure 7.1). The next chapter will present the results from CVS1. The monocular cut off values together with the key statistics will be presented using ROC curves in order to determine appropriate cut-off values of the tests in the computer screener for the detection of target conditions. The definitions for the target conditions have been outlined in Chapter 4 and it is these definitions that have been used to plot the ROC curves.

Chapter 8

Study one: Preliminary investigation of the effectiveness of a computer-based system for screening the vision of older people in the community

8.1 Introduction

The computer-based screener described in Chapter 4 was used to screen older people aged 65 and over for correctable visual loss. All participants also received a gold standard eye examination. The suitability of the tests in the screener were evaluated so that the appropriate tests could be incorporated into the refined vision screener. The computerised screener was well received by all participants and none of the participants found the instructions hard to understand. This Chapter describes the results from the first version of the computer vision screener (CVS1). The results from the refined computerised screener (CVS2) and the rapid flip chart screener are described in subsequent chapters.

A total of 180 patients participated in study one (46% male, 54% female). The mean age was 77 (range 67 to 99 year). The descriptive data from the study is outlined in Chapter 7. 22 patients (12%) were examined in the Pulross Intermediate Care centre, 14 patients (7%) were seen at a community-based optometric practice and the remainder (144 patients) were seen at the Institute of Optometry. The descriptive data including histograms showing the distributions of cataract, visual acuity and refractive error can be found in Chapter 7.

8.2 Monocular data: selection of appropriate cut offs

Receiver operator curves for Study 1 are presented below for each of the target conditions together with key statistics to evaluate the ability of the test to detect the target condition. 95% confidence intervals are quoted in parentheses. A full description of ROC curves can be found in Section 7.3. It should be noted that the ROCs in the next few sections, although necessary to select the optimum cut-offs for the screener, are likely to underestimate the screener's ability to detect patients with poor vision. This is because many of these ROCs compare a grading of the **appearance** of an ocular condition (e.g., cataract or AMD) in the gold standard examination with the **functional status** of the eye (e.g., high contrast visual acuity) as measured with the screener. Apart from the intuitive limitation of attempting to correlate structure with function, these ROCs will also be limited because many different conditions influence the functional measures (e.g., visual acuity). It could be argued that a more valid measure of screener performance is to evaluate whether it detects those cases that an optometrist would be likely to feel needed an eye examination taking account the spectrum of clinical findings. Such an evaluation is carried out in Section 8.2.7.

8.2.1 The ability of presenting screener visual acuity to determine significant cataract

(a) (b)

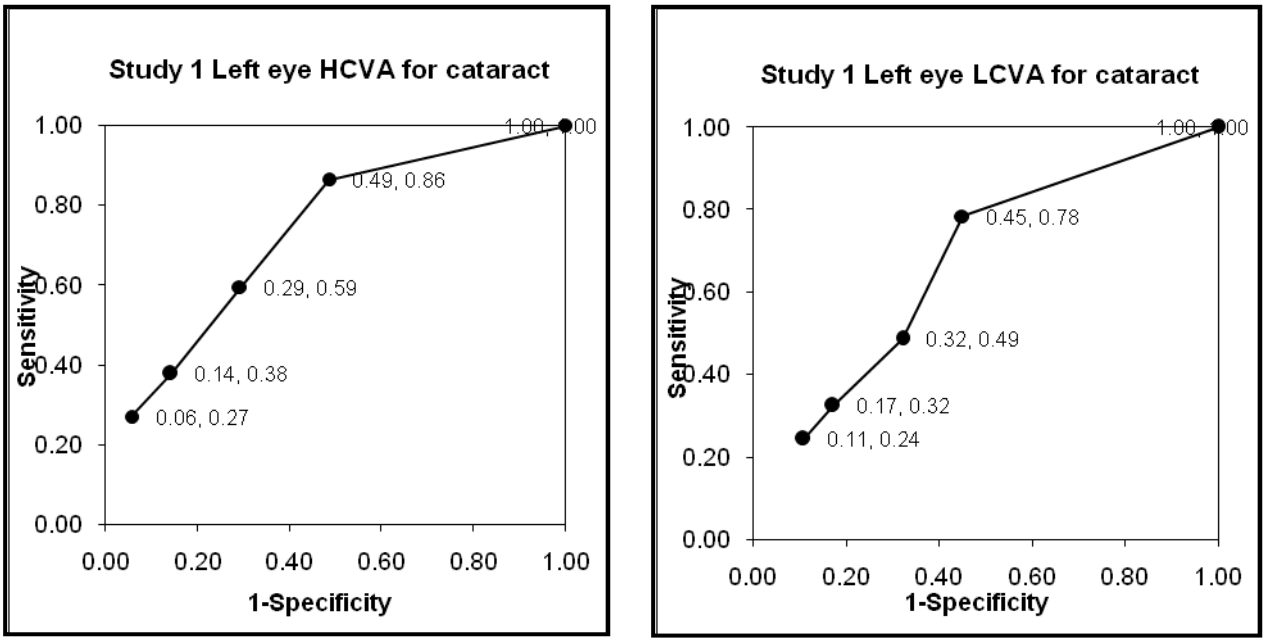


Figure 8.1 Graph illustrating the sensitivity versus 1-specificity for (a) high contrast visual acuity and (b) low contrast visual acuity of the left eye obtained with CVS1 for predicting presence of significant cataract in the left eye as defined in Chapter 4. The data labels state the X and Y coordinates

The key statistics for Figure 8.1 can be found in Table 8.1

Table 8.1 The key statistics for the LogMAR acuity cut off values obtained from Figure 8.1

Study 1 Cataract	High Contrast Acuity	Low Contrast Acuity
Ideal Cut Off (LogMAR)	VA>0.19	VA>0.39
Sensitivity (%)	86.5 (72- 94.1)	78.4 (62.8- 88.6)
Specificity (%)	51.4 (43.2- 59.6)	55 (46.7- 63)
PPV (%)	32 (23.7- 41.7)	31.5 (22.9- 41.6)
AUC	0.743 (0.663-0.823)	0.672 (0.580-0.765)

8.2.2 The ability of screener visual acuity to detect significant gain in acuity with new refractive correction (Rx)

(a) (b)

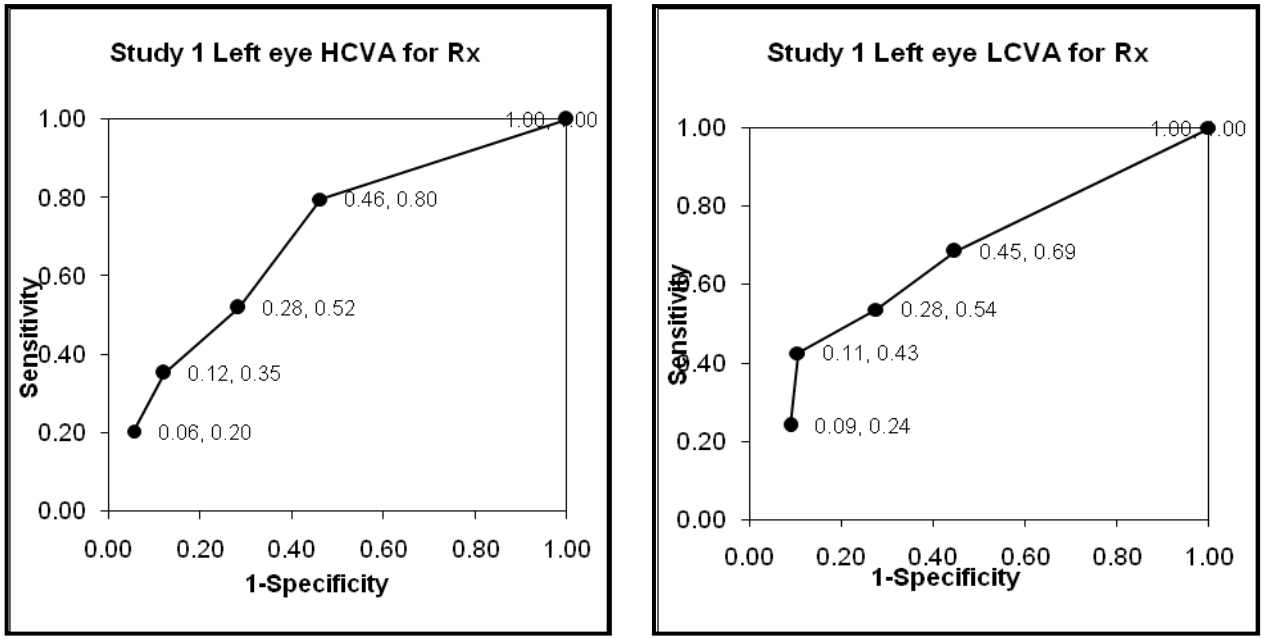


Figure 8.2 Graph illustrating the sensitivity versus 1-specificity for (a) high contrast visual acuity and (b) low contrast visual acuity of the left eye obtained with CVS1 for predicting presence of significant gain in acuity with new refractive correction as defined in Chapter 4. The data labels state the X and Y coordinates

Table 8.2 The key statistics for the LogMAR acuity cut off values obtained from Figure 8.2

Study 1 Refractive correction	High Contrast Acuity	Low Contrast Acuity
Ideal Cut Off (LogMAR)	VA>0.19	VA>0.39
Sensitivity (%)	79.6 (67.1-88.2)	68.5 (55.3-79.3)
Specificity (%)	53.7 (44.9-62.2)	55.3 (46.5-63.8)
PPV (%)	43 (33.7- 52.8)	40.2 (30.8- 50.4)
AUC	0.690 (0.603-0.777)	0.660 (0.565-0.755)

8.2.3 The ability of presenting visual acuity to detect correctable visual loss (CVL)

The results so far in this chapter have looked at the ability of distance acuity (high contrast and low contrast) to detect significant gain in distance acuity through refractive correction and the detection of significant cataract. For the purpose of the ROC curve below correctable visual loss is defined as the presence of significant cataract (defined in Chapter 4) and/or significant gain in distance acuity through refractive correction (defined in Chapter 4).

(a) (b)

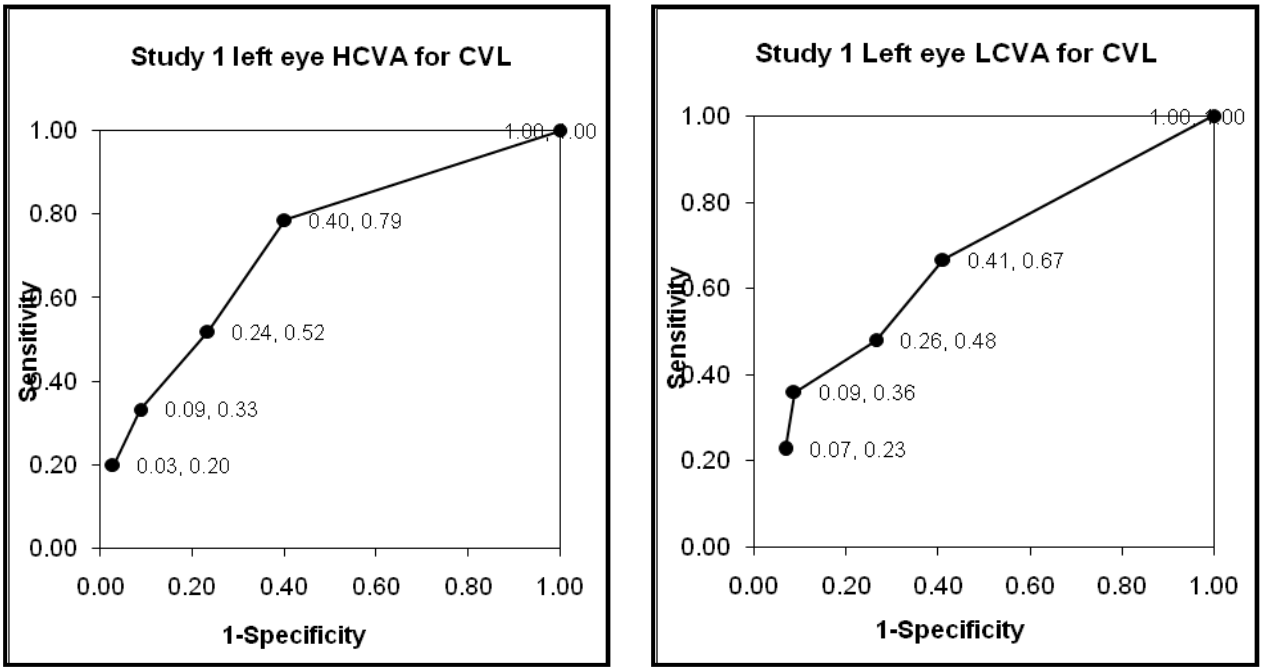


Figure 8.3 Graph illustrating the sensitivity versus 1-specificity for (a) high contrast visual acuity and (b) low contrast visual acuity of the left eye obtained with CVS1 for predicting presence of CVL as defined above. The data labels state the X and Y coordinates

Table 8.3 The key statistics for the LogMAR acuity cut off values obtained from Figure 8.3

Study 1 CVL	High Contrast Acuity	Low Contrast Acuity
Ideal Cut Off (LogMAR)	VA>0.19	VA>0.39
Sensitivity (%)	78.7 (68.1-86.4)	66.7 (55.4-76.3)
Specificity (%)	59.8 (50.1-68.8)	58.8 (49.1-67.9)
PPV (%)	59 (49.2-68.1)	54.3 (44.2- 64.1)
AUC	0.740 (0.667-0.814)	0.665 (0.583-0.747)

Figure 8.3 and Table 8.3 illustrate the fact that not all visual acuity deficits are correctable and this is discussed further in Chapter 12

8.2.4 The ability of presenting visual acuity to detect macular degeneration (MD)

(a) (b)

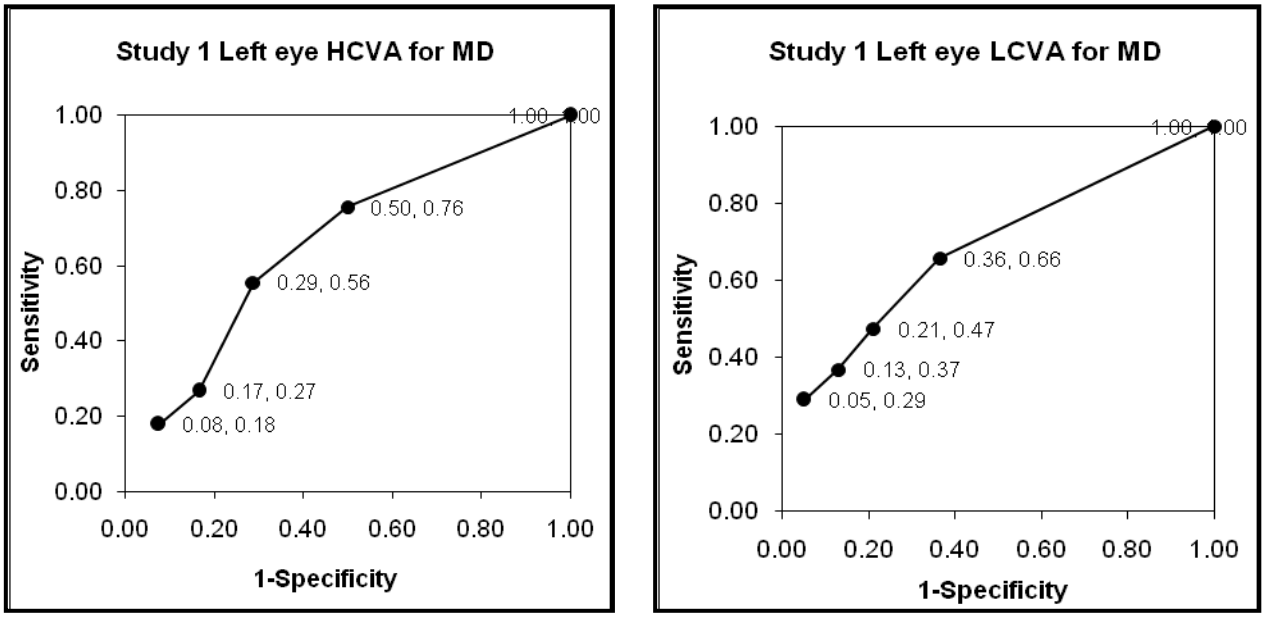


Figure 8.4 Graph illustrating the sensitivity versus 1-specificity for (a) high contrast visual acuity and (b) low contrast visual acuity of the left eye obtained with CVS1 for predicting presence of significant macular degeneration as defined in Chapter 4. The data labels state the X and Y coordinates.

Table 8.4 The key statistics for the LogMAR acuity cut off values obtained from Figure 8.4

Study 1 MD	High Contrast Acuity	Low Contrast Acuity
Ideal Cut Off LogMAR)	VA>0.19	VA>0.39
Sensitivity (%)	75.6 (61.3-85.8)	75.6 (61.3-85.8)
Specificity (%)	50 (41.6-58.4)	56.1 (47.5 -64.2)
PPV (%)	34 (25.5-43.7)	37 (27.8-47.2)
AUC	0.655 (0.563-0.748)	0.691 (0.603- 0.778)

8.2.5 The ability of presenting visual acuity to detect refractive error, cataract, and MD

The presence of refractive error, cataract, or MD is labelled in the graphs below as 'significant acuity impairing eye conditions' (SAIEC).

(a) (b)

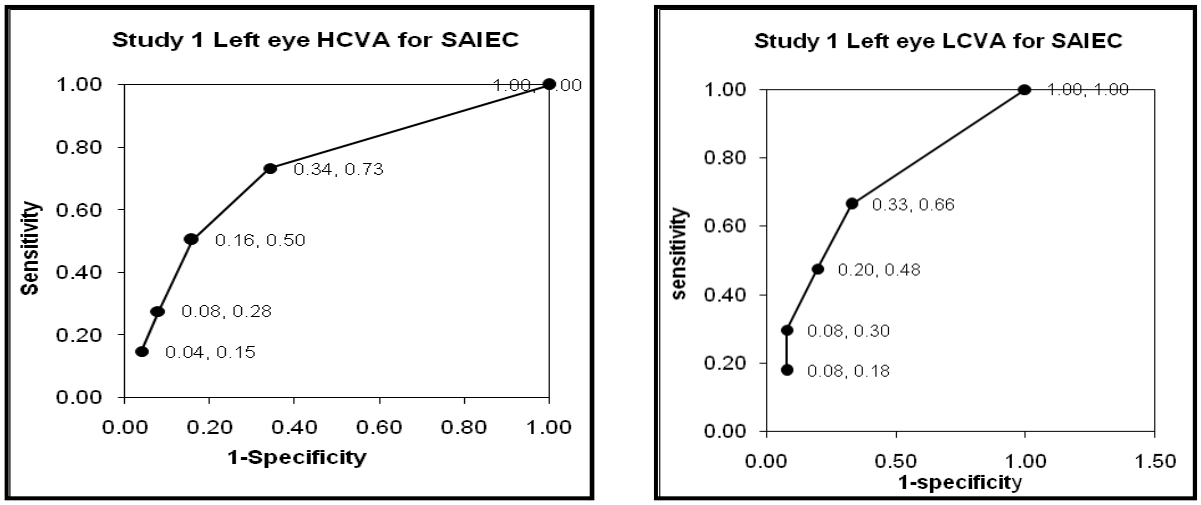


Figure 8.5 Graph illustrating the sensitivity versus 1-specificity for (a) high contrast visual acuity and (b) low contrast visual acuity of the left eye obtained with CVS1 for predicting SAIEC as defined above. The data labels state the X and Y coordinates

Table 8.5 The key statistics for the LogMAR acuity cut off values obtained from Figure 8.5

Study 1 SAIEC	High Contrast Acuity	Low Contrast Acuity
Ideal Cut Off (LogMAR)	VA>0.19	VA>0.39
Sensitivity (%)	73.3 (63.9-80.9)	66.3 (56.7-74.8)
Specificity (%)	65.8 (54.6-75.5)	67.1 (55.9-76.6)
PPV (%)	74 (64.6-81.6)	72.8 (63-80.9)
AUC	0.739 (0.665-0.813)	0.691 (0.612-0.770)

8.2.6 The ability of presenting visual acuity to determine significant acuity impairing eye conditions in either eye

The ROC curves above evaluated the ability of distance acuity in detecting significant acuity impairing eye conditions (SAIEC) in the left eye. The ROC curves below give an indication of how well HCVA and LCVA in the worst eye can detect significant acuity impairing eye conditions (i.e. significant uncorrected refractive error, significant cataract and/or macular degeneration) in either eye.

(a) (b)

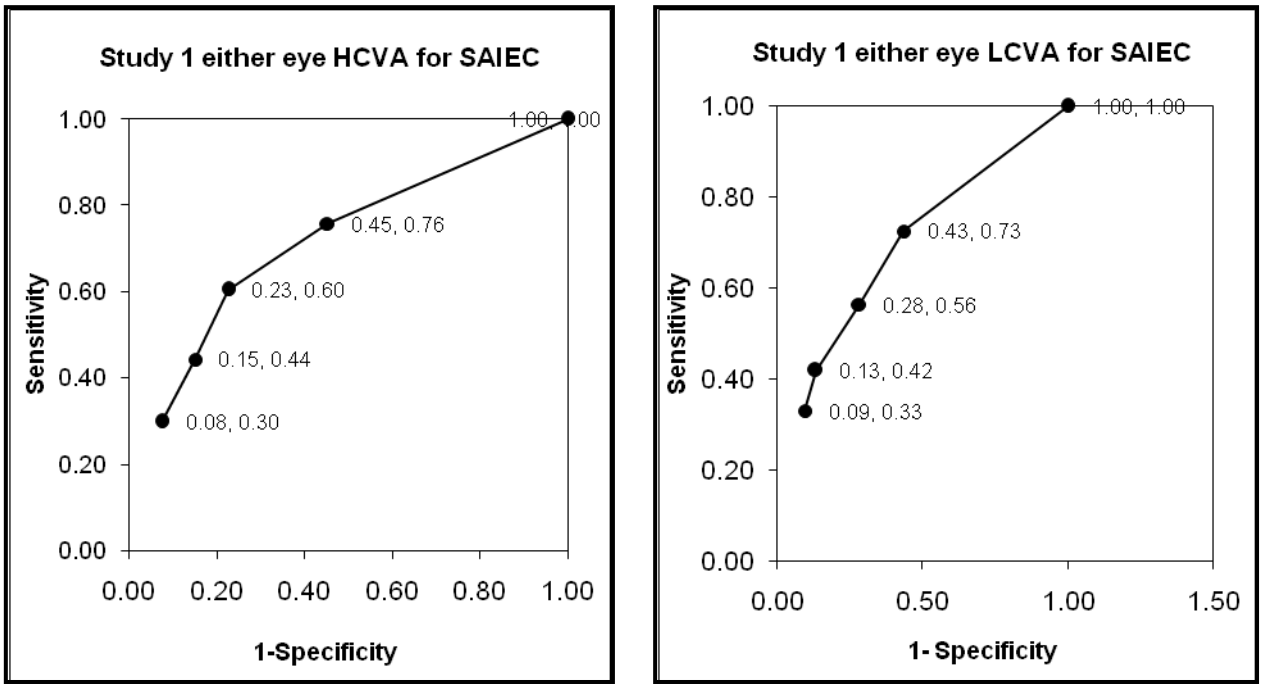


Figure 8.6 Graph illustrating the sensitivity versus 1-specificity for (a) high contrast visual acuity and (b) low contrast visual acuity of the worst eye obtained with CVS1 for predicting SAIEC as defined above. The data labels state the X and Y coordinates

Table 8.6 The key statistics for the LogMAR acuity cut off values obtained from Figure 8.6

Study 1 SAIEC (either eye)	High Contrast Acuity	Low Contrast Acuity
Ideal Cut Off (LogMAR)	VA>0.19	VA>0.39
Sensitivity (%)	75.8 (67.6-82.5)	72.6 (64.1-79.7)
Specificity (%)	54.7 (41.5-67.3)	56.6 (43.3-69)
PPV (%)	79.7 (71.5-85.9)	79.6 (71.3-86)
AUC	0.726 (0.646-0.806)	0.691 (0.612-0.770)

The value of testing distance acuity can be seen from the ROC curves presented in the chapter so far. The suitability of the near vision screening test in detecting correctable visual loss is evaluated later in the chapter. Table 8.7 below gives a summary of the cut off values obtained so far with the distance acuity screening tests

Table 8.7 Summary of CVS1 HCVA and LCVA cut off values

	HCVA			**LCVA**		
Condition	Cut off value (LogMAR)	Sensitivity (%)	Specificity (%)	Cut off value (LogMAR)	Sensitivity (%)	Specificity (%)
Cataract	VA>0.19	86.5	51.4	VA>0.39	78.4	55
Rx	VA>0.19	76.9	53.7	VA>0.39	68.5	55.3
CVL	VA>0.19	78.7	59.8	VA>0.39	66.7	58.8
MD	VA>0.19	75.6	50	VA>0.39	75.6	56.1
SAIEC (left eye)	VA>0.19	73.3	65.8	VA>0.39	66.3	67.1
SAIEC (either eye)	VA>0.19	75.8	54.7	VA>0.39	72.6	56.6

The table above shows that HCVA consistently has a reasonably high sensitivity for the detection of the conditions mentioned in the table and measuring LCVA

results in a slightly better specificity in most cases. This sensitivity is higher than might have been expected considering the point made at the beginning of Section 8.2 about the limitation of using visual function to predict structural appearance. If the results of these screening tests are combined (e.g., participants are selected who fail both or either test) then this combination may give the best sensitivity and specificity. This has also been noted in the data from Study 2 (Chapter 9) and is investigated further in the present Chapter and more so in Chapter 9.

8.2.7 Performance of the screener from an optometric perspective

It is noted at the beginning of Section 8.2 that the analyses above set a high criterion for the performance of the screener. In particular, the analyses investigate the ability of tests of visual function to detect conditions that are diagnosed by appearance during examination (e.g., cataract, AMD). From an optometric perspective, it could be argued that the screener needs to detect patients who a typical optometrist feels are likely to benefit from an eye examination. This could be defined, in a pragmatic operational way, as reduced high contrast visual acuity in one or both eyes and those who have not attended for an eye examination in the last year. Alternatively, it could be argued that optometrists may feel it appropriate to conduct an eye examination on those with reduced high contrast acuity or those who have not had an examination within the last year. The results of both of these criterion combinations are given in the table below. As with previous combinations in the present chapter, reduced high contrast acuity has been defined as VA>0.19 LogMAR.

Table 8.8 Performance of screener from an optometric perspective

Performance of screener from an optometric perspective	Sensitivity (%)	Specificity (%)	PPV (%)
HCVA >0.19 and no eye examination in the last year	82.2 (73.6-88.4)	82.9 (72.9-89.7)	86.5 (78.2-91.9)
HCVA>0.19 or no eye examination in the last year	97.6 (93.9-99.1)	75 (46.8-91.1)	98.2 (94.8-99.4)

8.2.8 The ability of fixation disparity (FD) to detect a history of falls

Fixation disparity was included in the initial test battery because one study (only) found an association between hyperphoria and driving accidents (Davison, 1985). Very few of the participants in the current study were drivers, but no studies were found that investigated whether there is a relationship between hyperphoria and falls and so the fixation disparity was included to investigate this. 25 participants reported a history of falls in the last 1 year. Only 13 participants had a hyperphoria and only 2 of these had a history of falls. 12 participants either had a hyperphoria, a horizontal fixation disparity, or suppression on the horizontal fixation disparity test.

Table 8.9 Evaluation of the fixation disparity screening test in CVS1. The coloured cells in the table below show that participants who had fixation disparity were not more likely to have a history of falls.

ACTUAL	Falls	no falls	
FD	12	67	79
no FD	13	85	98
	25	152	177

screening values	
sensitivity	48.00
specificity	55.92
positive predictive value	15.19
negative predictive value	86.73
overall accuracy	**54.80**

EXPECTED	Falls	no falls	
FD	11.	68	79
no FD	14	84	98
	25	152	

CHI-SQUARED	**p of chi-square**
Falls	0.73
No falls	0.89
FD	0.79
No FD	0.81
comparison	**0.71476**

The presence of fixation disparity was not significantly associated with a history of falls (chi-squared, p=0.71) and as such fixation disparity was not thought an appropriate test to include in the revised version of the computer screener. It should be noted that an additional reason for including fixation disparity testing might be to detect asthenopia, although since this was not a target condition and would not meet the Wilson criteria (Chapter 1) this was not analysed.

8.2.9 The ability of stereo-acuity to detect a history of falls

The stereo-acuity test was failed by an unexpectedly high proportion of participants (131 out of 177 participants). Therefore, no criterion gave better specificity than 25% for detecting a history of falls.

The reason why so many participants could not perceive any of the stimuli stereoscopically was investigated by looking at the effect of the coloured filters used in this test on visual acuity. Both filters reduced visual acuity by, on average, 0.17 LogMAR units. A paired t-test showed that the reduction in VA with the red filter was not significantly different to the reduction in VA with the green filter ($p=0.78$). It is possible that the visual acuity was reduced to a level that meant that participants could not resolve the pixels in the stereo-acuity test.

This might also explain a recent finding of reduced stereoacuity in older people with the TNO test, which also uses red/green filters (Garnham & Sloper, 2006). The results indicate that the stereoacuity test used in the screener was not suitable alone to detect a history of falls. In order to investigate whether another type of stereoacuity test would be useful, the gold standard data was investigated and the ROC curve for this is shown in Figure 8.7.

Figure 8.7 indicates that although the test is reasonably sensitive it is not specific at all. Taking this graph into account, it appears that stereoacuity has little value in this context and should not be included in the revised version of the computer screener. As noted in the introductory chapters and discussion, falls are multifactorial and it is perhaps not surprising that a single vision test, even one as intuitively relevant as stereoacuity, does not have good predictive ability in the present context.

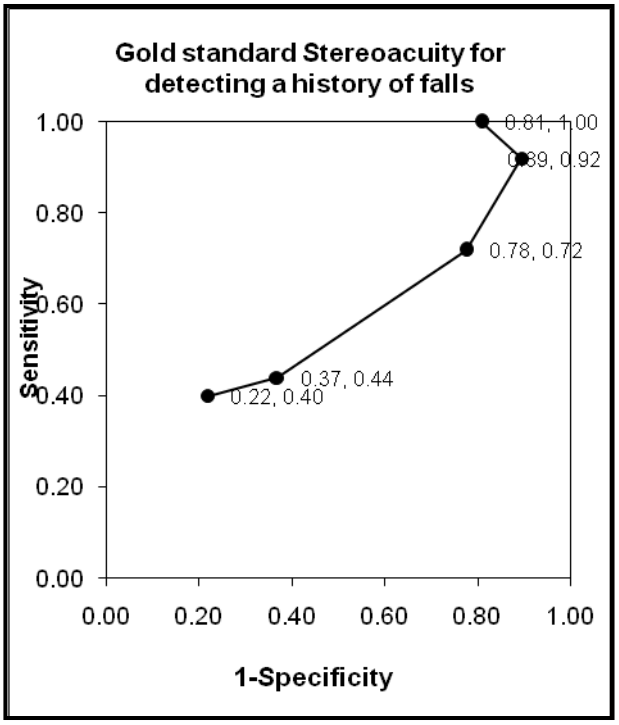


Figure 8.7 Graph illustrating the sensitivity versus 1-specificity for stereoacuity data obtained with the gold standard eye examination for detecting a history of falls within the last year. The data labels state the X and Y coordinates.

8.2.10 The ability of the visual field screening test (VF) to detect patients with or at risk of glaucoma

This category included patients who were already diagnosed with glaucoma as well as patients who were referred to the hospital eye service on the basis of the gold standard test results: fields, pressures, optic nerve head fundoscopy and in many cases GDX. It also included cases where it was necessary to monitor the patient closely due to the risk of glaucoma based on the gold standard test results. This definition has been outlined in Chapter 9 where more in depth analyses of the screener's ability to detect glaucoma are presented.

The graph below shows how well the data from the visual field test of the left eye on the screener was able to detect those with glaucoma or those who are 'suspected' of having glaucoma in the left eye. The monocular cut off point in this case is defined as the number of points missed above which a person may need to be referred for further investigation to rule out glaucoma.

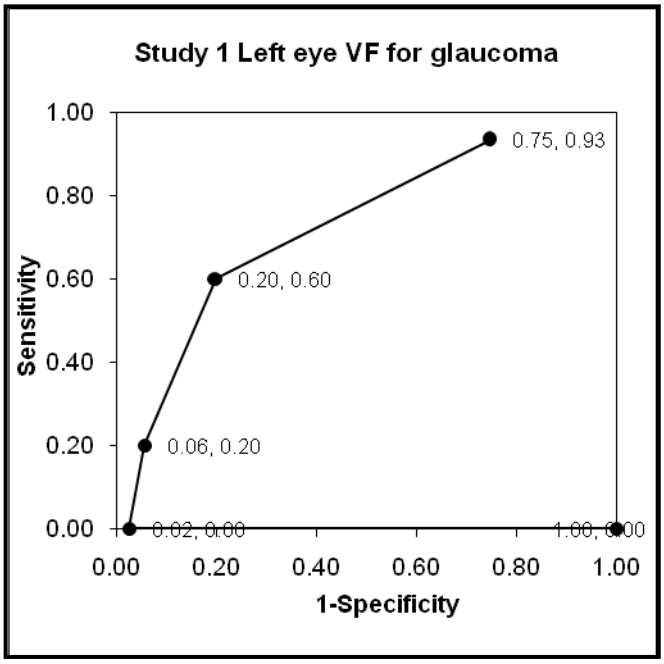


Figure 8.8 Graph illustrating the sensitivity versus 1-specificity for the visual field test data of the left eye obtained with CVS1 for detecting patients with or at risk of glaucoma in the left eye. The data labels state the X and Y coordinates

Table 8.10 The key statistics for the visual field test cut off value obtained from Figure 8.8

Study 1 VF test for Glaucoma	Points missed on VF test
Ideal Cut Off	Points missed >5
Sensitivity (%)	60 (35.7-80.2)
Specificity (%)	80.2 (73.4-85.6)
PPV (%)	22 (12-36.7)
AUC	0.731 (0.599-0.862)

When developing the computer screener it was thought important to include a visual field test because it was the only one of the three main glaucoma tests that was amenable to inclusion in a computerised vision screener. It was decided to include such a test so that its performance could be evaluated. Nonetheless, it was accepted from the outset that such a test was unlikely to match the accuracy of a full eye examination for detecting glaucoma.

The results from the above initial analyses of the visual field test incorporated in the screener indicate that it does have some value in the detection of glaucoma. It was decided to incorporate this test in the revised version of the computer screener in Study 2 so that further analyses could be conducted to investigate the performance of the visual field test when combined with the other screening tests (Chapter 9).

8.3 Evaluation of near acuity vision screening test

Most of the analyses so far in this chapter have considered screening tests where data for both the right and the left eye were obtained. As explained earlier in the chapter the CVS was designed to assess binocular near visual acuity. Therefore, in this section the graphs and tables illustrate the ability of the binocular near visual acuity to predict binocular target conditions (i.e. binocular cataract and binocular near refractive error and binocular correctable visual loss). At the end of this section, Table 8.14 which contains all the cut off values for near acuity, will summarise the section before the results of various test combinations are presented.

8.3.1 The ability of screener binocular near visual acuity test to detect significant gain in binocular near acuity with new near refractive correction (NvRx).

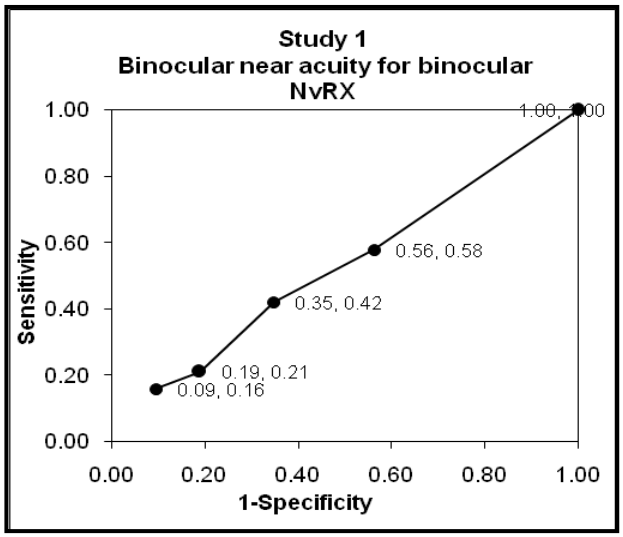


Figure 8.9 Graph illustrating the sensitivity versus 1-specificity for binocular near acuity obtained with CVS1 for predicting significant gain in binocular near acuity with new refractive correction as defined in Chapter 4. The data labels state the X and Y coordinates

Table 8.11 The key statistics for near acuity cut off values obtained from Figure 8.9

Study 1 **Near visual acuity predicting binocular NvRx**	Near acuity
Ideal Cut Off (N)	NVA> N 11.90
Sensitivity (%)	58 (36.3 -76.9)
Specificity (%)	44 (36.2 -51.5)
PPV (%)	11 (6.3 – 18.6)
AUC	0.569 (0.428 –0.709)

It is noted that the statistics in Table 8.11 obtained from the near acuity test show that the test does not appear to be as useful in the detection of the target conditions as the distance acuity tests that were evaluated earlier in the chapter. This becomes even more apparent in the analysis below and possible reasons for

this will be discussed in Chapter 12. These include the points made at the beginning of Section 8.2.

8.3.2 The ability of screener binocular near visual acuity test to detect significant binocular cataract

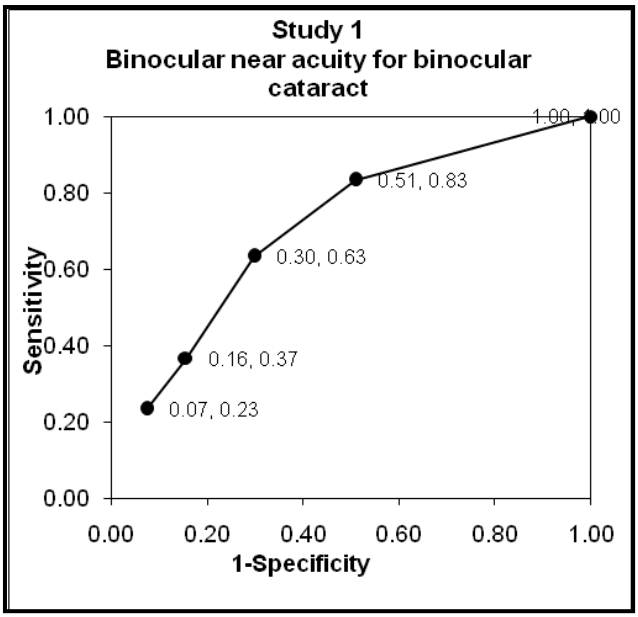


Figure 8.10 Graph illustrating the sensitivity versus 1-specificity for binocular near acuity obtained with CVS1 for predicting significant binocular cataract as defined in Chapter 4. The data labels state the X and Y coordinates

Table 8.12 The key statistics for near acuity cut off values obtained from Figure 8.10

Study 1 **Near visual acuity predicting binocular Significant cataract**	Near acuity
Ideal Cut Off (N)	NVA> N 15.90
Sensitivity (%)	63.3 (45.5-78.1)
Specificity (%)	70.1 (62.2-76.9)
PPV (%)	30.2 (20.2-42.4)
AUC	0.605 (0.493-0.716)

8.3.3 The ability of screener binocular near visual acuity test to detect significant binocular correctable visual loss (BinCVL)

Earlier in the chapter, when evaluating distance acuity correctable visual loss was defined as significant gain in distance acuity with new refractive correction or significant cataract. For the purpose of evaluating the binocular near vision screening test the definition of correctable visual loss will be amended for the next ROC curve to take into account the binocular near acuity test. Correctable visual loss has now been defined as the presence of significant **binocular** distance refractive error &/or presence of **binocular** cataract &/or significant **binocular** near refractive error.

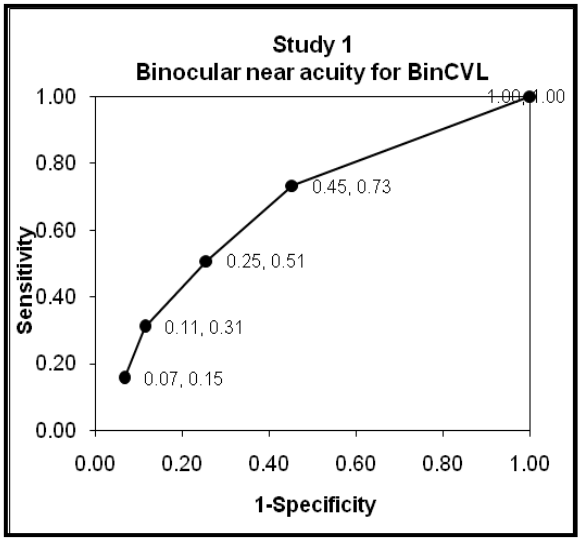


Figure 8.11 Graph illustrating the sensitivity versus 1-specificity for binocular near acuity obtained with CVS1 for predicting binocular correctable visual loss as defined above. The data labels state the X and Y coordinates

Table 8.13 The key statistics for near acuity cut off values obtained from Figure 8.11

Study 1 **Near visual acuity** **Predicting BinCVL**	Near acuity
Ideal Cut Off (N)	NVA> N 11.90
Sensitivity (%)	73.2 (61.9-82.1)
Specificity (%)	55 (45.2-63.9)
PPV (%)	52 (42.3-61.5)
AUC	0.561 (0.474-0.648)

This section will end with a summary table that states the near acuity cut off values obtained for the target conditions evaluated in this section.

Table 8.14 Summary of CVS1 near acuity cut off values

	Near acuity		
Condition	Cut off value (N)	Sensitivity (%)	Specificity (%)
Binocular Cataract	VA> N 15.9	63.3	70.1
NvRx	VA> N 11.9	58	44
Binocular CVL	VA> N 11.9	73.2	55

The chapter so far has shown that high contrast acuity is an important test to include in the revised computer screener (CVS2) due to the relatively high sensitivity obtained for the target conditions. Low contrast acuity may also be useful to include in CVS2 due to slightly better specificity it produces for the detection of the target conditions. In particular the combination of both these acuity tests may be valuable in detecting the majority of the patients with correctable visual loss. This combination of high contrast and low contrast acuity will be evaluated in the next section and in more detail in Chapter 9 with the results from Study 2. The visual field test was found to be of some value in the detection of glaucoma and glaucoma suspects and as such will be included in CVS2 and will be

evaluated in more detail with the results from Study 2. The near acuity screening test is the only method that the screening programme has of detecting uncorrected near refractive error and so this test will be incorporated in CVS2, even though the results indicate that distance acuity is more efficient at detecting the target conditions. It is possible that the near acuity test will perform better when in combination with other vision tests and this will be investigated in Chapter 9 with the results from Study 2.

8.4 Combining tests in CVS1

The purpose of this section is to give an overview of the performance of the screener before detailed test combinations for Study 2 are presented in Chapter 9.

The initial ROC curves showed the most appropriate cut-off values for the tests in the screener. In this section these tests are combined using an OR combination (i.e. the requirement that the individual has to fail either of the tests in the given combination in order to fail the screener) to obtain sensitivity and specificity values. This is calculated for the 3 conditions; significant gain in VA through refractive correction, significant cataract and correctable visual loss (combining significant refractive error and significant cataract).

The purpose of combining the tests in this way is to give a more general overview of the performance of the screener. For example if a patient presented with symptoms or has reduced HCVA in either eye or has reduced LCVA in either eye what is the likelihood that they will be correctly identified by the screener and be referred for a full eye examination. Furthermore, how many of those referred would actually have correctable visual impairment?

The sensitivity and specificity values are shown below and it is also possible to see how the sensitivity and specificity changes with the addition of each test. The screening tests that have been used in various combinations are HCVA, LCVA and the presence of visual symptoms. Tests of near acuity and visual fields will be incorporated in test combinations in the next chapter. In this chapter, the presence of symptoms has also been combined in an OR combination , as discussed earlier in this chapter, symptoms are likely to reflect more than one aspect of visual

function and as such it may be better to combine this test in an AND combination. This has been done in subsequent chapters.

By combining the tests in the way outlined, it is recognised that there is an increased chance of a patient failing the screening test (as in order to fail, the patient would only have to fail one test in the given combination). This would have the effect of increasing the sensitivity although decreasing the specificity of the test. In order to compensate for this, the cut-off value given in the initial ROC curves has been adjusted to a higher value. However, in doing this it is recognised that the correct weightings that each test has upon the target condition are not being accounted for.

In the tables below, the sensitivity and specificity of the combined tests was calculated when the cut-off values were decreased by one step (lowering the threshold so that patients would fail the test at a better acuity) and increased by one step (increasing the threshold so that patients would fail at a worse acuity).

In each table of combinations below, the best combinations for detecting the target conditions have been highlighted. In most cases this is clearly apparent from looking at the sensitivity and specificity values obtained. The combinations chosen as the most appropriate represent a compromise between sensitivity and specificity. As the instruments used in this study were for the purpose of screening, the choices of the best combinations have given priority to higher sensitivity values as opposed to specificity values. However care was taken not to compromise specificity more than was necessary. It is understood that there is a subjective element in the choices made below. The same method was used to find the most appropriate combinations in Chapter 9 (Section 9.4) and Chapter 10 (section 10.5).

8.4.1 The ability of screener test combinations to predict significant gain in acuity with new refractive correction

HCVA was found to be more valuable than LCVA in the detection of uncorrected refractive error and HCVA and the presence of symptoms have been combined in Table 8.15 below. In its present form, the screener could not be expected to differentiate between the different causes of reduced visual acuity. The inclusion of

a pinhole test might help to differentiate between those with uncorrected refractive error and other causes of reduced acuity, However, as discussed in Chapter 2, there are many disadvantages of using the pinhole.

Table 8.15 Test combinations from CVS1 for the detection of uncorrected refractive error. The cut off values used are in brackets. The shaded cell highlights the best combination.

TEST COMBINATIONS FOR REFRACTIVE ERROR	Sensitivity (%)	Specificity (%)	PPV (%)
Symptoms alone	59	63	51
HCVA alone, either eye (0.19)	74	38	43
Symptoms or HCVA(0.19)	88	29	44
Symptoms or HCVA (0.29)	80	41	46
Symptoms or HCVA (0.09)	Beyond limit of computer screener		
Symptoms or HCVA (0.14)	92	23	43

Key Points

- The table above shows that when the original cut off of 0.19 is coupled with symptoms in an OR combination the sensitivity is greater than when HCVA is taken alone. However, there is also a decrease in specificity when combining the tests in the way shown above.

- The effect of using a different cut off is also clear from the table. A slightly higher visual acuity cut off, results in the test becoming slightly harder to fail (as the patient would need a worse acuity than before) and so when this is coupled in an OR combination with symptoms, there is a slight compromise in sensitivity, but this is compensated for by a higher specificity value.

- A lower cut off would be more appropriate if the tests were combined in an 'AND' method where the patient would have to fail both tests in the combination in order to fail the screening. The 'AND' combination would make the screening harder to fail, in order to compensate for this a lower cut off can be used (this would enable patients to fail at better levels of acuity).

Using a lower cut off in the context of an ‘OR’ combination is not appropriate, as it makes the screening test even easier to fail.

- The positive predictive value indicates how many patients who fail the screening actually have the target condition when further investigated. When the tests are combined the greatest positive predictive value is 46%. This means that 46 out of every 100 patients who fail the screening tests in this combination will have significant gain in acuity through a new refractive correction.

- The shaded cells represent the best combination of tests for detecting significant gain in acuity through refractive correction. This is the combination where symptoms are combined with a higher cut off HCVA value.

8.4.2 The ability of screener test combinations to determine significant cataract

As has been noted throughout this chapter, these analyses are relating the appearance of cataract with the visual function of visual acuity. The correlation between function and appearance will be limited and other causes of poor visual acuity will also adversely affect the sensitivity and specificity. This is returned to in Chapter 12.

Table 8.16 Test combinations from CVS1 for the detection of significant cataract. The cut off values used are in brackets. The shaded cells highlight the best combinations.

TEST COMBINATIONS FOR CATARACT	Sensitivity (%)	Specificity (%)	PPV (%)
Symptoms alone	55	58	36
HCVA alone (0.19)	87	43	40
LCVA alone (0.39)	83	44	39
Symptoms or HCVA (0.19)	92	28	35.5
Symptoms or LCVA (0.39)	89	31	35
Symptoms or HCVA(0.29)	83	39.5	37
Symptoms or LCVA(0.49)	79	39.5	36
Symptoms or HCVA(0.19) or LCVA(0.39)	94	24	35
Symptoms or HCVA(0.29) or LCVA(0.49)	89	35	37

Key Points

- It is particularly interesting to note that the above table shows that adding symptoms as a screening test does not help significantly in the detection of cataract. The decrease in specificity that is obtained when combining symptoms with HCVA is greater than the increase in sensitivity that is achieved. Even when symptoms are combined with a higher value HCVA cut off, this is no better than using HCVA alone.

- Another approach is for the test combinations in Table 8.16 to be split in to 3 categories: the most appropriate single test for cataract detection; the most appropriate 2 test combination and the most 3 test combination. The shaded cells in the above table represent the most appropriate combination for each of these 3 categories. When comparing the shaded cells it can be seen that for determining significant cataract, HCVA (cut off value 0.19) alone seems to be the best screening test.

8.4.3 The ability of screener test combinations to detect correctable visual loss

Table 8.17 Test combinations from CVS1 for the detection of correctable visual loss. The cut off values used are in brackets. The shaded cells highlight the best combinations.

TEST COMBINATIONS FOR CORRECTABLE VISUAL LOSS	Sensitivity (%)	Specificity (%)	Positive predictive value(%)
Symptoms alone	54	65	67.9
HCVA alone (0.19)	76	47	66
LCVA alone (0.39)	70.5	45	64
Symptoms or HCVA(0.19)	88	36	65.2
Symptoms or LCVA(0.39)	83	36	64
Symptoms or HCVA(0.29)	78	48	67
Symptoms or LCVA(0.49)	75	47	66
HCVA (0.19) or LCVA(0.39)	80.4	41.3	65
HCVA(0.29)orLCVA(0.49)	66	56	67
Symptoms or HCVA (0.19) or LCVA(0.39)	80.4	17.3	57
Symptoms or HCVA (0.29) or LCVA (0.49)	82	41	66

Key Points

- The PPV values in this table are generally higher than in the other two tables, this is because the above table considers correctable visual loss which can be due to significant cataract or significant gain in acuity through refractive correction or both.

- The above table shows that many of the combinations would be suitable as a screening test to detect correctable visual loss. The shaded cells show the most appropriate single test for detection of correctable visual loss and the most appropriate two test and three test combinations.

- The shaded cells in the above table show that the two test combination of HCVA (cut off value 0.29) and symptoms is most appropriate and gives the best compromise between sensitivity and specificity.

8.4.3 The ability of screener test combinations to detect significant acuity impairing eye conditions (SAIEC)

Significant acuity impairing eye conditions has been defined earlier in the chapter as the presence of refractive error, cataract, or MD in either eye.

Table 8.18 Test combinations from CVS1 for the detection of SAIEC. The cut off values used are in brackets. The shaded cells highlight the best combinations.

TEST COMBINATIONS FOR SAIEC	Sensitivity (%)	Specificity (%)	Positive predictive value(%)
Symptoms alone	53	72	83
HCVA alone (0.19)	74	52	80
LCVA alone (0.39)	71	54	80
Symptoms or HCVA(0.19)	86	42	79
Symptoms or LCVA(0.39)	83	44	79
Symptoms or HCVA(0.29)	77	58	82
Symptoms or LCVA(0.49)	74	54	80
HCVA (0.19) or LCVA(0.39)	79	48	79
HCVA(0.29)or LCVA(0.49)	65	66	83
Symptoms or HCVA (0.19) or LCVA(0.39)	89	38	78
Symptoms or HCVA (0.29) or LCVA (0.49)	81	50	80

Key points

- Once again, the positive predictive values are generally higher than the previous tables, this is because, the ability of the screener to detect SAIEC takes in to account three conditions; refractive correction, cataract and macular degeneration.

- As before, the best single test, two test combinations and three test combination have been identified in the shaded cells. From the shaded cells the best combination for the detection of SAIEC is obtained when all 3 tests are combined with the higher cut off values to compensate for combining the tests in an OR combination

The best combinations that have been identified this section have been summarised in the table below

Table 8.19 Summary table incorporating the best test combinations (from HCVA, LCVA and symptoms) from CVS1 for the detection of the target conditions

	Best test combination	Sensitivity	Specificity	PPV
Gain in VA through refraction	Symptoms or HCVA (0.29)	80	41	46
Cataract	HCVA alone (0.19)	87	43	40
CVL	Symptoms or HCVA(0.29)	78	48	67
SAIEC	Symptoms or HCVA (0.29) or LCVA (0.49)	81	50	80

This section and Table 8.19 shows the value of combining tests and manipulating cut off values in order to achieve an acceptable compromise between sensitivity and specificity for the detection of the target conditions. This is explored in more detail in the following chapters.

The results from Study 1, presented in this chapter, have shown which tests are appropriate to incorporate in CVS2 and which tests would not be necessary in the detection of correctable visual loss. This chapter has also provided an initial insight into combining tests and manipulation of cut off values. The information at the start of this chapter regarding conventions in statistical analyses will be taken into consideration when evaluating the results from Study 2. Since the goal of Study 2 is to assess the efficacy of the final computerised vision screener to detect the target conditions, a more detailed analysis of various test combinations will be carried out for this study.

Chapter 9

Study two: Investigation of the effectiveness of a refined computer-based system for screening the vision of older people in the community

9.1 Introduction

Analyses of the screening results from Study 1 involved calculating the sensitivity and specificity of various tests in combination, so that the most appropriate battery of tests could be identified and incorporated in to CVS2 and also to evaluate the performance of the screener for the target conditions. This chapter focuses solely on the revised computer vision screener (CVS2); the next chapter will give details of the results obtained from the rapid flipchart screener.

Study 1 showed that tests of stereoacuity and fixation disparity were not likely to produce a high yield of the target conditions and so these tests were not included in CVS2. Tests of high contrast acuity and low contrast acuity were found to be useful in the detection of correctable visual loss. The full battery of tests included in CVS2 is discussed in Chapter 4. The analyses of CVS2 began with calculating the monocular cut off values for distance acuity for the target conditions obtained from the ROC curves. The definitions for the target conditions have been outlined in Chapter 4 and it is these definitions that have been used to plot the ROC curves. As with Chapter 8, the tables below the graphs give the key statistics of the cut off values chosen from the graphs. A full description of ROC curves can be found in Section 7.3.The procedure for the analyses of CVS2 followed that of CVS1. The left eye was used to obtain the monocular cut off values. These cut off values were then used to assess the effectiveness of CVS2 at detecting the target conditions in

either eye (i.e., right eye, left eye or both). The tests were then combined using an OR operator as discussed in Chapter 7 to give an idea of the overall performance of the screener. Distance acuity was evaluated first followed by near acuity. The screener measured near acuity binocularly. In the analysis of near acuity, the target conditions were considered significant only if both eyes were affected as outlined in Chapter 7. This chapter will end with a section on the ability of CVS2 to detect those patients with glaucoma or at risk of glaucoma.

The flow chart at the beginning of Chapter 7 (Figure 7.1) provided an overview of the analysis for this study. The descriptive statistics and the comparison of the screener data with the gold standard data has already been dealt with at the beginning of Chapter 7. The first section in this chapter will determine the individual test cut offs from monocular ROCs.

As in the previous chapter, it should be pointed out that most of the ROC curves below attempt to relate the appearance of a target condition (e.g., grade of cataract) to a function (e.g., visual acuity). This approach, although necessary to determine cut-off values and to gain an insight into the ability of a test to detect a condition, will inevitably limit the performance of a test for two reasons. First, a disease (e.g., cataract or AMD) may influence structure (e.g., appearance) relatively independent of its influence on function. Second, functions like visual acuity are influenced by a variety of factors. From a pragmatic optometric viewpoint, it could be argued that the screener will perform well if it detects those patients who an optometrist would wish to see for an eye examination. This is considered in Section 9.2.8.

9.2 Monocular data: selection of appropriate cut offs

The suitability of the screening distance acuity test for determining various eye conditions will now be presented. At the end of this section, Table 9.8 which contains all the cut off values for distance acuity, will summarise the section before the results of the near acuity test are presented.

9.2.1 The ability of presenting screener visual acuity to determine significant cataract

(a) (b)

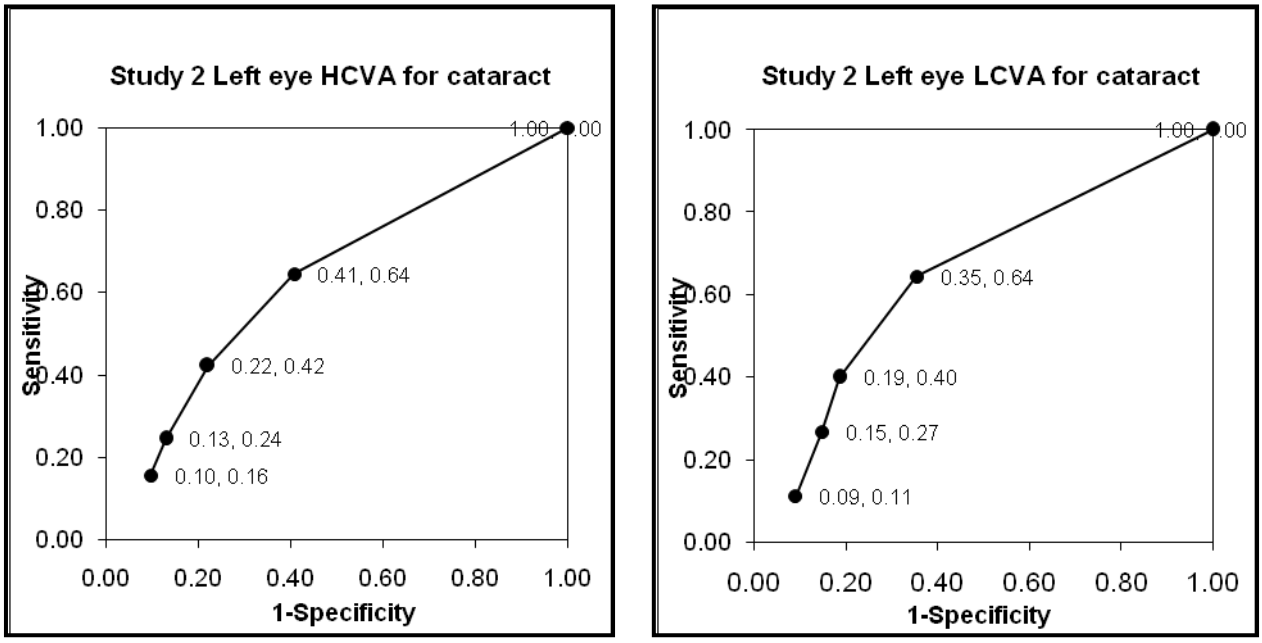


Figure 9.1 Graph illustrating the sensitivity versus 1-specificity for (a) high contrast visual acuity and (b) low contrast visual acuity of the left eye obtained with CVS2 for predicting presence of significant cataract in the left eye as defined in Chapter 4. The data labels state the X and Y coordinates

Table 9.1 The key statistics for the LogMAR acuity cut off values obtained from Figure 9.1

Study 2 Cataract	High Contrast Acuity	Low Contrast Acuity
Ideal Cut Off (LogMAR)	VA>0.19	VA>0.39
Sensitivity (%)	64.4 (49.8-76.8)	64.4 (49.8-76.8)
Specificity (%)	59.4 (51.5-66.8)	64.5 (56.7-71.6)
PPV (%)	31.5 (22.9-41.6)	34.5 (25.2-45.2)
AUC	0.659 (0.572-0.746)	0.668 (0.581-0.756)

9.2.2 The ability of screener visual acuity to detect significant gain in acuity with new refractive correction (Rx)

(a) (b)

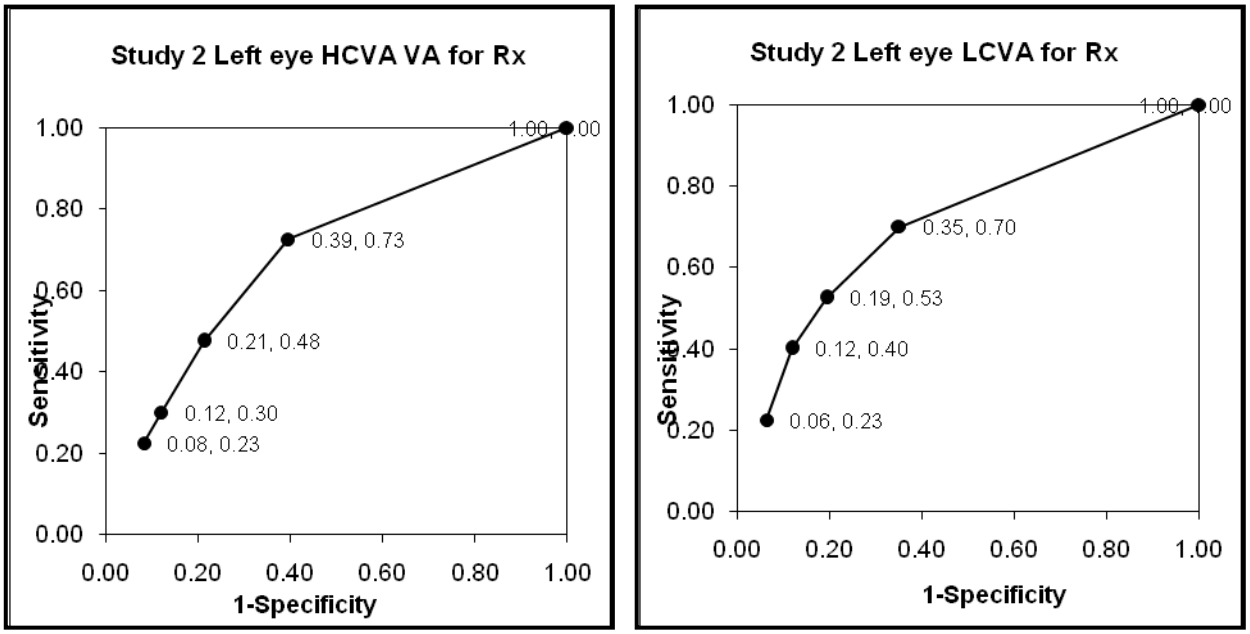


Figure 9.2 Graph illustrating the sensitivity versus 1-specificity for (a) high contrast visual acuity and (b) low contrast visual acuity of the left eye obtained with CVS2 for predicting presence of significant gain in acuity with new refractive correction as defined in Chapter 4. The data labels state the X and Y coordinates

Table 9.2 The key statistics for the LogMAR acuity cut off values obtained from Figure 9.2

Study 2 **Refractive correction**	High Contrast Acuity	Low Contrast Acuity
Ideal Cut Off (LogMAR)	VA>0.19	VA>0.39
Sensitivity (%)	72.5 (57.2-83.9)	70 (54.6-81.9)
Specificity (%)	60.6 (52.9-67.9)	65 (57.3-72)
PPV (%)	31.5 (22.9-.41.6)	33.3 (24.2-43.9)
AUC	0.667 (0.569-0.765)	0.688 (0.588-0.788)

9.2.3 The ability of presenting visual acuity to detect correctable visual loss (CVL)

The results so far in this chapter have looked at the ability of distance acuity (high contrast and low contrast) to detect significant gain in distance acuity through refractive correction and the detection of significant cataract. Correctable visual loss is defined as the presence of significant cataract and/or significant gain in distance acuity through refractive correction. Further on in this chapter, the definition of CVL will be amended to take account of significant binocular gain in near acuity through near refractive correction. This will be done when evaluating the binocular near acuity screening test.

(a) (b)

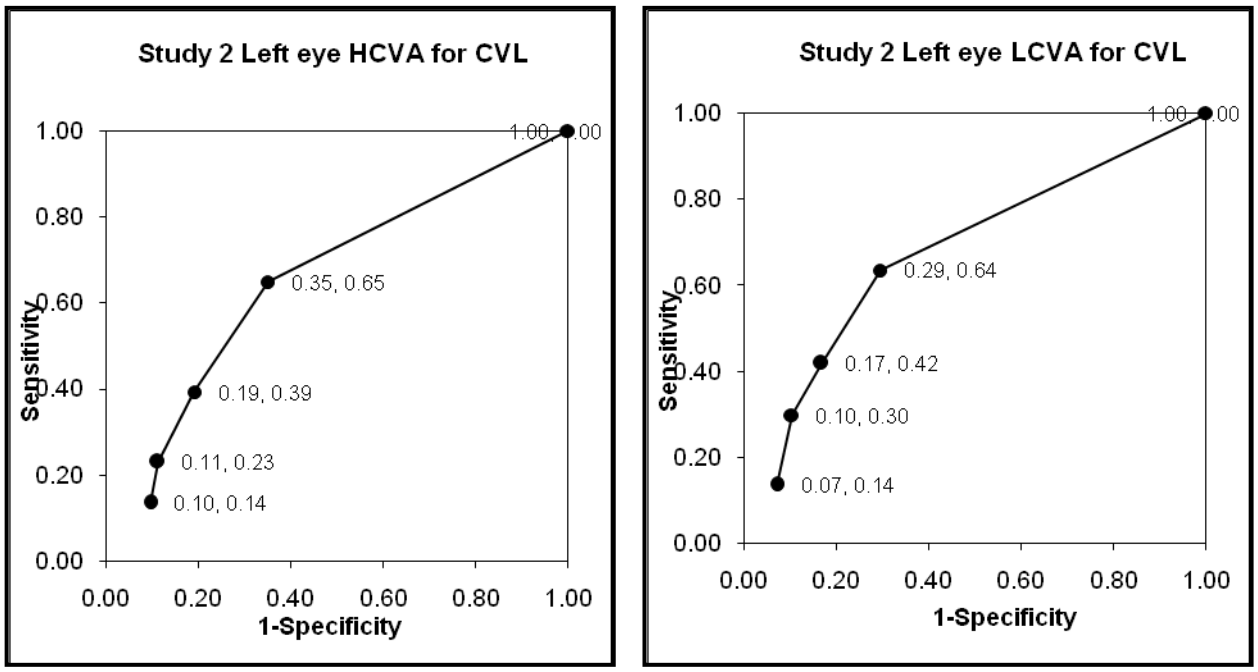


Figure 9.3 Graph illustrating the sensitivity versus 1-specificity for (a) high contrast visual acuity and (b) low contrast visual acuity of the left eye obtained with CVS2 for predicting presence of CVL as defined above. The data labels state the X and Y coordinates

Table 9.3 The key statistics for the LogMAR acuity cut off values obtained from Figure 9.3

Study 2 CVL	High Contrast Acuity	Low Contrast Acuity
Ideal Cut Off (LogMAR)	VA>0.19	VA>0.39
Sensitivity (%)	64.9 (53.5-74.8)	63.5 (52.1-73.6)
Specificity (%)	65.1 (56.4-72.8)	70.6 (62.2-77.9)
PPV (%)	52.2 (42.1-62.1)	56 (45.3-66.1)
AUC	0.670 (0.593-0.747)	0.699 (0.623-0.776)

9.2.4 The ability of presenting visual acuity to detect Macular Degeneration (MD)

The ability of the screener to detect MD is illustrated in Figure 9.4 and Table 9.4. High sensitivity and specificity are not to be expected for the reasons outlined in Section 9.1 (see Section 9.2.8) and this is returned to in Chapter 12.

(a) (b)

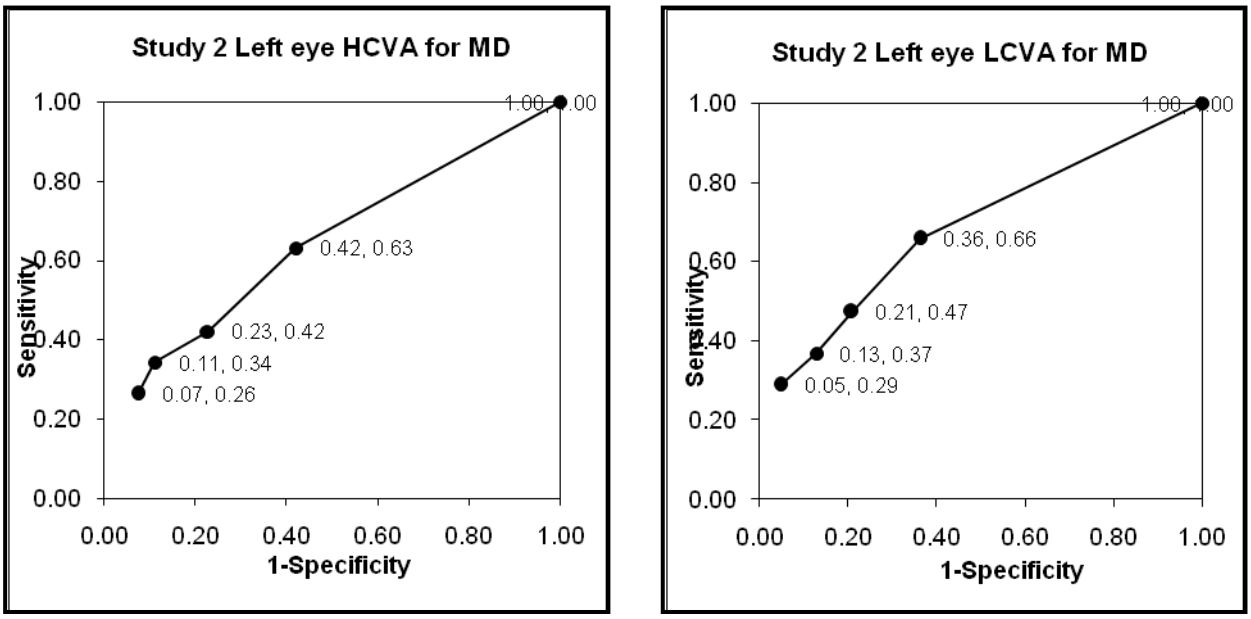


Figure 9.4 Graph illustrating the sensitivity versus 1-specificity for (a) high contrast visual acuity and (b) low contrast visual acuity of the left eye obtained with CVS2 for predicting presence of significant macular degeneration as defined in Chapter 4. The data labels state the X and Y coordinates

Table 9.4 The key statistics for the LogMAR acuity cut off values obtained from Figure 9.4

Study 2 MD	High Contrast Acuity	Low Contrast Acuity
Ideal Cut Off (LogMAR)	VA>0.19	VA>0.39
Sensitivity (%)	63.2 (47.3-76.6)	65.8 (49.9-78.8)
Specificity (%)	58.0 (50.3-65.4)	63.6 (55.9-70.6)
PPV (%)	26.1 (18.2-35.9)	29.8 (21-40.2)
AUC	0.636 (0.531-0.740)	0.666 (0.562-0.771)

9.2.5 The ability of presenting visual acuity to detect Macular degeneration risk of progression (MD risk prog)

This category has been introduced in study 2 and is based on the risk of macular degeneration progressing to advanced macular degeneration (neovascular disease or geographic atrophy) as defined in Chapter 4.

(a) (b)

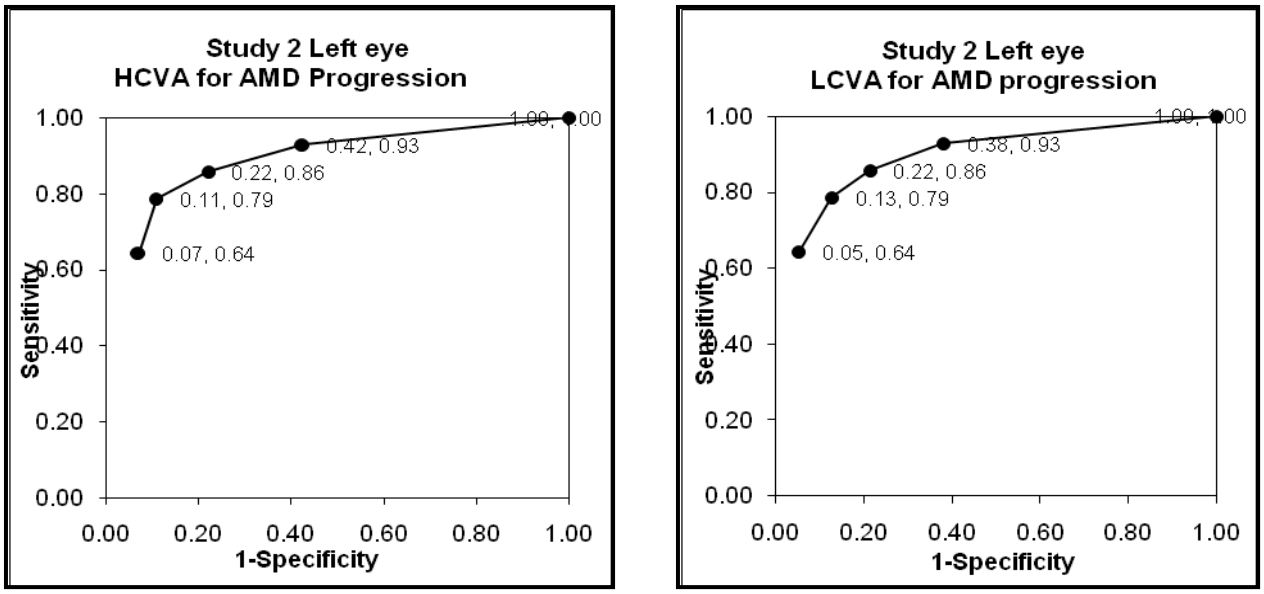


Figure 9.5 Graph illustrating the sensitivity versus 1-specificity for (a) high contrast visual acuity and (b) low contrast visual acuity of the left eye obtained with CVS2 for predicting presence of macular degeneration at risk of progression as defined in Chapter 4. The data labels state the X and Y coordinates

Table 9.5 The key statistics for the LogMAR acuity cut off values obtained from Figure 9.5

Study 2 **MD risk prog**	High Contrast Acuity	Low Contrast Acuity
Ideal Cut Off (LogMAR)	VA>0.29	VA>0.49
Sensitivity (%)	85.7 (60.1-96)	85.7 (60.1-96)
Specificity (%)	78.0 (71.5-83.3)	78.5 (72-83.8)
PPV (%)	22.6 (13.5-35.5)	23.1 (13.7-36.1)
AUC	0.877 (0.772-0.982)	0.882 (0.776-0.988)

It can be seen that the ability of the screener to detect macular degeneration at risk of progression is better than the ability of the screener to detect macular degeneration. This is because the category of macular degeneration at risk of progression included patients with advanced stages of macular disease who were more likely to have poor vision. The ability of the screening tests to detect these patients was better than with the detection of macular degeneration where although clinical signs may be seen, vision in the early stages may not always be as significantly affected as with degeneration at risk of progression.

Further on in this chapter the screening tests will be combined to assess their suitability to detect the target conditions (significant refractive correction and cataract). Macular degeneration at risk of progression will be combined with the target conditions when test combinations are being evaluated. A more pragmatic assessment of the screener's performance will also be obtained in Section 9.2.8.

9.2.6 The ability of presenting visual acuity to detect refractive error, cataract, and MD

The presence of refractive error, cataract, or MD is labelled in the graphs below as significant acuity impairing eye conditions (SAIEC). This definition will be amended as further analyses are presented to give a more overall impression of the ability of the screener at detecting the target conditions. The graphs below show the ability of the screener to detect SAIEC in the left eye. Further in the chapter, the ability of the screener to detect SAIEC in either eye will also be presented.

(a) (b)

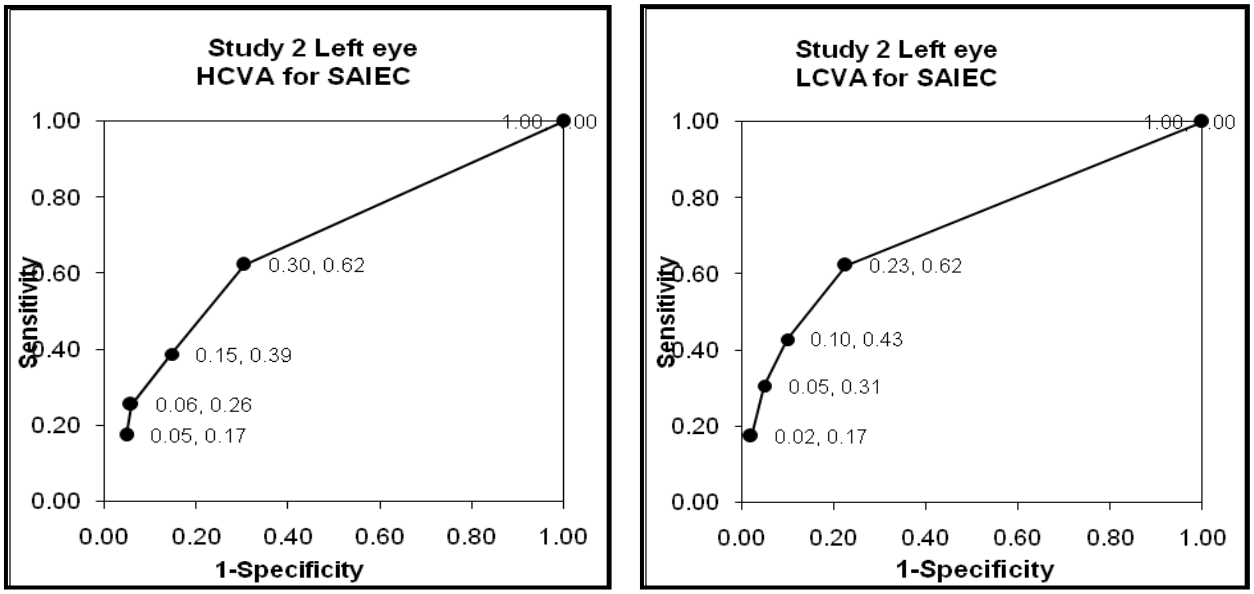


Figure 9.6 Graph illustrating the sensitivity versus 1-specificity for (a) high contrast visual acuity and (b) low contrast visual acuity of the left eye obtained with CVS2 for predicting SAIEC as defined above. The data labels state the X and Y coordinates.

Table 9.6 The key statistics for the LogMAR acuity cut off values obtained from Figure 9.6

Study 2 SAIEC (left eye)	High Contrast Acuity	Low Contrast Acuity
Ideal Cut Off (LogMAR)	VA>0.19	VA>0.39
Sensitivity (%)	62.2 (52.4-71.2)	62.2 (52.4-71.2)
Specificity (%)	69.6 (60.1-77.7)	77.5 (68.4-84.5)
PPV (%)	66.3 (56.2- 75.1)	72.6 (62.3-81)
AUC	0.696 (0.623-0.770)	0.730 (0.659-0.801)

9.2.7 The ability of presenting visual acuity to determine significant acuity impairing eye conditions in either eye (SAIEC).

In order to give an idea of the overall screener performance, the ROC curves below give an indication of how well HCVA and LCVA can detect any significant acuity impairing eye conditions (i.e. the presence of refractive error, cataract, or MD) in either eye.

(a) (b)

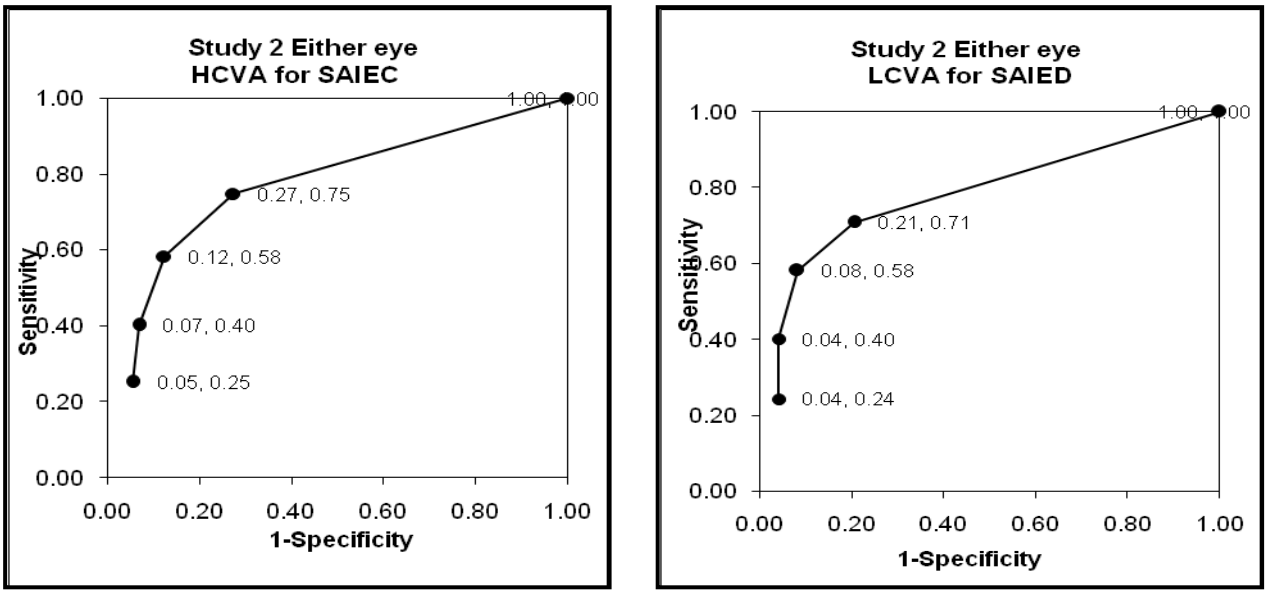


Figure 9.7 Graph illustrating the sensitivity versus 1-specificity for (a) high contrast visual acuity and (b) low contrast visual acuity of either eye obtained with CVS2 for predicting SAIEC as defined above. The data labels state the X and Y coordinates

Table 9.7 The key statistics for the LogMAR acuity cut off values obtained from Figure 9.7

Study 2 **SAIEC (either eye)**	High Contrast Acuity	Low Contrast Acuity
Ideal Cut Off (LogMAR)	VA>0.19	VA>0.39
Sensitivity (%)	74.8 (66.6-81.5)	70.9 (62.4-78.1)
Specificity (%)	72.6 (61.4-81.5	79.5 (68.8-87.1)
PPV (%)	82.6 (74.7-88.5)	85.7 (77.8-91.1)
AUC (%)	0.793 (0.728-0.858)	0.800 (0.737-0.862)

The values in Table 9.7 indicate that the best sensitivity is obtained with the high contrast acuity and the best specificity is obtained with low contrast acuity. This has implications for the possibility of combining tests: if the results of these screening tests are combined (e.g., participants are selected who fail both or either test) then will this combination give best sensitivity and specificity? This is analysed in section 9.4

The table below gives a summary of the cut off values obtained so far with the distance acuity screening tests.

Table 9.8 Summary of CVS2 HCVA and LCVA cut off values

	HCVA			LCVA		
Condition	Cut off value (LogMAR)	Sensitivity (%)	Specificity (%)	Cut off value (LogMAR)	Sensitivity (%)	Specificity (%)
Cataract	VA>0.19	64.4	59.4	VA>0.39	64.4	64.5
Rx	VA>0.19	72.5	60.6	VA>0.39	70	65
CVL	VA>0.19	64.9	65.1	VA>0.39	63.5	70.6
MD	VA>0.19	63.2	58	VA>0.39	65.8	63.6
MD risk prog	VA.0.29	85.7	78	VA>0.49	85.7	78.5
SAIEC (left eye)	VA>0.19	62.2	69.6	VA>0.39	62.2	77.5
SAIEC (either eye)	VA>0.19	74.8	72.6	VA>0.39	70.9	79.5

9.2.8 Performance of the screener from an optometric perspective

As discussed at the beginning of this Chapter, it is perhaps unreasonable to expect a screener which measures visual performance to reliably detect conditions defined by their appearance when it is well known that the appearance of conditions such as cataracts and macular degeneration is poorly correlated with visual function. The analysis in Table 9.9 shows the ability of the screener to detect patients who a “typical” optometrist feels would need an eye examination. This has been defined in Chapter 8 as patients with a reduced high contrast visual acuity in one or both eyes and those who have not attended for an eye examination in the last year. An alternative criterion may be set including all those

with reduced high contrast acuity or those who have not had an examination within the last year. The results of both of these criterion combinations are stated in the table below. Reduced high contrast acuity has been defined as VA>0.19 LogMAR.

Table 9.9 Performance of screener from an optometric perspective

Performance of screener from an optometric perspective	Sensitivity (%)	Specificity (%)	PPV (%)
HCVA >0.19 and no eye examination in the last year	81.8 (73.1-88.2)	94.1 (87.6-97.2)	93.1 (85.8-96.1)
HCVA>0.19 or no eye examination in the last year	94.6 (90.3-97)	93.8 (71.7-99.7)	99.4 (96.8-100)

A simple combination of acuity testing and knowledge of the patient's last eye examination can result in a high sensitivity and specificity for detecting those patients that should be seen by an optometrist whether this be for a routine eye examination or to receive intervention to improve their vision.

9.3 Evaluation of near acuity vision screening test

The analyses so far in this chapter have considered screening tests where data for both the right and the left eye were obtained. In view of the comments in Chapter 7, the left eye's data were taken (i.e., the ROC curves have been drawn to illustrate how well the left eye's screening test data predict the presence of the target condition in the left eye). For reasons explained in Chapter 7, the CVS was designed to assess binocular near visual acuity. Therefore, in this section the graphs and tables illustrate the ability of the binocular near visual acuity to predict binocular conditions. At the end of this section, Table 9.13 which contains all the cut off values for near acuity, will summarise the section before the results of various test combinations are presented.

9.3.1 The ability of screener binocular near visual acuity test to detect significant gain in binocular near acuity with new near refractive correction (NvRx).

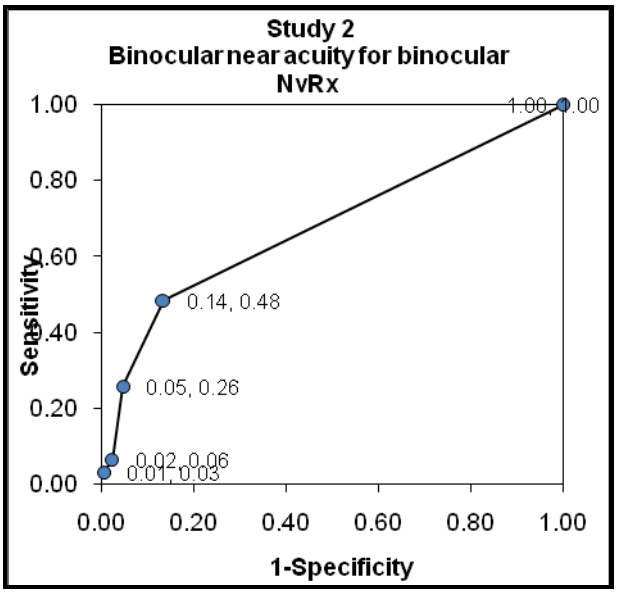


Figure 9.8 Graph illustrating the sensitivity versus 1-specificity for binocular near acuity obtained with CVS2 for predicting significant gain in binocular near acuity with new refractive correction as defined in Chapter 4. The data labels state the X and Y coordinates

Table 9.10 The key statistics for near acuity cut off values obtained from Figure 9.8

Study 2 **Near visual acuity predicting binocular NvRx**	Near acuity
Ideal Cut Off (N)	NVA> N 11.90
Sensitivity (%)	48.4 (32 -65.2)
Specificity (%)	86.4 (80.4-90.8)
PPV (%)	39.5 (25.6 – 55.3)
AUC	0.684 (0.570 –0.798)

As noted with CVS1 in Chapter 8 the screening near acuity test does not appear to be as useful in the detection of the target conditions as the distance acuity tests. Possible reasons for this will be discussed in Chapter 12. These include the points made at the beginning of Section 9.2.

9.3.2 The ability of screener binocular near visual acuity test to detect significant binocular cataract

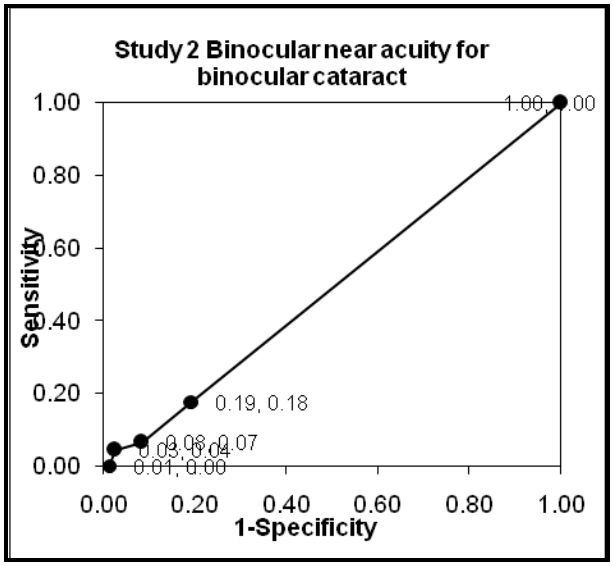


Figure 9.9 Graph illustrating the sensitivity versus 1-specificity for binocular near acuity obtained with CVS2 for predicting significant binocular cataract as defined in Chapter 4. The data labels state the X and Y coordinates

Table 9.11 The key statistics for near acuity cut off values obtained from Figure 9.9

Study 2 Near visual acuity predicting binocular Significant cataract	Near acuity
Ideal Cut Off (N)	NVA> N 11.90
Sensitivity (%)	17.8 (9.3-31.3)
Specificity (%)	80.6 (73.7-86.1)
PPV (%)	21.1 (11.1-36.3)
AUC	0.539 (0.444-0.634)

9.3.3 The ability of screener binocular near visual acuity test to detect significant binocular correctable visual loss (BinCVL)

When evaluating the distance acuity screening test earlier in the chapter, correctable visual loss was defined as significant gain in distance acuity with new refractive correction or significant cataract. The ROC curve for this (Figure 9.3) was calculated for the left eye because the computer screener tested presenting acuity monocularly. The definition of correctable visual loss will be amended for the next ROC curve to take into account the binocular near acuity test. For the purposes of evaluating the near vision test, correctable visual loss has now been defined as the presence of significant **binocular** distance refractive error &/or presence of **binocular** cataract &/or significant **binocular** near refractive error.

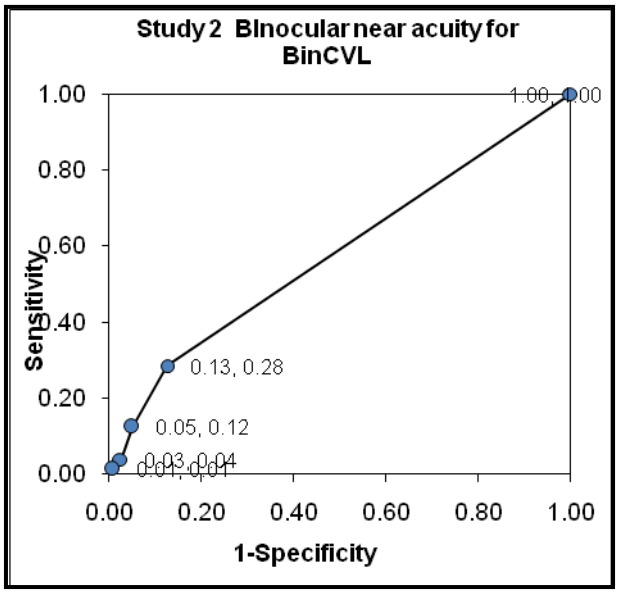


Figure 9.10 Graph illustrating the sensitivity versus 1-specificity for binocular near acuity obtained with CVS2 for predicting binocular correctable visual loss as defined above. The data labels state the X and Y coordinates

Table 9.12 The key statistics for near acuity cut off values obtained from Figure 9.10

Study 2 **Near visual acuity** **Predicting BinCVL**	Near acuity
Ideal Cut Off (N)	NVA> N 11.90
Sensitivity (%)	28.4 (19.7-39)
Specificity (%)	87.4 (80.2-92.2)
PPV (%)	60.5 (44.7 -74.4)
AUC	0.618 (0.538- 0.699)

This section will end with a summary table (Table 9.13) that states the near acuity cut off values obtained for the eye conditions evaluated in this section. The next section of this chapter will focus on test combinations to give an overall view of the performance of the screener. This will involve not only combining the screening tests, but also combining the eye conditions and evaluating the ability of the screener to detect these conditions in either eye as opposed to just the left eye as done earlier in the chapter.

Table 9.13 Summary of CVS2 near acuity cut off values

	Near acuity		
Condition	Cut off value (N)	Sensitivity (%)	Specificity (%)
Binocular Cataract	VA> N 11.9	17.8	80.6
NvRx	VA> N 11.9	48.4	86.4
Binocular CVL	VA> N 11.9	28.4	87.4

9.4 Combining tests

The next stage in the analyses will involve calculating how well the **overall** performance of the screener is able to detect significant acuity impairing eye conditions (SAIEC) identified in the gold standard. The definition of SAIEC has been amended from earlier in the chapter and has been defined as refractive error

that can be corrected with spectacles or significant cataract or macular degeneration that is at risk of rapid progression. This definition is summarised in the table below.

Table 9.14 Defining significant acuity impairing eye conditions (SAIEC)

Significant acuity impairing eye conditions	**Monocular/Binocular**
Significant gain in distance acuity through refractive correction.	RE or LE or Both
Significant gain in near acuity through refractive correction	Both eyes only
Significant cataract	RE or LE or Both
Risk of rapid progression macular degeneration	RE or LE or Both

Having now defined SAIEC, 'overall performance of screener' also needs to be defined. 'Overall performance' will initially take into account all the tests that are included in the computer vision screener except visual fields, which will be discussed later in the chapter. All these tests will be combined in an 'OR' method to give the overall screener performance. The only exception to this will be the presence of symptoms, which will be combined in an 'AND' method and also in an 'OR' method in order to determine the ideal combination. The criterion for the definition of overall performance of screener is summarised in the table below.

Table 9.15 Defining overall performance of screener

Overall screener performance	**Monocular/Binocular**
Presenting HCVA	RE or LE or Both
Presenting LCVA	RE or LE or Both
Presenting near acuity	Both eyes only
Presenting symptoms	Distance/near or both RE or LE or both

In the analyses below, all the combinations of vision tests will be evaluated. In each combination the effect of incorporating symptoms will be noted and also the cut off values will be altered to see what effect this has on the key statistics. The combinations of the vision tests used are given in the table below.

Table 9.16 Combinations of vision tests to be used in analyses

Vision test combinations
HCVA OR LCVA OR NVA
HCVA,OR LCVA
HCVA OR NVA
HCVA
LCVA OR NVA
LCVA

For each combination the sensitivity, specificity and the PPV will be calculated. It was originally thought that overall accuracy may also be of use: this is a measure of the proportion of people correctly classified by a diagnostic test. Alberg et al (2004) pointed out that this measure is strongly influenced by prevalence and cautioned that “Despite its intuitive appeal as a single summary estimate of test validity, overall accuracy blurs the distinction between sensitivity and specificity, allowing the relative importance of each to be arbitrarily dictated by the level of disease prevalence." These authors cited 25 examples from the literature showing the misleading nature of this statistic and it was decided therefore not to present this variable.

9.4.1 Screener test combinations for detecting significant acuity impairing eye condition (SAIEC)

The tables below show the various test combinations and the change in sensitivity and specificity that occurs when one of the tests is eliminated. The combinations in red represent the best compromise between sensitivity and specificity. At the end these combinations will be compared to give the ideal test combination. By narrowing down the best combinations in this way, the ideal compromise can be found between sensitivity and specificity to give best overall combination. It should be noted that one of the limitations described in Section 9.1 still applies. For cataract and MD the screener is still being required to use a test of visual function to detect a condition that is being defined, with the gold standard, by appearance. This issue is returned to in Chapter 12.

Table 9.17 Overall screener performance for detecting SAIEC. The combinations in red represent the best compromise between sensitivity and specificity

Test Combination	Sensitivity	Specificity	PPV
HCVA(0.19) or LCVA(0.39) or NVA	80.3 (72.4-86.4)	66.7 (55.6-76.1)	79 (71-85.3)
HCVA(0.19) or LCVA(0.39) or NVA & symptoms	38.5 (30.4-47.4)	87.2 (78-92.9)	82.5 (70.6-85.3)
HCVA(0.19) or LCVA(0.39) or NVA or symptoms	88.5 (81.7-93)	48.7 (37.9-59.6)	73 (65.3-79.5)
HCVA(0.29) or LCVA(0.49) or NVA	68.9 (60.2-76.4)	80.8 (70.7-88)	84.8 (76.5-90.6)
HCVA(0.29) or LCVA(0.49) or NVA & symptoms	33.6 (25.8-42.4)	89.7 (81-94.7)	83.7 (71-91.5)
HCVA(0.29) or LCVA(0.49) or NVA or symptoms	82 (74.2-87.8)	60.3 (49.2-70.4)	76.3 (68.4-82.8)

Table 9.18 Overall screener performance (excluding presenting NVA) for detecting SAIEC. The combinations in red represent the best compromise between sensitivity and specificity

Test Combination	Sensitivity	Specificity	PPV
HCVA(0.19) or LCVA(0.39)	77.9 (69.7-84.3)	69.2 (58.3-78.4)	79.8 (71.7-86.1)
HCVA(0.19) or LCVA(0.39) & symptoms	37.7 (29.6-46.6)	88.5 (79.5-93.8)	83.6 (71.7-91.1)
HCVA(0.19) or LCVA(0.39) or symptoms	86.9 (79.8-91.8)	50 (39.2-60.8)	73.1 (65.4-79.7)
HCVA(0.29) or LCVA(0.49)	65.6 (56.8-73.4)	87.2 (78-92.9)	88.9 (80.7-93.9)
HCVA(0.29) or LCVA(0.49) & symptoms	32 (24.4-40.7)	93.6 (85.9-97.2)	88.6 (76-95)
HCVA(0.29) or LCVA(0.49) or symptoms	80.3 (72.4-86.4)	62.8 (51.7-72.7)	77.2 (69.1-83.6)

Table 9.19 Overall screener performance (excluding presenting LCVA) for detecting SAIEC. The combinations in red represent the best compromise between sensitivity and specificity

Test Combination	Sensitivity	Specificity	PPV
HCVA(0.19) or NVA	79.5 (71.5-85.7)	67.9 (57-77.3)	79.5 (71.5-85.7)
HCVA(0.19) or NVA & symptoms	38.5 (30.4-47.4)	87.2 (78-92.9)	82.5 (70.6-90.2)
HCVA(0.19) or NVA or symptoms	46.7 (38.1-55.5)	69.2 (58.3-78.4)	70.4 (59.7-79.2)
HCVA(0.29) or NVA	65.6 (56.8-73.4)	80.8 (70.7-88)	84.2 (75.6-90.2)
HCVA(0.29) or NVA & symptoms	32 (24.4-40.7)	89.7 (81-94.7)	83 (69.9-91.1)
HCVA(0.29) or NVA or symptoms	80.3 (72.4-86.4)	60.3 (49.2-70.4)	76 (67.9-82.5)

Table 9.20 Overall screener performance (excluding presenting LCVA & NVA) for detecting SAIEC. The combinations in red represent the best compromise between sensitivity and specificity

Test Combination	Sensitivity	Specificity	PPV
HCVA(0.19)	77 (68.8-83.6)	73.1 (62.3-81.7)	81.7 (73.7-87.7)
HCVA(0.19) & symptoms	37.7 (29.6-46.6)	89.7 (81-94.7)	85.2 (73.4-92.3)
HCVA(0.19) or symptoms	86.1 (78.8-91.1)	52.6 (41.6-63.3)	73.9 (66.2-80.5)
HCVA(0.29)	60.7 (51.8-68.9)	88.5 (79.5-93.8)	89.2 (80.7-94.2)
HCVA(0.29) & symptoms	29.5 (22.1-38.1)	94.9 (87.5-98)	90 (76.9-96)
HCVA(0.29) or symptoms	77.9 (69.7-84.3)	62.8 (51.7-72.7)	76.6 (68.4-83.2)
Symptoms	46.7 (38.1-55.5)	69.2 (58.3-78.4)	70.4 (59.7-79.2)

Table 9.21 Overall screener performance (excluding presenting HCVA) for detecting SAIEC. The combinations in red represent the best compromise between sensitivity and specificity

Test Combination	Sensitivity	Specificity	PPV
LCVA(0.39) or NVA	74.6 (66.2-81.5)	74.4 (63.7-82.7)	82 (73.8-88)
LCVA(0.39) or NVA &symptoms	36.9 (28.8-45.7)	87.2 (78-92.9)	81.8 (69.7-89.8)
LCVA(0.39) or NVA or symptoms	84.4 (77-89.8)	56.4 (45.4-66.9)	75.2 (67.3-81.7)
LCVA(0.49) or NVA	65.6 (56.8-73.4)	83.3 (73.5-90)	86 (77.5-91.6)
LCVA(0.49) or NVA & symptoms	33.6 (25.8-42.4)	89.7 (81-94.7)	83.7 (71-91.5)
LCVA(0.49) or NVA or symptoms	78.7 (90.6-85)	62.8 (51.7-72.7)	76.8 (68.7-83.3)

Table 9.22 Overall screener performance (excluding presenting HCVA & NVA) for detecting SAIEC. The combinations in red represent the best compromise between sensitivity and specificity

Test Combination	Sensitivity	Specificity	PPV
LCVA(0.39)	71.3 (62.7-78.6)	76.9 (66.4-84.9)	82.9 (74.5-88.9)
LCVA(0.39) & symptoms	35.2 (27.3-44.1)	88.5 (79.5-93.8)	82.7 (70.3-90.6)
LCVA(0.39) or symptoms	82.8 (75.2-88.5)	57.7 (46.6-68)	75.4 (67.4-81.9)
LCVA(0.49)	59 (50.1-67.3)	89.7 (81-94.7)	90 (81.5-94.8)
LCVA(0.49) & symptoms	28.7 (21.4-37.3)	93.6 (85.9-97.2)	87.5 (73.9-94.5)
LCVA(0.49) or symptoms	77 (68.8-83.6)	65.4 (54.3-75)	77.7 (69.5-84.2)
Symptoms	46.7 (38.1-55.5)	69.2 (58.3-78.4)	70.4 (59.7-79.2)

9.4.2 Best Combinations for detecting significant acuity impairing eye conditions

From all the above tables it seems as though the best combinations in each table occur when the tests are used at their original cut off values without incorporating symptoms, or when the tests are used at the higher cut off values incorporating symptoms in an OR method. The best combinations will now be compared in the table below.

Table 9.23 Best test combinations for detecting SAIEC. The significance of the yellow highlighted cell is described in the text below the table. The combinations in red represent the best compromise between sensitivity and specificity

Test Combination	Sensitivity	Specificity	PPV
HCVA(0.19) or LCVA(0.39) or NVA	80.3 (72.4-86.4)	66.7 (55.6-76.1)	79 (71-85.3)
HCVA(0.29) or LCVA(0.49) or NVA or symptoms	82 (74.2-87.8)	60.3 (49.2-70.4)	76.3 (68.4-82.8)
HCVA(0.19) or LCVA(0.39)	77.9 (69.7-84.3)	69.2 (58.3-78.4)	79.8 (71.7-86.1)
HCVA(0.29) or LCVA(0.49) or symptoms	80.3 (72.4-86.4)	62.8 (51.7-72.7)	77.2 (69.1-83.6)
HCVA(0.19) or NVA	79.5 (71.5-85.7)	67.9 (57-77.3)	79.5 (71.5-85.7)
HCVA(0.29) or NVA or symptoms	80.3 (72.4-86.4)	60.3 (49.2-70.4)	76 (67.9-82.5)
HCVA(0.19)	77 (68.8-83.6)	73.1 (62.3-81.7)	81.7 (73.7-87.7)
LCVA(0.39) or NVA	74.6 (66.2-81.5)	74.4 (63.7-82.7)	82 (73.8-88)
LCVA(0.49) or NVA or symptoms	78.7 (90.6-85)	62.8 (51.7-72.7)	76.8 (68.7-83.3)
LCVA(0.39)	71.3 (62.7-78.6)	76.9 (66.4-84.9)	82.9 (74.5-88.9)
LCVA(0.49) or symptoms	77 (68.8-83.6)	65.4 (54.3-75)	77.7 (69.5-84.2)

Summary

The following key points can be derived from the above table: All the combinations give reasonable sensitivity but the combinations that give a suitable compromise between sensitivity and specificity are highlighted in red. The addition of near acuity provides a slightly higher sensitivity and may be useful in a situation where it is important to detect as many people as possible with visual loss.

- In a country where there are few optometric services (e.g., developing countries), specificity may be more important than sensitivity and in this case low contrast VA alone may be a simple screening tool that it is appropriate (see cell highlighted in yellow in table). This single test provides the best specificity out of all the combinations.

- Combining all the tests together increases the chances of detecting visual loss (i.e. a high sensitivity value) but the high number of false positives (those who are normal according to the gold standard but are identified as been abnormal according to the screener) results in a low specificity value which may lead to unnecessary referrals for further eye care.

- The single best test to use for screening of visual loss is HCVA which provides both relatively high sensitivity and specificity. However, a higher sensitivity can be obtained, with minimal effect on specificity, by combining this with other tests.

- From a pragmatic viewpoint, the most appropriate assessment of screener performance in the UK may be the screening test's performance at detecting the cases who an optometrist would feel require eye examinations. The screener obtains 94.6 % sensitivity and 93.8% specificity in this type of analysis.

9.5 Glaucoma

Glaucoma is not one of the target conditions as discussed in Chapter 4, but nonetheless the screening test's performance at detecting glaucoma patients/suspects was analysed. The discussion in Chapter 4 acknowledges that it would be difficult to detect glaucoma with vision screening since all three commonly used glaucoma tests have a low sensitivity and/or specificity in isolation, (Harper & Reeves, 1999a) and using all three tests in screening would be impractical. Although visual loss from glaucoma cannot be treated, further visual loss can be prevented through timely detection. The most appropriate test for the detection of glaucoma that could be incorporated into a vision screener was a visual field test.

"With or at risk of glaucoma" was defined as those cases that a community optometrist would be likely to refer or wish to closely monitor because of glaucoma/suspicion of glaucoma. This definition is summarised in Table 9.24.

Table 9.24 Defining 'with or at risk of glaucoma'

Patients who are already diagnosed with glaucoma
Patients who were referred to the hospital eye service on the basis of the gold standard test results: fields, pressures, optic nerve head fundoscopy and in many cases GDX
In cases where it was necessary to monitor the patient closely due to the risk of glaucoma based on the gold standard test results.

There were 19 patients in Study 2 that fell in to the category of 'with or at risk of glaucoma' as defined Table 9.24. The clinical characteristics of these patients are outlined in the table below. The defining clinical characteristics of 'with or at risk of glaucoma' included optic nerve head assessment, intraocular pressure readings and visual field assessment. The presence of a family history of glaucoma was also noted. Where ever possible, a GDX test was performed to assess the health of the retinal nerve fibre layer around the optic disc.

Table 9.25 Clinical characteristics of patients 'with or at risk of glaucoma' as defined in Table 9.24

	Optic nerve head cup: disc ratio and description including integrity of neural retinal rim (NNR)	**Intraocular pressure (mmHg)**	**Visual fields Repeated on 2 occasions** 1) Within normal limits 2) borderline 3) Outside normal limits	**GDX Nerve fibre indicator analysis** 1) Low risk 2) Suspect 3) high risk	**Family history of glaucoma**	**Outcome** 1)Already diagnosed and under hospital eye service 2) referred for possible glaucoma 3) monitor for "at risk' of glaucoma
1	R) 0.55 L) 0.3 R appears pale with inferior thinning of NRR	R) 18 L) 18	R) 3 L) 1	R) 2 L) 2	None	2
2	R) 0.5 L)0.5 Pale with inferior loss of NRR	R) 18 L) 18	R) 3 L) 3		None	1
3	R) 0.45 L)0.45 Very deep Slightly pale, but NRR even	R)13 L 12	R) 3 L) 3		None	3
4	R) 0.25 L) 0.25 Moderate depth, pale, NRR even	R) 13 L) 15	R) 2 L) 3	R) 2 L) 2	Yes	1
5	R) 0.45 L) 0.4 Moderate depth, NRR even	R) 11 L) 13	R) 3 L) 3	R)1 L) 1	None	1
6	R) 0.45 L) 0.45 Moderate depth NRR even	R) 15 L) 17	R) 3 L) 3	R) 1 L) 1 But significant asymmetry	Yes	2
7	R) 0.3 L) 0.4 NRR inferior notching L eye	R) 16 L) 17	R) 3 L) 3		none	2
8	R) 0.3 L) 0.35 Slightly pale, NRR even	R) 12 L) 11	R) 3 L) 3	R) 3 L) 3	yes	2
9	R) 0.25 L) 0.25 Very pale, deep, indistinct margins	R) 17 L) 18	R) 3 L) 3		none	2

10	R) 0.2 L) 0.2 NRR even moderate depth	R) 11 L) 11	R) 3 L) 2	R) 1 L) 1	Yes	3
11	R) 0.6 L) 0.5 Very pale and uneven NRR	R) 15 L) 15	R) 3 L) 3	R) 3 L) 3	none	2
12	R) 0.35 L)0.35 Moderate depth NRR even	R) 14 L) 13	R) 2 L) 1	R) 1 L) border between 1 and 2	yes	3
13	R) 0.7 L)0.7 Deep and pale	R) 15 L 17	R) 3 L) 3	R) 2 L) 2		2
14	R) 0.75 L) 0.85 Inferior NRR loss, deep and pale	R) 12 L) 12	R) 3 L) 3			1
15	R) 0.25 L0.25 Moderate depth NRR even	R) 14 L) 14	R) 1 L) 2	R) 1 L) 2		3
16	R) 0.75 L)0.80 Pale, loss of NRR	R) 11 L) 12	R) 3 L) 3			1
17	R) 0.6 L) 0.6 Deep, pale, thinning of NRR	R) 11 L) 12	R) 3 L) 3			1
18	R) 0.6 L)0.8 Pale with uneven NRR	R) 14 L) 17	R) 3 L) 3			2
19	R) 0.4 L)0.4 Slightly pale, moderate depth NRR slight thinning of NRR	R) 11 L) 11	R) 3 L) 3	R) 2 L) 2	None	2

The definition of SAIEC has been amended in the table below to incorporate those with glaucoma or those at risk of glaucoma in one eye or both eyes. This is stated in Table 9.26

Table 9.26 Defining SAIEC, incorporating glaucoma

Significant acuity impairing eye conditions	Monocular/Binocular
Significant gain in distance acuity through refractive correction.	RE or LE or Both
Significant gain in near acuity through refractive correction	Both eyes only
Significant cataract	RE or LE or Both
Risk of rapid progression macular degeneration	RE or LE or Both
Those with glaucoma/glaucoma suspect.	RE or LE or Both

In the analyses described earlier in this chapter it was found that HCVA alone and HCVA or NVA produced good sensitivity and specificity for detecting SAIEC (excluding glaucoma). These two combinations will now be combined with the visual field test in an OR method to give a complete overview of screener performance for detecting SAIEC. Study 1 showed that the most appropriate cut off for the visual field test was missing more than 5 points (VF>5), Study 2 found a different cut off: missing more than 10 points (VF>10). Both these cut off values will be used to find the most appropriate combination. As with HCVA and LCVA, it was thought important that the visual field test was able to detect a monocular defect and so the visual field data were analysed monocularly.

This section of the analysis will also look at the ability of LCVA together with visual field results to screen for glaucoma. Research has shown that LCVA may be abnormal in glaucoma and other visual pathway dysfunction that is not detected by HCVA (Regan & Neima, 1984). Also in this part of the analysis, all the vision screening tests including the visual field test are combined together to see how well the screener detects significant acuity impairing eye conditions including glaucoma. The various test groupings and the key statistics derived are included in the section below.

9.5.1 Screener test combinations for detecting significant acuity impairing eye conditions including glaucoma.

The key statistics for the above combinations are given in the table below. A further column has been added to the table below to show the number of glaucoma patients/ glaucoma suspects that were correctly identified by the screener using the various combinations. The gold standard eye examination indicated that there

were 19 patients who had glaucoma or were at risk of glaucoma in accordance with the above definition.

Table 9.27 Test combinations with visual fields for the detection of SAIEC including glaucoma. The significance of the yellow highlighted cell is described in the section below the table. The combinations in red represent the best compromise between sensitivity and specificity

Test Combination	Sensitivity	Specificity	PPV	Glaucoma detection
HCVA(0.19)	71.2 (63-78.2)	69.1 (57.4-78.8)	81.7 (73.7-87.7)	7/19
HCVA(0.19) or NVA	74.2 (66.2-80.9)	64.7 (52.8-75)	80.3 (72.4-86.4)	8/19
LCVA (0.39)	65.9 (57.5-73.4)	73.5 (62-82.6)	82.9 (74.5-88.9)	7/19
HCVA(0.19) or LCVA(0.39) or NVA	75 (67-81.6)	63.2 (51.4-73.7)	79.8 (71.9-86)	8/19
VF>5	72 (63.8-78.9)	32.4 (22.4-44.2)	67.4 (59.3-74.6)	14/19
VF>10	50 (41.6-58.4)	72 (60.4-81.3)	77.6 (67.7-85.2)	10/19
HCVA (0.19) OR VF>5	87.9 (81.2-92.4)	25 (16.2-36.4)	69.5 (62.1-75.9)	15/19
HCVA (0.19) OR VF>10	80.3 (72.7-86.2)	51.5 (39.8-62.9)	76.3 (68.5-83.6)	11/19
LCVA (0.39) OR VF>5	85.6 (78.6-90.6)	26.5 (17.4-38)	69.3 (61.9-75.9)	15/19
LCVA (0.39) OR VF>10	76.5 (68.6-82.9)	54.4 (42.7-65.7)	76.5 (68.6-82.9)	11/19
HCVA OR NVA OR VF>5	87.9 (81.2-92.4)	25 (16.2-36.4)	69.5 (62.1-75.9	15/19
HCVA OR NVA OR VF>10	81.1 (73.5-86.8)	50 (38.4-61.6)	75.9 (68.2-82.2)	11/19
HCVA(0.19) or LCVA(0.39) or NVA OR VF (>5)	87.9 (81.2-92.4)	25 (16.2-36.4)	69.5 (62.1-75.9)	15/19
HCVA(0.19) or LCVA(0.39) or NVA OR VF (>10)	81.1 (73.5-86.8)	48.5 (37.1-60.2)	75.4 (67.7-81.7)	11/19

Summary

Although the vision tests alone produce a good sensitivity and specificity result, the ability to detect glaucoma patients is poor, this is improved by using the visual field test The highest specificity value for the detection of all common ocular abnormalities, including glaucoma, is achieved by the visual field test alone (highlighted cell). Introducing the visual field test in to the combinations does help to increase the number of glaucoma patients that are detected and also increases the sensitivity, but the overall specificity values are reduced. The combinations that

give a suitable compromise between sensitivity, specificity and glaucoma detection are highlighted in red. As mentioned in Chapter 8 (Section 8.4), there is a subjective element in the choices made. The bottom two rows of the table represent a combination of the entire screening tool which results in high sensitivity and glaucoma detection but low specificity.

9.6 Conclusions

The above analyses highlight that the combination of tests that are most appropriate in screening for eye disease in older patients is dependent on the aim of the screening program and also on the resources that are available after the screening has taken place. Below is table that summarises this, and which also includes the data on the pragmatic analysis of the cases that require an eye examination.

Table 9.28 Summary table of test combinations for the detection of SAIEC. The combinations in red represent the best compromise between sensitivity and specificity

Test Combination	Sensitivity	Specificity	PPV	Comment
HCVA(0.19) or NVA	79.5 (71.5-85.7)	67.9 (57-77.3)	79.5 (71.5-85.7)	These two combinations give a good compromise between sensitivity and specificity for detecting SAIEC excluding glaucoma. The glaucoma detection values on these combinations are very low.
HCVA(0.19)	77 (68.8-83.6)	73.1 (62.3-81.7)	81.7 (73.7-87.7)	
LCVA(0.39)	71.3 (62.7-78.6)	76.9 (66.4-84.9)	82.9 (74.5-88.9)	This combination gives a slightly higher specificity value for detecting SAIEC excluding glaucoma and may be useful in an area where eye care resources are limited.
HCVA (0.19) OR VF>10	80.3 (72.7-86.2)	51.5 (39.8-62.9)	76.3 (68.5-83.6)	This combination gives a high sensitivity value for detection of SAIEC including glaucoma. The glaucoma detection was 11/19. This may be useful in area where eye care services are not limited and where the aim of the screening program is to detect as many people as possible with visual problems.
LCVA (0.39) OR VF>10	76.5 (68.6-82.9)	54.4 (42.7-65.7)	76.5 (68.6-82.9)	This combination is possibly a better compromise than the above for the detection of SAIEC including glaucoma. It still results in a glaucoma detection of 11/19 but gives a slightly better specificity
Performance of screener from an optometric	94.6 (90.3-97)	93.8 (71.7-99.7)	99.4 (96.8-100)	This shows the ability of the screener

perspective Reduced HCVA or no eye examination in the last year				to detect patients who a typical optometrist feels would need an eye examination.
Performance of screener from an optometric perspective Reduced HCVA and no eye examination in the last year	81.8 (73.1-88.2)	94.1 (87.6-97.2)	93.1 (85.8-96.1)	

If one of the aims of the screening program is to include glaucoma detection (as well as significant refractive error, significant cataract and MD progression), then LCVA OR VF>10 would be the best combination. If glaucoma detection is not one of the conditions that the screening program is including then HCVA alone would be the best compromise or LCVA alone would give a higher specificity in areas where resources are limited. The three most appropriate combinations have been highlighted in red.

In the next chapter, the results from the rapid flipchart will be analysed.

Chapter 10

Investigation of the effectiveness of a rapid flipchart screener for screening the vision of older people in the community

10.1 Rapid flipchart screener

The first version of the computer screener was used to determine the best test battery to be incorporated in to the revised computerised vision screener (CVS2). In addition to the computerised screener, the key tests were made available in a flipchart format. In this chapter the flipchart vision screener (FVS) will be evaluated in the same way as the computerised screener.

Receiver operator curves for the flipchart screener are presented below for each of the target conditions together with key statistics to evaluate the ability of the test to detect the target conditions. The target conditions were defined previously in Chapter 4 and these definitions are used to define the conditions found in the gold standard with which the screening tests are compared. High Contrast visual acuity (HCVA) and low contrast visual acuity (LCVA) have been evaluated first because these were monocular tests; this is followed by near visual acuity (NVA) which was evaluated binocularly.

The cut off values for both CVS1 and CVS2 relate to LogMAR values. However, the scoring system for the FVS is slightly different. The scoring system for distance acuity when using the FVS as discussed in Chapter 4, relates to how many letters the patient could not read or read incorrectly. Each letter incorrectly read relates to a score of 1; if the patient read all the letters correctly this would give a score of 0. The near acuity is scored in the same way but is based on how difficult the patient found the text to read. In order to relate the scores from the FVS to logmar acuity,

conversion tables at the back of the FVS enabled the scores to be converted into acuity values. These tables are reproduced below.

Table 10.1 Conversion table for distance HCVA FVS scores to LogMAR and Snellen acuities

Snellen	6/9.5				6/12				6/15				6/18				6/24 +
LogMAR	0.2				0.3				0.4				0.5				0.6
FVS Score	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16

Table 10.2 Conversion table for converting distance LCVA FVS scores to LogMAR and Snellen acuities

Snellen	6/15				6/18				6/24 +
LogMAR	0.4				0.5				0.6
FVS score	0	1	2	3	4	5	6	7	8

Table 10.3 Conversion table for converting NVA FVS scores to N notation

N Notation	N7 Easy	N9 Easy	N12 Easy	N12 (Not easy)
FVS score	1	2	3	4

The analyses in this chapter will present the cut off values using the FVS score. The distance acuity tests will be evaluated first using the left eye, followed by near acuity and then test combinations will be analysed. At the end of the next section evaluating the monocular cut-offs, Table 10.11 which contains all the cut-off values for distance acuity, will summarise the section before the results of the near acuity test are presented. The near acuity cut-off values will be summarised in Table 10.16 before the results of the test combinations are presented.

In accordance with the flow chart at the beginning of Chapter 7 (Figure 7.1) The descriptive statistics and the comparison of the data from the FVS with the gold standard data will be dealt with first before the individual test cut-offs from monocular ROCs are determined.

10.2 Descriptive statistics of FVS results

This section will give an overall analysis of the acuity tests in the FVS. The data from the screening tool will be compared to the gold standard eye examination in a similar approach to that used for the CVS1 and CVS2 in Chapter 7.

High contrast acuity

The methods for measuring visual acuity have been discussed in Chapter 4. The graphs below show the frequency distributions of the presenting visual acuities achieved from the FVS and from the gold standard eye examination.

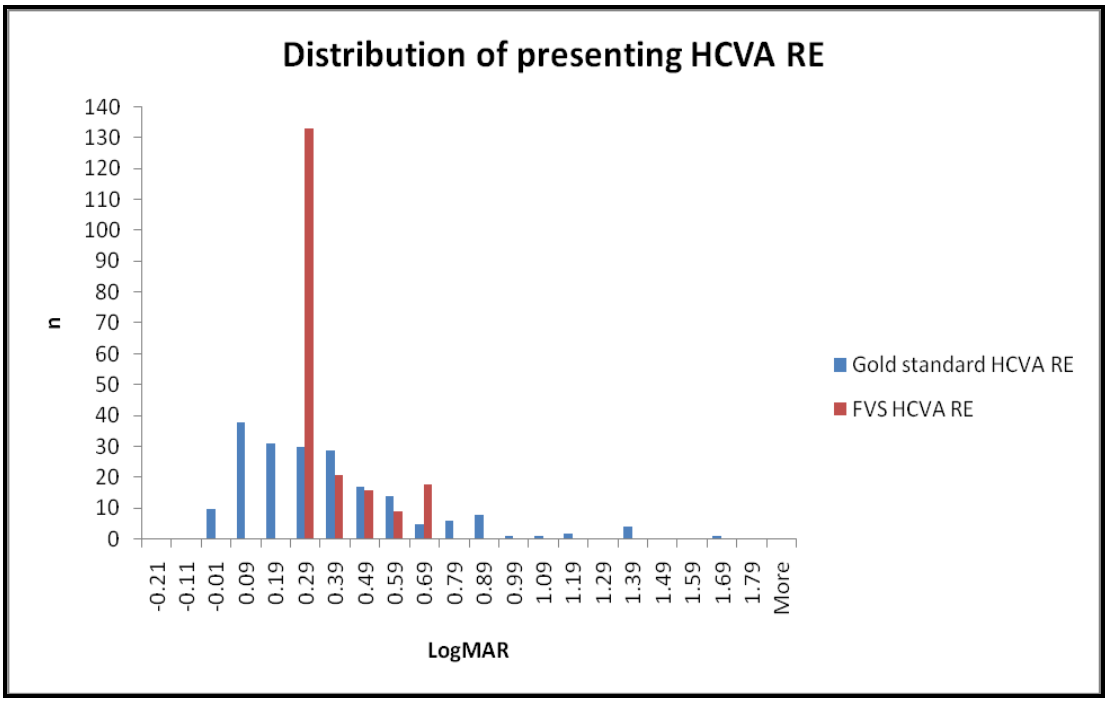


Figure 10.1 Distribution of presenting HCVA in RE for Study 2. The FVS test measurement range was 0.20 to 0.60 (see text).

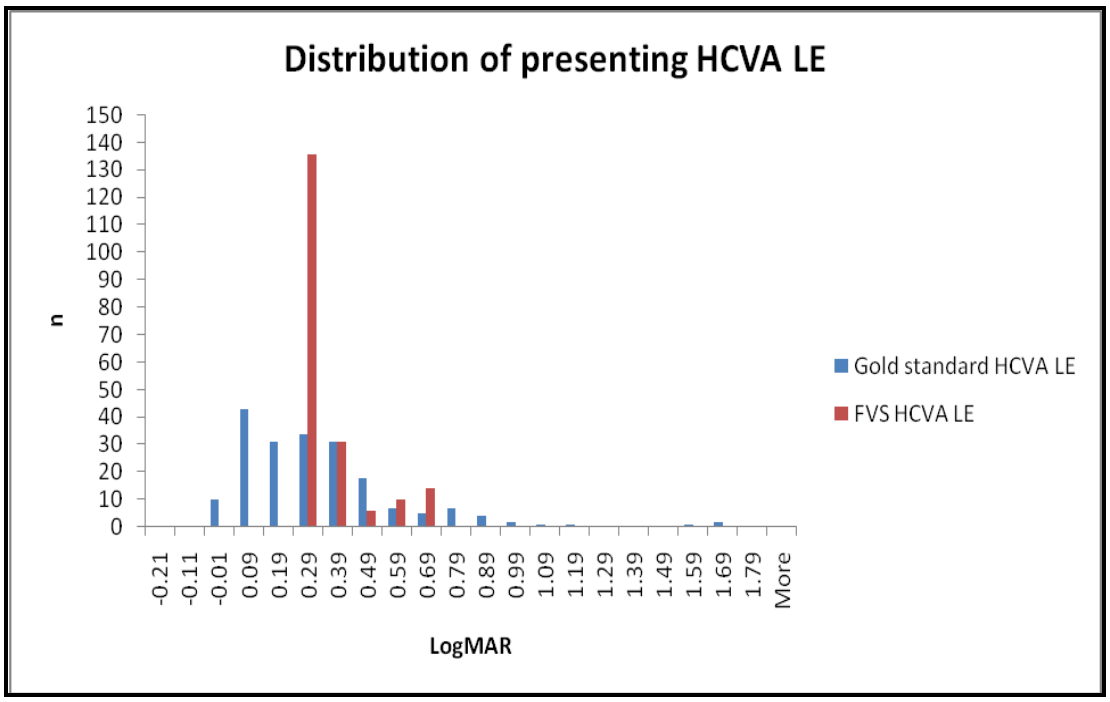


Figure 10.2 Distribution of presenting HCVA in LE for Study 2. The FVS test measurement range was 0.20 to 0.60 (see text).

Figure 10.1 and Figure 10.2 show the distributions of high contrast visual acuities measured in the gold standard eye examination and with the FVS. The results are not directly comparable as the FVS has a minimum size of 0.2 LogMAR and a maximum size of 0.6 LogMAR resulting in “ceiling” effects at both ends of the distribution. As noted in Chapter 7 with figures 7.13 and 7.14, graphs showing the correlation between the acuity achieved in the gold standard eye examination and the acuity achieved with the screener will be influenced by the measurement range of the screener test (0.20 to 0.60 LogMAR for HCVA with the FVS). To give a more accurate estimate of the inter-test agreement between the high contrast visual acuity tests of the screener and the gold standard test, Bland and Altman graphs (Bland and Altman, 1986) were plotted based on the central range of data, for which the two tests are comparable (data points that for the gold standard lay between 0.30 and 0.50 LogMAR). These are shown for the right and left eyes in Figure 10.3 and Figure 10.4.

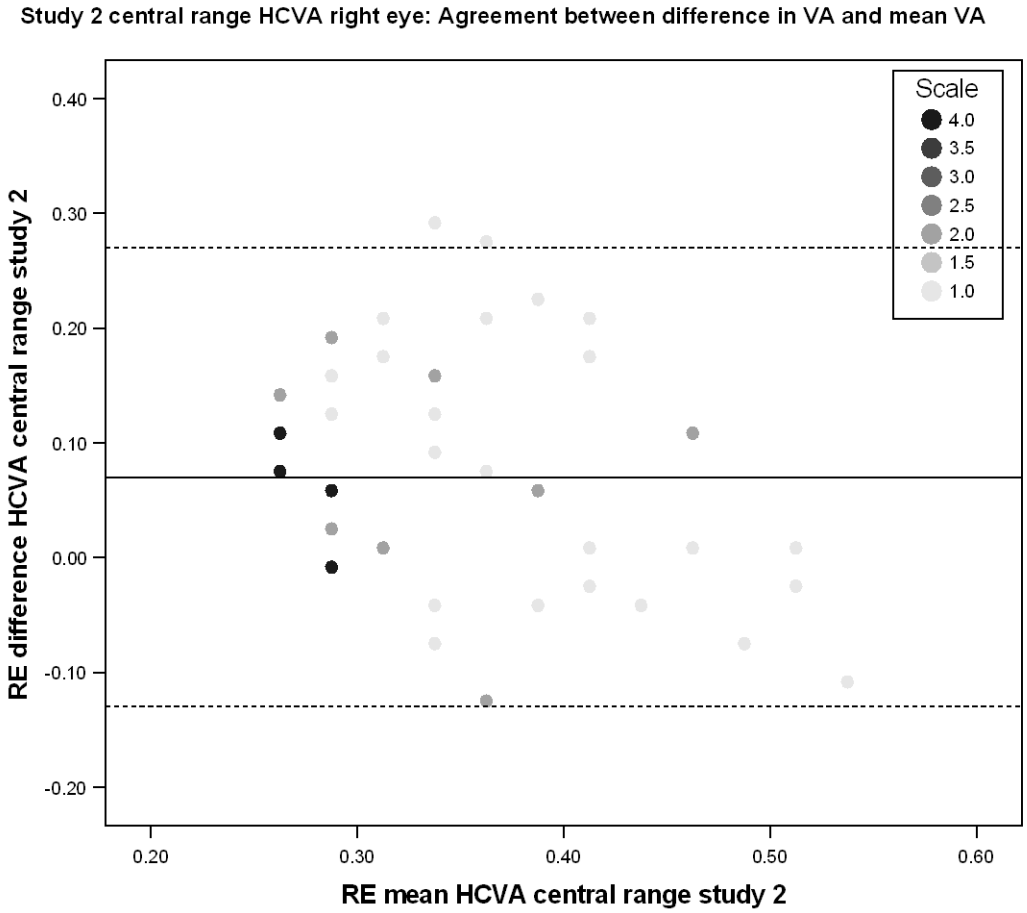


Figure 10.3 Bland and Altman plot of the difference in VA v mean VA in right eye, for gold standard and FVS high contrast VA. The central range of data used excludes those with gold standard acuity of less than 0.3 LogMAR and greater than 0.5 LogMAR (N=56). The mean difference (solid horizontal line) is 0.072 and the standard deviation is 0.10. The upper and lower dashed lines represent + and – 2 standard deviations from the mean (0.27 and -0.13).

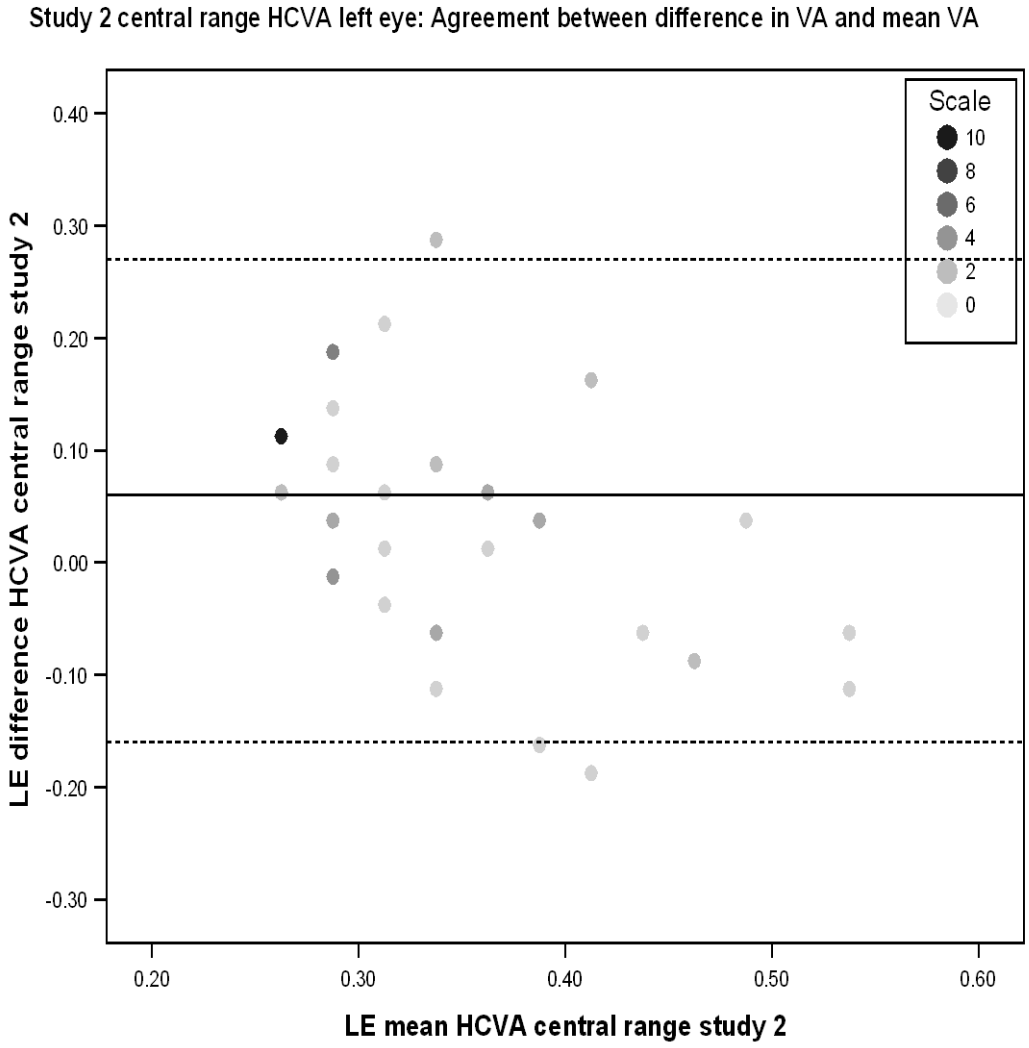


Figure 10.4 Bland and Altman plot of the difference in VA v mean VA in left eye, for gold standard and FVS high contrast VA. The central range of data used excludes those with a gold standard acuity of less than 0.3 LogMAR and greater than 0.5 LogMAR (N=55). The mean difference (solid horizontal line) is 0.059 and the standard deviation is 0.11. The upper and lower dashed lines represent + and – 2 standard deviations from the mean (0.27 and -0.16).

The horizontal reference lines in Figure 10.3 and Figure 10.4 show the key variables for the inter-test repeatability of high contrast visual acuity. The mean difference between the two measurement methods is 0.072 for the right eye and 0.059 for the left eye and the 95% limits are approximately two lines for each method. These results are consistent with the results from the computer vision

screener (Figures 7.15 and 7.16) and as noted in Chapter 7, these findings are fairly consistent with the literature on repeatability of visual acuity measurements.

Low contrast acuity

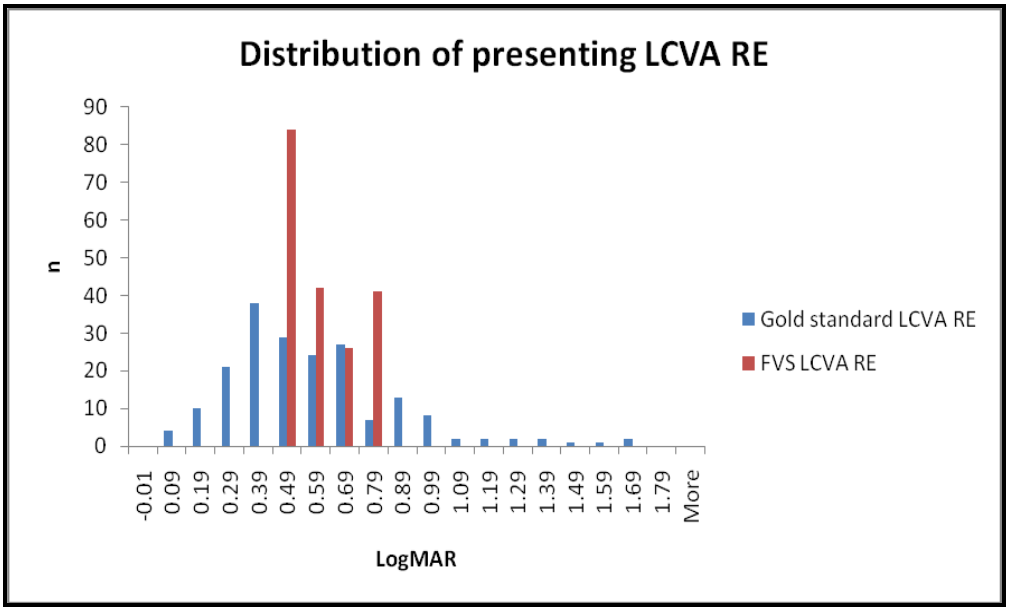


Figure 10.5 Distribution of presenting LCVA in RE for Study 2. The FVS test measurement range was 0.40 to 0.70.

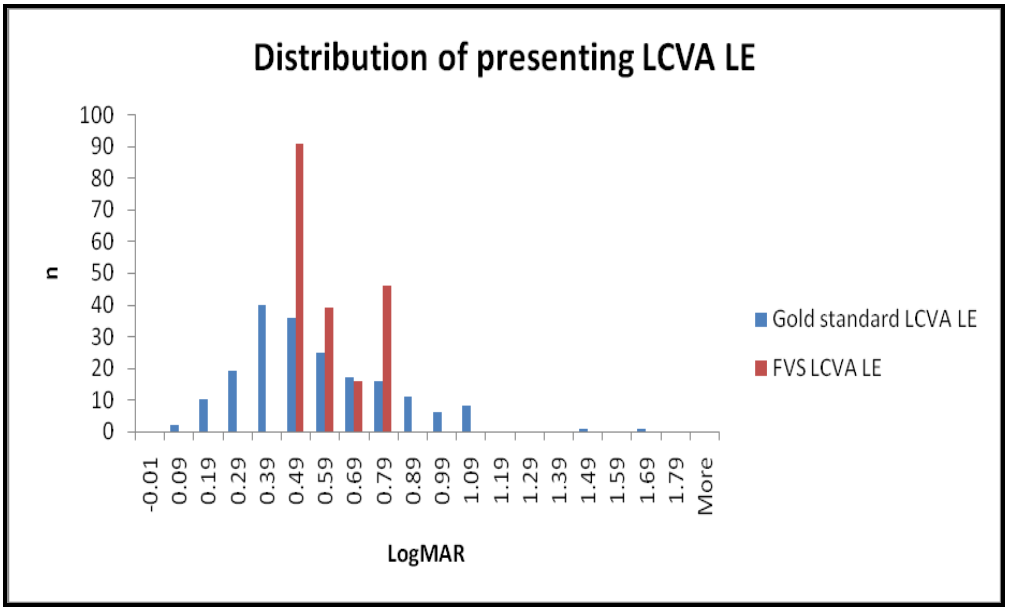


Figure 10.6 Distribution of presenting LCVA in LE for Study 2. The FVS test measurement range was 0.40 to 0.70.

Figure 10.5 and Figure 10.6 show the distributions of low contrast visual acuities measured in the gold standard eye examination and with the FVS. Again, the graphs show the upper and lower ceiling effect imposed by the measurement range of the FVS. The graphs below (Figure 10.7 and Figure 10.8) give an estimate of the inter-test agreement between the low contrast visual acuity tests of the screener and the gold standard test. As with high contrast acuity (Figure 10.3 and Figure 10.4), Bland and Altman graphs (Bland and Altman, 1986) were plotted based on the central range of data, for which the two tests are comparable (data points that for the gold standard low contrast acuity lay between 0.45 and 0.65 LogMAR). The central range for low contrast acuity was obtained by eliminating measurements that were in the 0.5 LogMAR extremes. This is slightly different than for high contrast acuity in Figure 10.3 and Figure 10.4 where gold standard acuity values that were in the 1.0 LogMAR extremes of the measurement range of the screener were eliminated. The reason for this is because the screener had a greater measurement range for high contrast acuity (0.2 - 0.6 LogMAR) than for low contrast acuity (0.40 – 0.70 LogMAR).

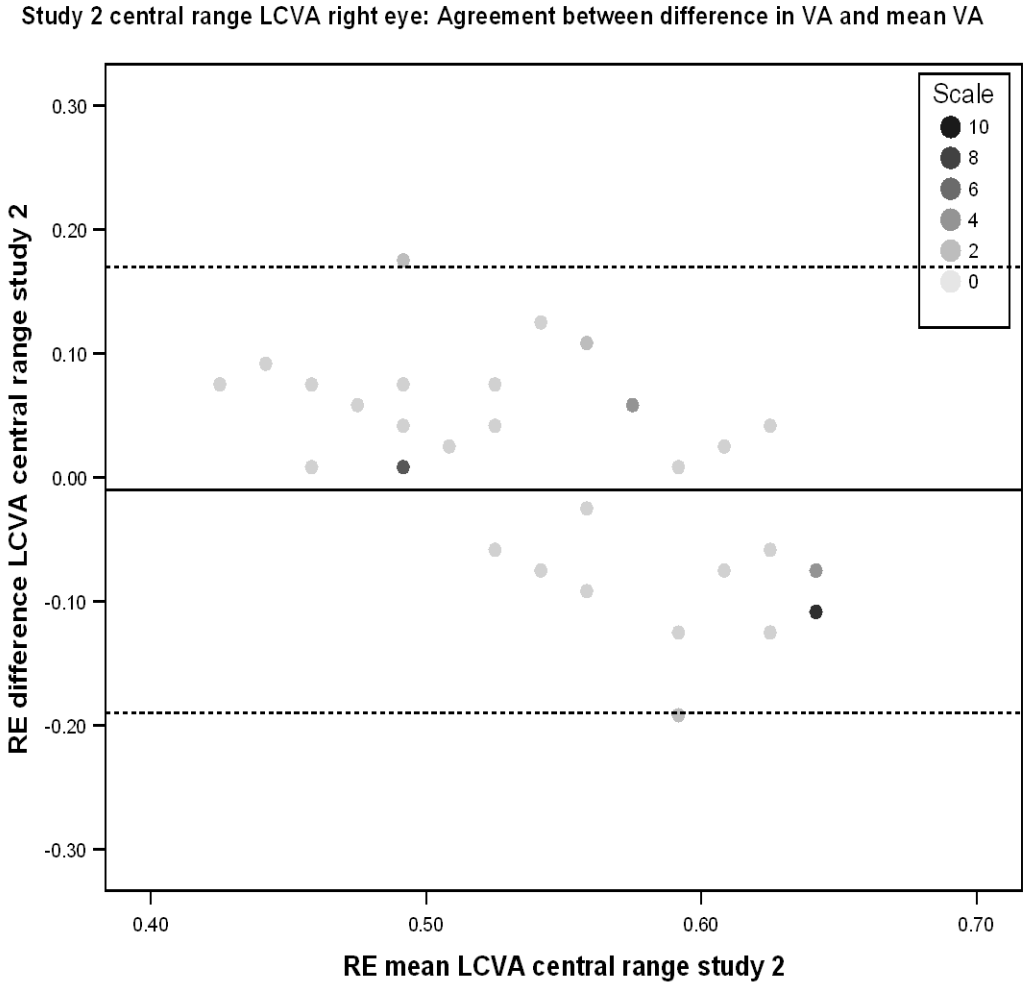


Figure 10.7 Bland and Altman plot of the difference in LCVA v mean LCVA in right eye, for gold standard and FVS low contrast VA. The central range of data used excludes those with gold standard acuity of less than 0.45 LogMAR and greater than 0.65 LogMAR (N=52). The mean difference (solid horizontal line) is -0.014 and the standard deviation is 0.09. The upper and lower dashed lines represent + and – 2 standard deviations from the mean (0.17 and -0.19)

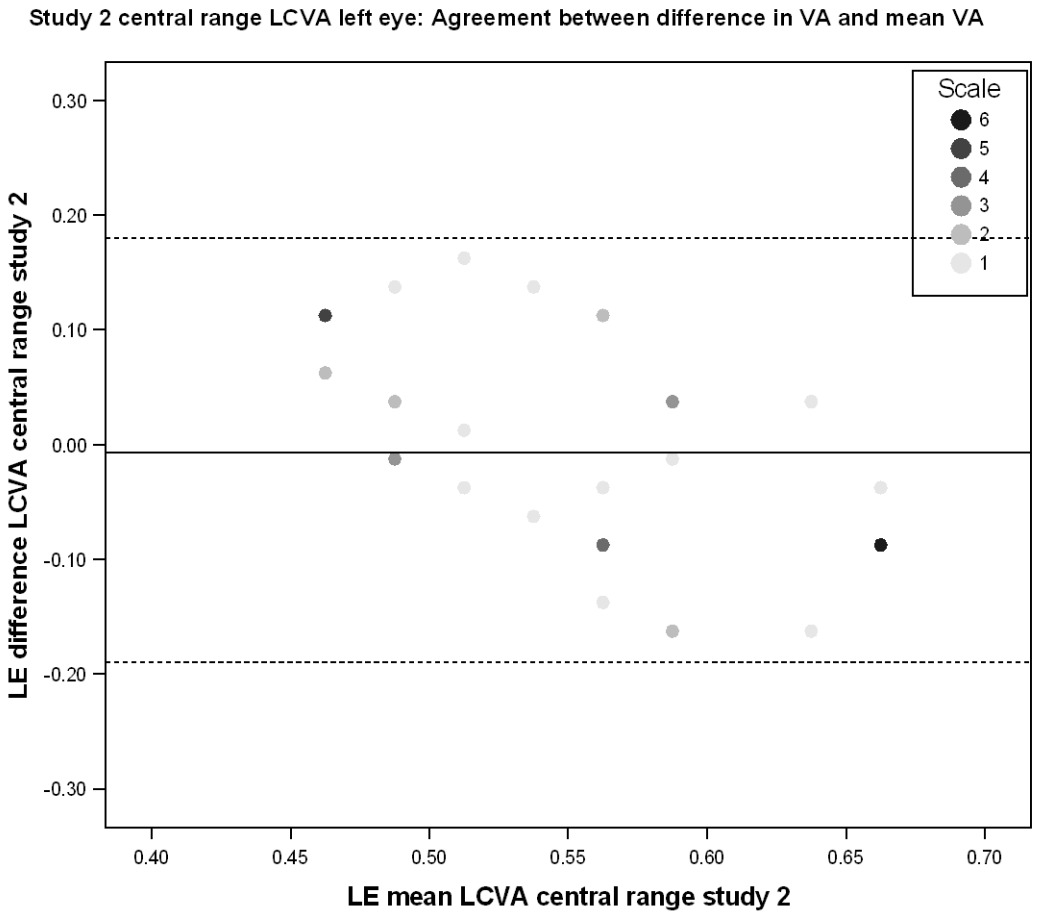


Figure 10.8 Bland and Altman plot of the difference in LCVA v mean LCVA in left eye, for gold standard and FVS low contrast VA. The central range of data used excludes those with a gold standard acuity of less than 0.45 LogMAR and greater than 0.65 LogMAR (N=41). The mean difference (solid horizontal line) is -0.007 and the standard deviation is 0.09. The upper and lower dashed lines represent + and – 2 standard deviations from the mean (0.18 and -0.19)

The horizontal reference lines in Figure 10.7 and Figure 10.8 show the key variables for the inter-test repeatability of high contrast visual acuity. The mean difference between the two measurement methods is -0.014 for the right eye and -0.007 for the left eye and the 95% limits are approximately two lines. It is interesting to note that the mean difference for low contrast acuity for the right and left eye are both negative values. This is because measurement of low contrast acuity with the FVS was giving worse acuities (higher LogMAR values) than with the gold standard. This is discussed further in Chapter 12.

Near acuity

Near acuity was measured binocularly with the flipchart screener and monocularly with the gold standard. Figure 10.9 below has used the gold standard near acuity data from the better eye to compare with the binocular measurement from the flipchart screener. The range of near acuity measured with the flipchart was N7-N12 (0.3-0.5 LogMAR). The scoring system for near acuity was not based on how many letters were incorrectly read as it was for distance acuity but on how easy the patient found the text to read. For the purpose of the graph below, patients that found the N7 text “easy” to read have been assumed to have a near acuity of N6 (although it may have been better than this). Patients that found the N12 text “not easy” have been assumed to have a near acuity of N14 (although it may have been worse than this).Therefore, the measurement range of the screener has been taken to be N6- N14 (0.2- 0.6 LogMAR). As with the Bland and Altman graphs so far in this chapter, Figure 10.9 below has been plotted based on the central range of data, for which the two tests are comparable (data points that for the gold standard near acuity lay between 0.25 and 0.55 LogMAR).

The horizontal reference lines in Figure 10.9 show the key variables for the inter-test repeatability of near visual acuity. The mean difference between the two measurement methods is 0.118.

An important point to consider is that the near vision test on the screener is simply trying to determine if reading is easy or not with different size prints. It is not attempting to measure an acuity threshold.

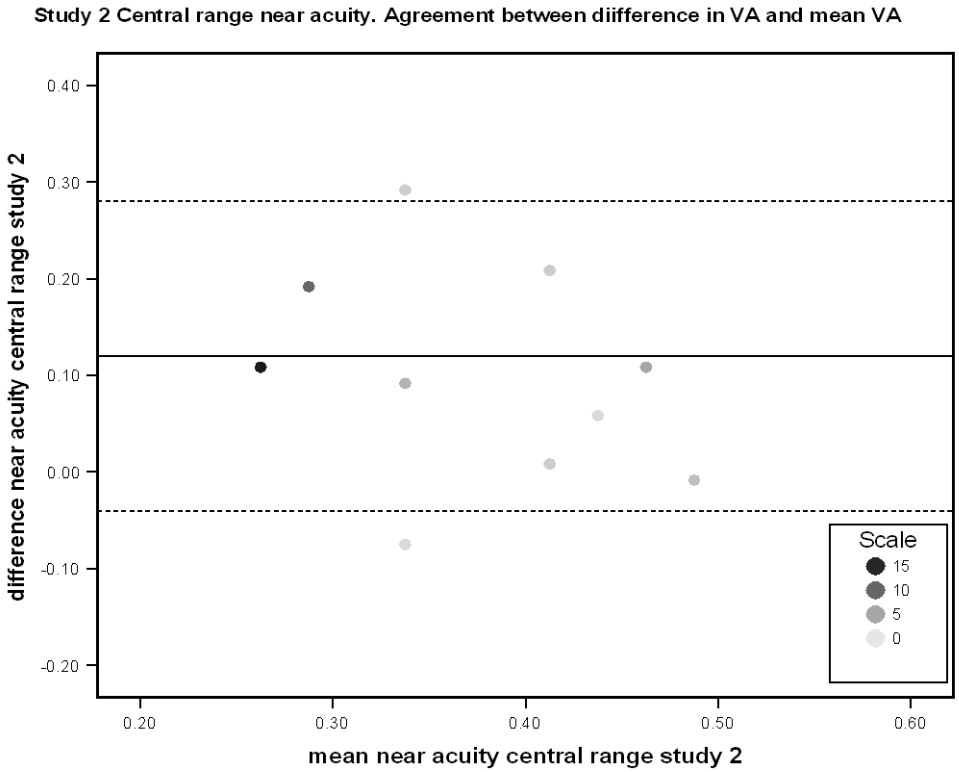


Figure 10.9 Bland and Altman plot of the difference in near acuity v mean near acuity, for gold standard and FVS. The central range of data used excludes those with a gold standard near acuity of less than 0.25 LogMAR and greater than 0.55 LogMAR (N=46). The mean difference (solid horizontal line) is 0.118 and the standard deviation is 0.08. The upper and lower dashed lines represent + and – 2 standard deviations from the mean (0.28 and -0.04).

The above section has focussed on the descriptive data from the FVS. In the next section ROCs will be used to derive the monocular cut off values for each of the tests. A full description of ROC curves can be found in Section 7.3 and the limitations of the ROCs in this study have been noted in Chapter 8 and Chapter 9. The same limitations apply here, including the high criterion set to assess the screener's performance and the difficulty with relating structural appearance to functional measures. These points will be discussed further in Chapter 12. As acknowledged in previous chapters the ROCs will also be limited because many different conditions influence the functional measures, it could be argued that a more valid measure of screener performance is to evaluate whether it detects those cases that an optometrist would be likely to feel needed an eye examination. Such an evaluation is carried out in Section 10.3.8.

10.3 Monocular data: selection of appropriate cut offs

The suitability of the screening distance acuity test for determining various eye conditions will now be investigated. At the end of this section, Table 10.11 which contains all the cut off values for distance acuity, will summarise the section before the results of the near acuity test are presented.

10.3.1 The ability of presenting screener visual acuity to determine significant cataract

(a) (b)

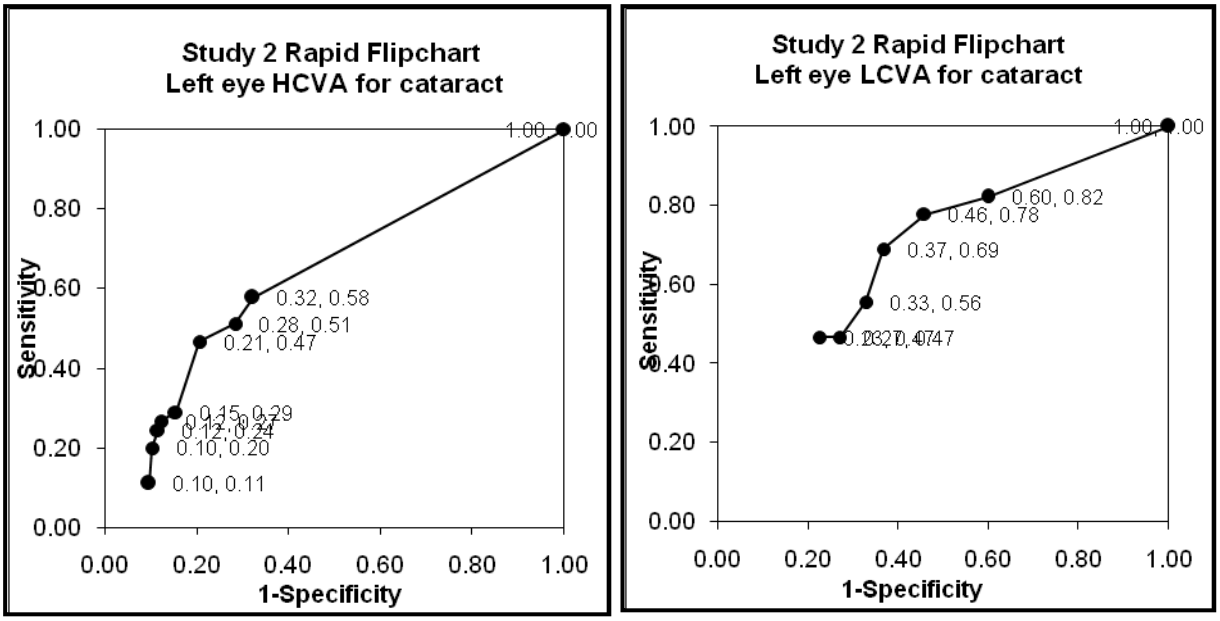


Figure 10.10. Graph illustrating the sensitivity versus 1-specificity for (a) high contrast visual acuity and (b) low contrast visual acuity of the left eye obtained with FVS for predicting presence of significant cataract in the left eye as defined in Chapter 4. The data labels state the X and Y coordinates.

Table 10.4 The key statistics for the FVS score cut off values obtained from Figure 10.10

Study 2 Flipchart Cataract	High Contrast Acuity	Low Contrast Acuity
Ideal Cut Off	Score>0.9	Score>4.9
Sensitivity (%)	57.8 (43.3-71)	68.9 (54.3-80.5)
Specificity (%)	67.7 (60-74.6)	63.2 (55.4-70.4)
PPV (%)	34.2 (24.5-45.4)	35.5 (26.1-45.6)
AUC	0.633 (0.538-0.727)	0.662 (0.573-0.751)

10.3.2 The ability of screener distance visual acuity to determine significant gain in acuity with new refractive correction (Rx)

(a) (b)

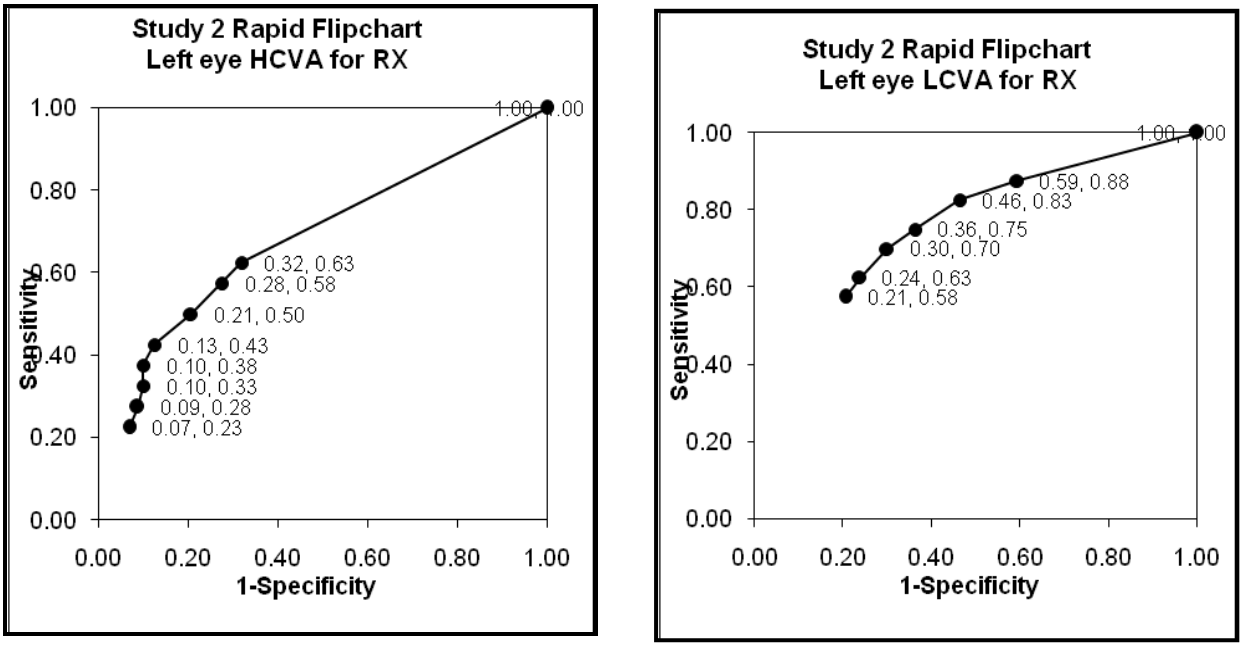


Figure 10.11 Graph illustrating the sensitivity versus 1-specificity for (a) high contrast visual acuity and (b) low contrast visual acuity of the left eye obtained with FVS for determining significant gain in acuity with new refractive correction as defined in Chapter 4. The data labels state the X and Y coordinates

Table 10.5 The key statistics for the FVS score cut off values obtained from Figure 10.11

Study 2 flipchart RX	High Contrast Acuity	Low Contrast Acuity
Ideal Cut Off	Score>0.9	Score>6.9
Sensitivity (%)	62.5 (47-75.8)	70 (54.6-81.9)
Specificity (%)	68.1 (60.6-74.8)	70 (62.5-76.6)
PPV (%)	32.9 (23.4-44.1)	36.8 (26.9-48.1)
AUC	0.659 (0.555-0.763)	0.719 (0.629-0.810)

10.3.3 The ability of presenting visual acuity to detect correctable visual loss (CVL)

Defining Correctable Visual loss

The results so far in this chapter have looked at the ability of distance acuity (high contrast and low contrast) to detect significant gain in distance acuity through refractive correction and the detection of significant cataract. As with the results from CVS2 (Chapter 9, p.238) correctable visual loss is defined as the presence of significant cataract and/or significant gain in distance acuity through refractive correction. Further on in this chapter, the definition of CVL will be amended to take account of significant binocular gain in near acuity through near refractive correction. This will be done when evaluating the binocular near acuity screening test.

(a) (b)

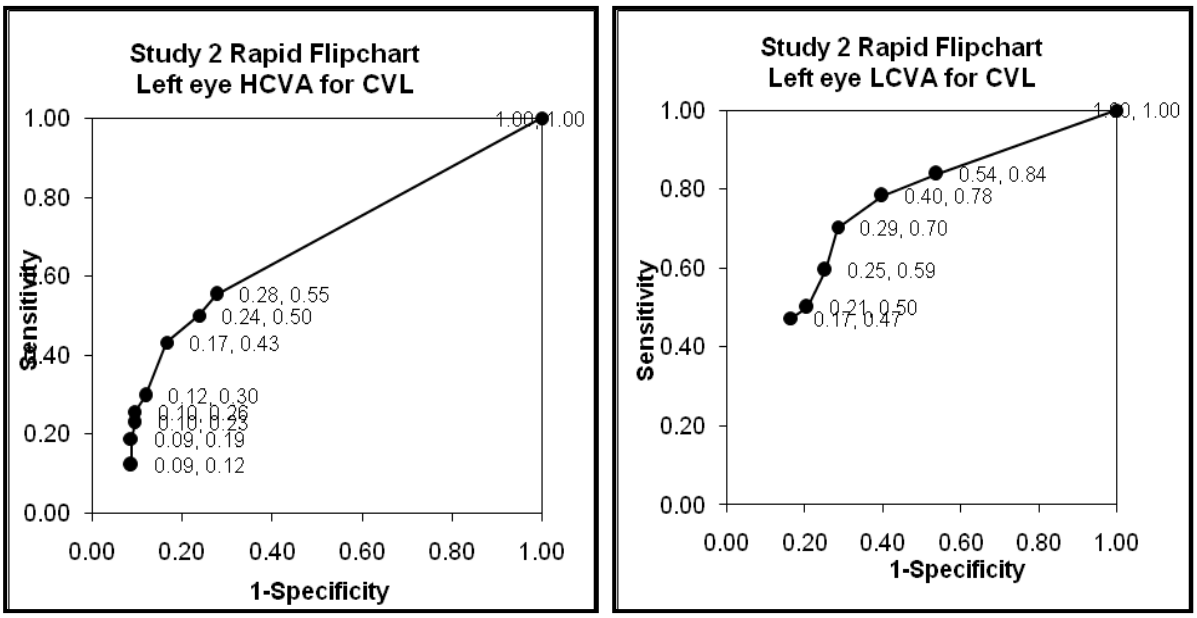


Figure 10.12 Graph illustrating the sensitivity versus 1-specificity for (a) high contrast visual acuity and (b) low contrast visual acuity of the left eye obtained with FVS for determining correctable visual loss as defined above. The data labels state the X and Y coordinates

Table 10.6 The key statistics for the FVS score cut off values obtained from Figure 10.12

Study 2 Flipchart CVL	High Contrast Acuity	Low Contrast Acuity
Ideal Cut Off	Score>0.9	Score>4.9
Sensitivity (%)	55.4 (44.1-66.2)	70.3 (59.1-79.5)
Specificity (%)	72.2 (63.8-79.3)	71.4 (63-78.6)
PPV (%)	53.9 (42.8-64.7)	59.1 (48.6-68.8)
AUC	0.647 (0.506-0.728)	0.723 (0.649-0.796)

The next 4 graphs will demonstrate the effectiveness of the FVS in detecting macular degeneration and macular degeneration at risk of progression. These two

categories have been defined in Chapter 4. As discussed in Chapter 4, although macular degeneration was not initially one of the target conditions it was thought important that tests of visual acuity in the screening tools ought to be able to detect macular conditions because of the significant effect it has on central vision.

10.3.4 The ability of presenting visual acuity to detect macular degeneration (MD)

(a) (b)

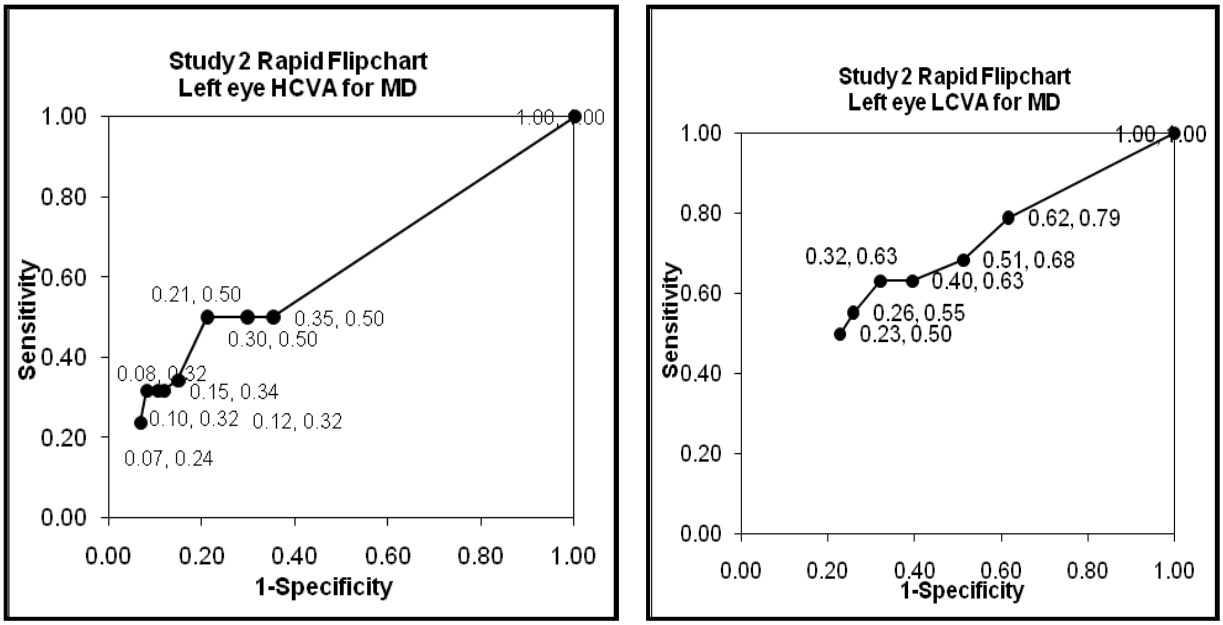


Figure 10.13 Graph illustrating the sensitivity versus 1-specificity for (a) high contrast visual acuity and (b) low contrast visual acuity of the left eye obtained with FVS for determining macular degeneration as defined in Chapter 4. The data labels state the X and Y coordinates

Table 10.7 The key statistics for the FVS score cut off values obtained from figure 10.13

Study 2 **Flipchart MD**	High Contrast Acuity	Low Contrast Acuity
Ideal Cut Off	Score>4.9	Score>6.9
Sensitivity (%)	50 (34.8-65.2)	63.2 (47.3-76.6)
Specificity (%)	79 (72.1-84.6)	67.9 (60.4-74.6)
PPV (%)	35.8 (24.3-49.3)	31.6 (22.2-42.7)
AUC	0.617 (0.507-0.726)	0.651 (0.550-0.751)

10.3.5 The ability of presenting visual acuity to detect macular degeneration risk of progression

(a) (b)

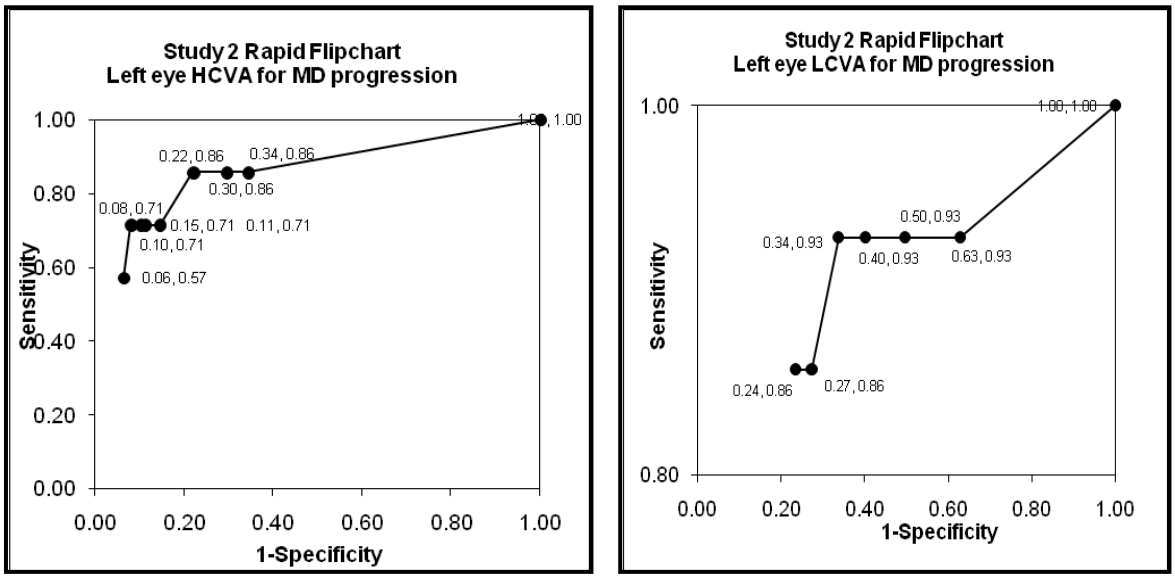


Figure 10.14 Graph illustrating the sensitivity versus 1-specificity for (a) high contrast visual acuity and (b) low contrast visual acuity of the left eye obtained with FVS for determining macular degeneration at risk of progression as defined in Chapter 4. The data labels state the X and Y coordinates

Table 10.8 The key statistics for the FVS score cut off values obtained from Figure 10.14

Study 2 Flipchart MD risk of Progression	High Contrast Acuity	Low Contrast Acuity
Ideal Cut Off	Score>4.9	Score>8.9
Sensitivity (%)	85.7 (60.1-946)	85.7 (60.1-96)
Specificity (%)	78.0 (71.5-83.3)	72.6 (65.8-78.5)
PPV (%)	22.6 (13.5-35.5)	19 (11.2-30.4)
AUC	0.851 (0.728-0.9)	0.822 (0.713-0.931)

The above results indicate that as with CVS2, FVS is far better when detecting MD at risk of progression compared with the basic measure of MD. As discussed in Chapter 9 this outcome is expected because visual loss is more significant in MD at risk of progression and it based on the higher grades of MD.

Further on in this chapter the screening tests will be combined to assess their suitability to detect the target conditions and macular degeneration at risk of progression will be combined with the target conditions when test combinations are being evaluated. A more practical assessment of the screener's performance will also be obtained in section 10.3.8

10.3.6 The ability of presenting visual acuity to detect refractive error, cataract, and MD

The presence of refractive error, cataract, or MD is labelled in the graphs below as significant acuity impairing eye conditions (SAIEC). This is defined in the same way as in Chapter 9 (p.242). As in the analyses of CVS2, this definition of CVS2 will be amended as further analyses are presented to give a more overall impression of the ability of the screener at detecting the target conditions. The graphs below show the ability of the screener to detect SAIEC in the left eye.

(a) (b)

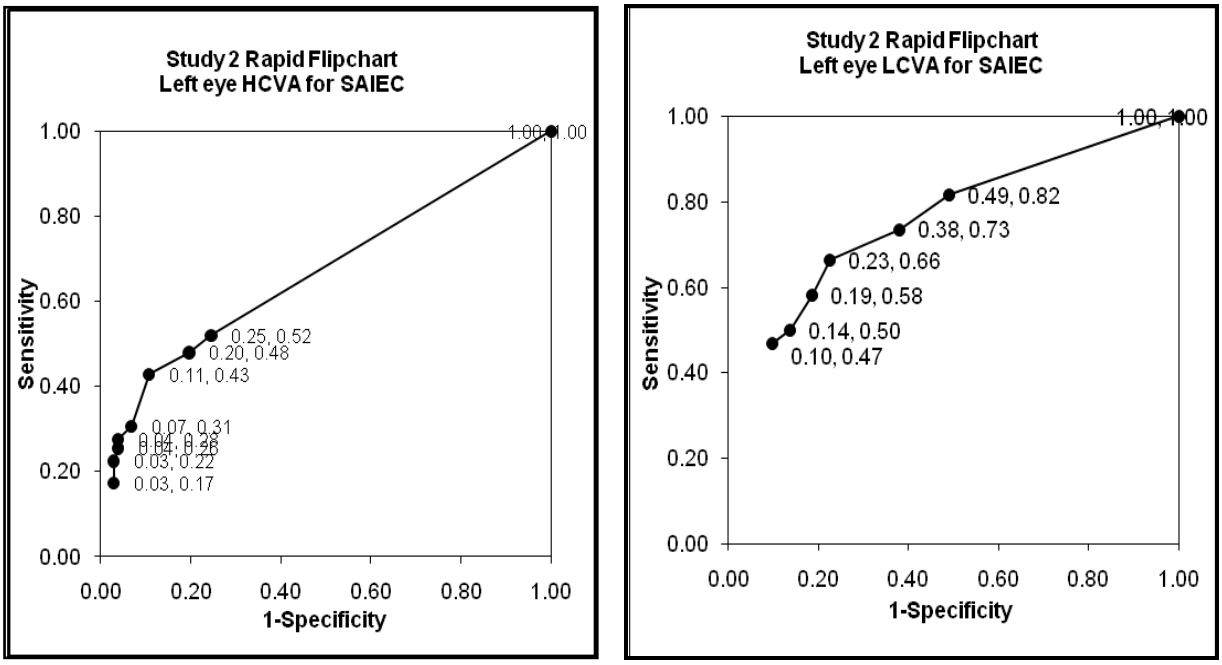


Figure 10.15 Graph illustrating the sensitivity versus 1-specificity for (a) high contrast visual acuity and (b) low contrast visual acuity of the left eye obtained with FVS for determining SAIEC as above. The data labels state the X and Y coordinates

Table 10.9 The key statistics for the FVS score cut off values obtained from

Study 2 Flipchart SAIEC	High Contrast Acuity	Low Contrast Acuity
Ideal Cut Off	Score>0.9	Score>4.9
Sensitivity (%)	52 (42.3-61.7)	66.3 (56.5-74.9)
Specificity (%)	75.5 (66.3-82.8)	77.5 (68.4-84.5)
PPV (%)	67.1 (55.9-76.6)	73.9 (63.8-81.9)
AUC	0.651 (0.550-0.751)	0.746 (0.678-0.815)

The validity of LCVA in detecting SAIEC can be seen in the above table and its performance remains stable across both screening tools. It is interesting to note that with FVS, LCVA performs better than HCVA.

10.3.7 The ability of presenting visual acuity to determine significant eye condition in either eye.

The ROC curves above evaluated the ability of distance acuity in detecting SAIEC in the left eye. The ROC curves below give an indication of how well HCVA and LCVA can detect SAIEC (i.e. the presence of refractive error, cataract, or MD) in either eye.

(a) (b)

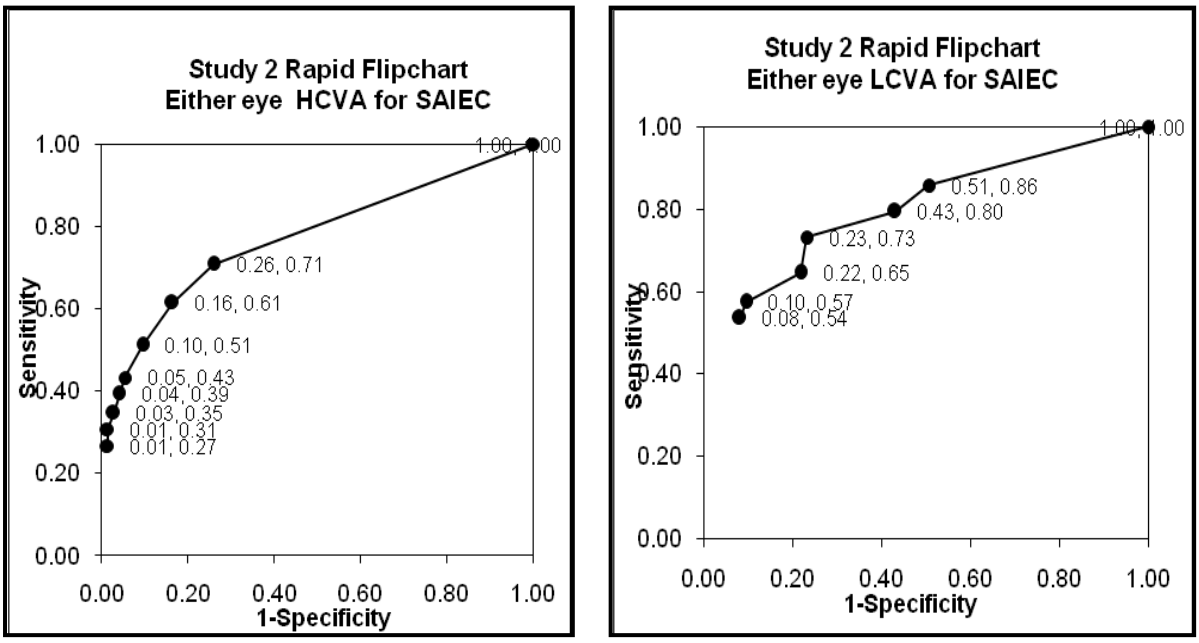


Figure 10.16 Graph illustrating the sensitivity versus 1-specificity for (a) high contrast visual acuity and (b) low contrast visual acuity of either eye obtained with FVS for determining SAIEC as defined above. The data labels state the X and Y coordinates

Table 10.10 The key statistics for the FVS score cut off values obtained from Figure 10.16

Study 2 Flipchart SAIEC Either eye	High Contrast Acuity	Low Contrast Acuity
Ideal Cut Off	Score>0.9	Score>4.9
Sensitivity (%)	70.9 (62.4-78.1)	73.2 (64.9-80.2)
Specificity (%)	74.0 (62.9-82.7)	76.7 (65.8-84.9)
PPV (%)	82.6 (74.4-88.5)	84.5 (76.6-90.1)
AUC (%)	0.771 (0.707-0836)	0.786 (0.722-0.850)

The values in Table 10.10 show the importance of LCVA in the detection of significant acuity impairing eye conditions (SAIEC). The results show that the sensitivity and specificity of LCVA for the detection of SAIEC in either eye is slightly better than HCVA. The effect of combining tests will be evaluated further in section 10.4.

Before the evaluation of the near acuity screening test the table below gives a summary of the cut off values obtained so far with the distance acuity screening tests.

Table 10.11 Summary of FVS HCVA and LCVA cut off values

	HCVA			**LCVA**		
Condition	Cut off value FVS score	Sensitivity (%)	Specificity (%)	Cut off value FVS score	Sensitivity (%)	Specificity (%)
Cataract	Score>0.9	57.8	67.7	Score>4.9	68.9	63.2
Rx	Score>0.9	62.5	68.1	Score>6.9	70	70
CVL	Score>0.9	55.4	72.2	Score>4.9	70.3	71.4
MD	Score>4.9	50	79	Score>6.9	63.2	67.9
MD risk prog	Score>4.9	85.7	78	Score>8.9	85.7	72.6
SAIEC (left eye)	Score>0.9	52	75.5	Score>4.9	66.3	77.5
SAIEC (either eye)	Score>0.9	70.9	74.0	Score>4.9	73.2	76.7

It can be seen that the distance acuity tests demonstrate a greater sensitivity and specificity for determining SAIEC in either eye compared with just the left eye. This is an expected outcome and gives a more accurate indication of screener performance. The importance of the screener to be able to detect monocular deficits is discussed in Chapter 7.

10.3.8 Performance of the screener from an optometric perspective

As discussed at the beginning of this Chapter, the ROC analyses above set a high criterion for the performance of the screener. In particular, the analyses investigate the ability of tests of visual **function** to detect conditions that are diagnosed by **appearance** during examination (e.g., cataract, AMD). The analysis in Table 10.12 shows the ability of the screener to detect patients that in the opinion of a "typical" optometrist is likely to benefit from an eye examination. This has been defined in Chapter 8 (p.245) as patients with a reduced high contrast visual acuity in one or both eyes and those who have not attended for an eye examination in the last year. An alternative criterion was also evaluated in Chapter 8: those with reduced high contrast acuity or those who have not had an examination within the last year. The results of both of these criteria combinations are stated in the table below. The ROCs so far show that the optimum cut-off value for HCVA using the FVS is score>0.9. If this score is converted to a LogMAR acuity using Table 10.1, a score of 0.9 corresponds to a LogMAR acuity of 0.2. This is in accordance with the findings from CVS1 and CVS2 and for the calculation in this section reduced HCVA for the gold standard has been defined as VA>0.19 LogMAR (as in Chapter 8 and 9) and reduced HCVA for the FVS has been defined as a score>0.9.

Table 10.12 Performance of screener from an optometric perspective

Performance of screener from an optometric perspective	Sensitivity (%)	Specificity (%)	PPV (%)
Reduced HCVA and no eye examination in the last year	76.8 (67.5-84)	95.0 (88.9-97.9)	93.8 (86.4-97.3)
Reduced HCVA or no eye examination in the last year	94.0 (89.6-96.6)	87.5 (64-96.5)	98.9 (95.9-99.7)

The above table shows that combining acuity testing with knowledge of the patient's last eye examination can result in a high sensitivity and specificity for detecting those patients that should be seen by an optometrist.

So far, the results above have focused on the ability of distance acuity to detect the target conditions. The section below will evaluate the ability of the binocular near acuity test to detect binocular acuity impairing eye conditions.

10.4 Evaluation of near acuity screening test

In this section the graphs and tables illustrate the ability of the binocular near visual acuity to predict binocular conditions. At the end of this section, Table 10.16 which contains all the cut-off values for near acuity, will summarise the section before the results of various test combinations are presented. This is the same procedure that was implemented for the analysis of CVS2 in Chapter 9 and the decision to analyse near visual acuity binocularly has been discussed in Chapter 8.

10.4.1 The ability of the binocular near vision screening test to detect significant under- corrected binocular near refractive error (NvRx).

Patients whose binocular visual acuity was at least 0.2 LogMAR units better with near subjective refractive findings than presenting binocular near visual acuity were defined as having a significantly under-corrected binocular near refractive error.

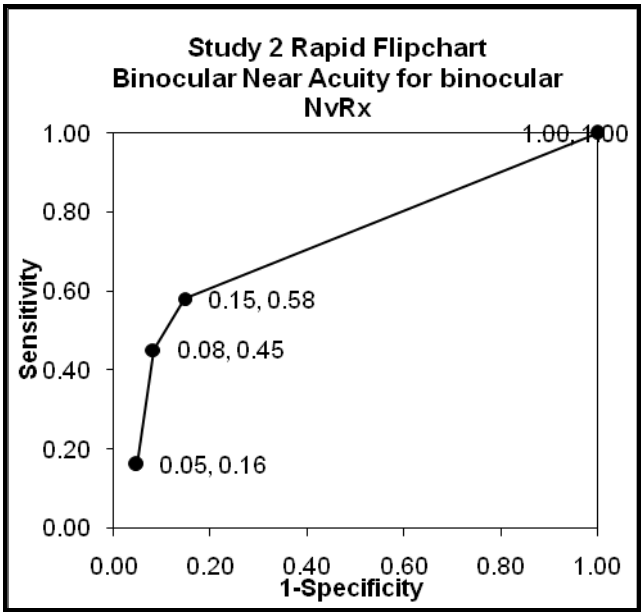


Figure 10.17 Graph illustrating the sensitivity versus 1-specificity for binocular near acuity obtained with CVS2 for predicting significant gain in binocular near acuity with new refractive correction as defined above. The data labels state the X and Y coordinates

Table 10.13 The key statistics for near acuity cut off values obtained from Figure 10.17

Study 2 Flipchart Near visual acuity Predicting significant binocular NvRx	Significant uncorrected near refractive error being defined as 0.2LogMar unit increase
Ideal Cut Off	Score>1.9
Sensitivity (%)	58.1 (40.8-73.6)
Specificity (%)	85.2 (79.1-89.8)
PPV (%)	41.9 (28.4-56.7)
AUC	0.722 (0.612-0.832)

10.4.2 The ability of the binocular near vision screening test to detect significant binocular cataract.

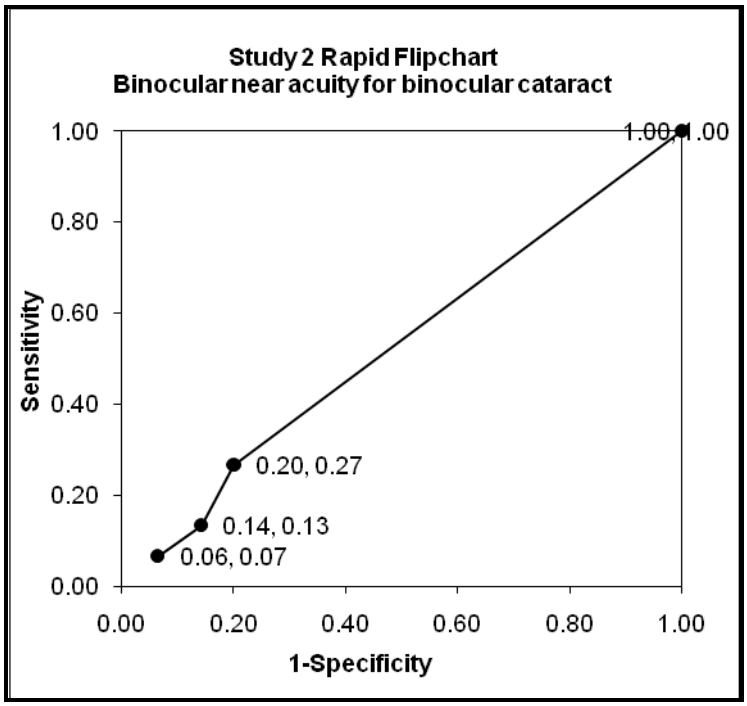


Figure 10.18 Graph illustrating the sensitivity versus 1-specificity for binocular near acuity obtained with FVS for predicting significant binocular cataract as defined in Chapter 4. The data labels state the X and Y coordinates

Table 10.14 The key statistics for near acuity cut off values obtained from Figure 10.18

STUDY 2 Flipchart Near visual acuity Predicting binocular Significant cataract	Near Acuity Score
Ideal Cut Off	Score >1.9
Sensitivity (%)	26.7 (16-41)
Specificity (%)	80 (73-85.5)
PPV (%)	27.9 (16.7-42.7)
AUC	0.528 (0.432-0.625)

10.4.3 The ability of the binocular near vision screening test to detect significant binocular correctable visual loss (BinCVL)

For the purposes of evaluating the near vision test, correctable visual loss has been defined as the presence of significant **binocular** distance refractive error &/or presence of **binocular** cataract &/or significant **binocular** near refractive error. This is the same procedure that was followed when evaluating the near acuity test in CVS2 (Chapter 9)

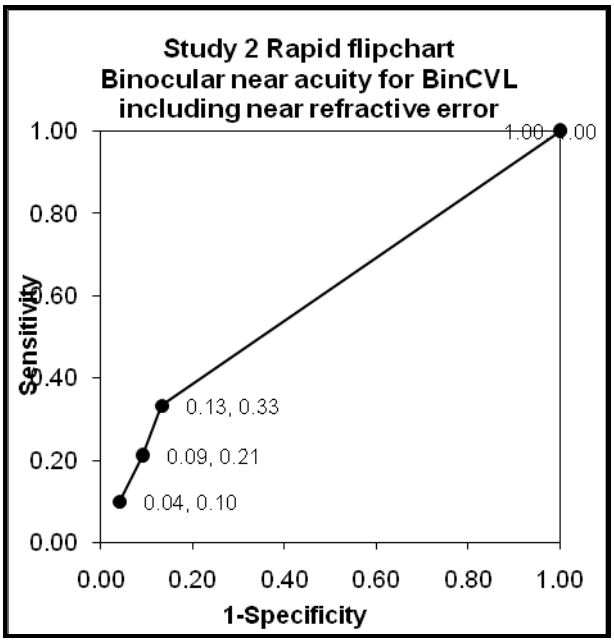


Figure 10.19 Graph illustrating the sensitivity versus 1-specificity for binocular near acuity obtained with CVS2 for predicting binocular correctable visual loss as defined above. The data labels state the X and Y coordinates

Table 10.15 The key statistics for near acuity cut off values obtained from Figure 10.19

Study 2 Flipchart Near visual acuity Predicting BinCVL	
Ideal Cut Off	Score>1.9
Sensitivity (%)	33.3 (24-44.1)
Specificity (%)	86.6 (79.3-91.6)
PPV (%)	62.8 (47.9-75.6)
AUC	0.598 (0.517-0.680)

This section will end with a summary table (Table 10.16) that states the near acuity cut off values obtained for the eye conditions evaluated in this section. The next section of this chapter will focus on test combinations to give an overall view of the performance of the screener. As in Chapter 9, this will involve not only combining the screening tests, but also combining the eye conditions and evaluating the ability of the screener to detect these conditions in either eye as opposed to just the left eye as done earlier in the chapter.

Table 10.16 Summary of FVS near acuity cut off values

	Near acuity		
Condition	Cut off value FVS score	Sensitivity (%)	Specificity (%)
Binocular Cataract	Score> 1.9	26.7	80
NvRx	Score>1.9	58.1	85.2
Binocular CVL	Score>1.9	33.3	86.6

As mentioned earlier in the chapter, the screener does not measure the near acuity but rather the minimum font size required to read text easily since it was judged important to detect older people whose vision made reading difficult. In view of the acuity reserve, this may be some way above the acuity threshold. A disadvantage of this pragmatic approach is that the criterion used is likely to be more variable than threshold acuity because it is dependent on the patient's interpretation of "easy". Consequently, one would expect that an evaluation of the near vision screening test using the ROC curves, although necessary to determine the cut off values, would not be expected to reveal high levels of sensitivity or specificity. If it is assumed that most near vision tasks are of size N9 or larger (LogMAR>0.39) then participants with an acuity of this measured in the gold standard might be expected to also fail the screener (cut off score > 1.9).

Table 10.17 below shows the sensitivity and specificity values obtained when evaluating the performance of the screener in this way.

Table 10.17 Performance of FVS for near vision

Performance of screener for near vision	Sensitivity (%)	Specificity (%)	PPV (%)
Reduced gold standard near acuity (worse eye>0.39 LogMAR)	61.9 (40.9-79.2)	96.4 (92.4-98.3)	68.4 (46-84.6)

The table above shows that the near vision test in the flipchart screener is of value in detecting those with reduced near acuity that may be experiencing problems in everyday tasks.

The next section of the chapter will evaluate various test combinations in the FVS.

10.5 Rapid Flipchart Screener test combinations

The tests in the flipchart have been evaluated to give cut-off values for failing individual tests. The cut-off values for HCVA and LCVA were determined using monocular data because it was thought important that the screener was able to detect a monocular visual defect (see p.201). However near visual acuity was conducted as a binocular test and the cut-off for this was determined using data from the right eye and the left eye, rather than right eye or left eye.

The next stage in the analyses will involve evaluating the overall performance of the flip-chart screener for detecting significant acuity impairing eye conditions identified in the gold standard. In this section “significant acuity impairing eye conditions” has been defined as refractive error that can be corrected with spectacles or significant cataract or macular degeneration that is at risk of rapid progression. This definition is stated in Chapter 9, Table 9.14.

Having now defined significant eye disease, ‘overall performance of screener’ also needs to be defined. ‘Overall performance’ will initially take into account all the tests that are included in the flipchart screener. All these tests will be combined in an ‘OR’ method to give the overall screener performance. The criterion for the definition of overall performance of screener is summarised in the table below.

Table 10.18 Defining overall performance of FVS

Overall screener performance	Monocular/Binocular
Presenting HCVA	RE or LE or Both
Presenting LCVA	RE or LE or Both
Presenting near acuity	Both eyes only

The sensitivity and specificity of various test combinations to determine significant eye disease has also been calculated in order to establish the minimum test battery that would be efficient in detecting the target conditions. The combinations of screening tests are outlined in Chapter 9, Table 9.16.

10.5.1 Overall screener performance for detecting significant acuity impairing eye conditions.

Table 10.19 below show the various test combinations for detecting SAIEC. The combinations in red represent the best compromise between sensitivity and specificity. At the end these combinations will be compared to give the ideal test combination. It should be noted that one of the limitations described in Section 10.1 still applies: for cataract and MD the screener is still being required to use a test of visual function to detect a condition that is being defined, with the gold standard, by appearance. Table 10.19 therefore also includes the data on the pragmatic analysis of the cases that require an eye examination (Section 10.3.8) and this issue is returned to in Chapter 12.

Table 10.19 Overall FVS screener performance for detecting SAIEC. The combinations in red represent the best compromise between sensitivity and specificity

Test Combination, with FVS cut off scores in brackets	Sensitivity (%)	Specificity (%)	PPV (%)
HCVA(0.9) or LCVA(4.9) or NVA (1.9)	82 (74.2-87.8)	61.5 (50.4-71.6)	76.9 (69-83.3)
HCVA (0.9) or LCVA (4.9)	79.5 (71.5-85.7)	66.7 (55.6-76.1)	78.9 (70.8-85.1)
HCVA (0.9) or NVA (1.9)	75.4 (67.1-82.2)	69.2 (58.3-78.4)	79.3 (71.1-85.7)
HCVA (0.9)	73 (64.5-80)	74.4 (63.7-82.7)	81.7 (73.4-87.8)

LCVA (4.9) or NVA (1.9)	78.7 (70.6-85)	70.5 (59.6-79.5)	80.7 (72.7-86.8)
LCVA (4.9)	75.4 (67.1-82.2)	76.9 (66.4-84.9)	83.6 (75.6-89.4)
Performance of screener from an optometric perspective Reduced HCVA or no eye examination in the last year	94.0 (89.6-96.6)	87.5 (64-96.5)	98.9 (95.9-99.7)
Performance of screener from an optometric perspective Reduced HCVA and no eye examination in the last year	76.8 (67.5-84)	95.0 (88.9-97.9)	93.8 (86.4-97.3)

The table above shows that, as expected, an increased sensitivity is achieved when more tests are used, but this has the effect of decreasing specificity. The results show that if one test should be used on the rapid flipchart tool, it ought to be LCVA with a cut off score of 4.9. This means that patients who achieve a score of 5 or more (0.5 LogMAR) should be referred for an eye examination. It is particularly interesting to note that LCVA fares better than HCVA as a single test to detect correctable visual loss in the flipchart format.

From a pragmatic viewpoint, the most appropriate assessment of screener performance in the UK may be the screening test's performance at detecting the cases who an optometrist would feel requires an eye examination. The screener obtains 94% sensitivity and 87.5% specificity with this type of analysis.

The above section has evaluated the results from the flipchart screener. The next chapter will look at the data from the quality of life questionnaires that participants completed before the eye examination and after any intervention.

Chapter 11
Quality of Life

11.1 Introduction

The review by Evans and Rowlands (2004) found considerable evidence that reduced vision is associated with impaired quality of life (QoL) and ability to carry out activities of daily living, depression, falls and other accidents (Evans & Rowlands, 2004p). The primary objectives of the present study outlined in chapter 3 centred around the development of screening tools with a battery of tests that could be used to detect correctable visual loss in older people. However, QoL measures were also incorporated into the study in order to establish the effect of screening and the eye examination on the QoL of older patients. The data on QoL will be outlined below and will give an indication of the effect that reduced vision may have on QoL.

11.2 Quality of life descriptive data

The method of measuring quality of life has been explained in Chapter 4. The participants completed the quality of life questionnaire before and up to 3 months after any intervention. Patients were contacted between 2 and 3 months after intervention was recommended. Data were obtained before and after the study using the same implementation method (either by phone or post) (Wolffsohn & Peterson, 2003). The Quality of Life questionnaire (LVQOL) has a summed score between 0 (a low quality of life) and 125 (a high quality of life).

The normality of the QoL data was investigated by plotting the frequency distributions and carrying out the Kolmogorov-Smirnov test of normality. There was a ceiling effect apparent with the test so that the data significantly differed from a normal distribution ($p<0.01$). An additional variable was calculated, ‘gain in QoL’, by subtracting the first reading from the second. This variable was also not normally distributed, with a high number of zero results. Non-parametric analyses were therefore used in this section, although in addition to the median, a mean and

standard deviation are quoted below where these are compared with other workers who have used the mean and standard deviation.

The table below gives a brief summary of the results obtained from the questionnaires. The results shows that the average increase in the quality of life achieved by intervention is comparable with the results of Wolffsohn and Cochrane (2000)(Wolffsohn & Cochrane, 2000). A copy of the LVQOL can be found in the appendix.

Table 11.1 Key statistics from Quality of Life questionnaires.

<table>
<tr><th></th><th colspan="2">Study 2</th><th>Scores according to Wolffsohn (Wolffsohn & Cochrane, 2000)</th></tr>
<tr><td>Number of participants</td><td colspan="2">200</td><td></td></tr>
<tr><td>Number of participants that responded to follow up</td><td colspan="2">194.
Response rate of 97%</td><td></td></tr>
<tr><td></td><td>Initial</td><td>Post study</td><td rowspan="5">The average LVQOL score for a population with low vision (60.9 +/- 25.1) was significantly lower than the average score of those with normal vision (100.3 +/- 20.8).</td></tr>
<tr><td>Average LVQOL Score</td><td>108</td><td>114</td></tr>
<tr><td>Median LCQOL Score</td><td>111</td><td>119</td></tr>
<tr><td>Min LVQOL Score</td><td>54</td><td>59</td></tr>
<tr><td>Max LVQOL score</td><td>125</td><td>125</td></tr>
<tr><td>Average increase between initial and post study scores</td><td colspan="2">7 +/- 7.3
(where 7.3 is the SD)</td><td rowspan="2">Rehabilitation improved the LVQOL score of those with low vision by an average of 6.8 +/- 15.6. (where 15.6 is the SD)</td></tr>
<tr><td>Median increase between initial and post study score</td><td colspan="2">5</td></tr>
<tr><td>Min difference between initial and post study LVQOL scores</td><td colspan="2">0</td><td></td></tr>
<tr><td>Max difference between Initial and Post study</td><td colspan="2">48</td><td></td></tr>
<tr><td>Patients whose score remained the same initial and post study</td><td colspan="2">56 patients out of 194, reported no difference in the QoL. This is a proportion of 29%</td><td></td></tr>
<tr><td>Patients whose score decreased after the eye examination</td><td colspan="3">No one reported a decrease in QoL. The questions in the LVQOL questionnaire relate to visual problems only and this may be a reason why no patients reported a decrease in QoL.</td></tr>
<tr><td>Those that did not take up the recommended intervention</td><td colspan="2">21 patients did not respond to intervention out of 148 patients that were recommended intervention. This is a proportion of 14% that did not respond to recommended intervention</td><td></td></tr>
<tr><td>No Intervention needed</td><td colspan="2">24% of patients did not require intervention</td><td></td></tr>
</table>

11.3 Further analyses

A comparison of the first QoL data with the second QoL data in all subjects showed a significant improvement (Wilcoxon signed ranks test, Z=10.5, p<0.001). The participants were divided into three groups: those (N=75) who were recommended a spectacle intervention and received this; those (n=46) who were recommended no intervention (mostly because no abnormality was detected) and those (N=21) who were recommended an intervention but did not accept this recommendation and therefore received no intervention. Wilcoxon signed ranks test revealed significant improvements in QoL in all three subgroups after an eye examination, with the largest effect size in the spectacle intervention group (Z=-7.33, p<0.001), then the no intervention recommended (Z=-4.69, p<0.001) and least improvement in the no intervention accepted group (Z=-2.91, p=0.004). An inspection of the QoL data reveals that a significant improvement occurred even in the no intervention accepted group is due to the question 'How well has your eye condition been explained to you?' These differences between the groups are explored further below and in the table by examining the gain in QoL.

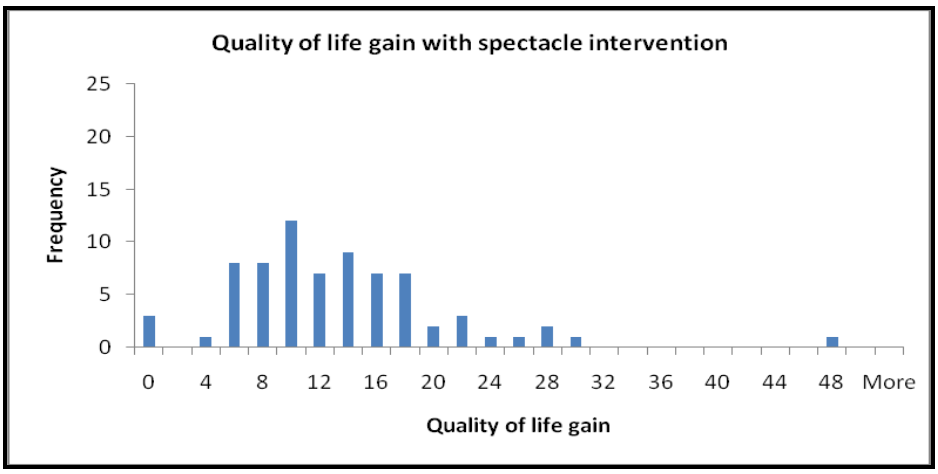
The QoL data in the three groups are summarised in Table 11.2 and the frequency distributions of the gain in QoL are plotted in Figure 11.1.

Table 11.2 Quality of life scores, including gain in quality of life for different patient groups

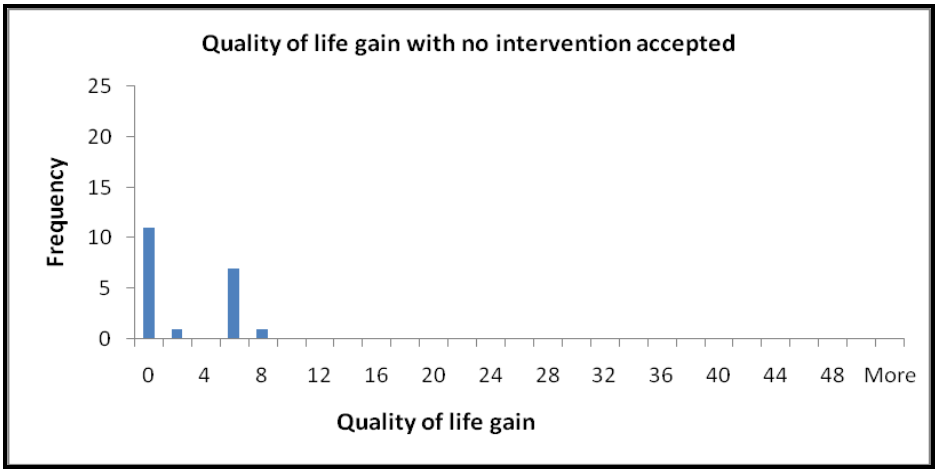
		All subjects	**No intervention required (NIR)**	**No intervention accepted (NIA)**	**Spectacle intervention (Spec)**
N		194	46	21	75
Initial-QoL	Median	111	120	109	108
	Minimum	54	96	75	54
	Maximum	125	125	121	125
Post study-QoL	Median	119	123	111	120
	Minimum	59	96	77	68
	Maximum	125	125	121	125
Gain	Median	5	0	0	12
	Minimum	0	0	0	0
	Maximum	48	5	7	48

Below are the distributions of the gain in quality of life in the three groups described above.

(a)



(b)



(c)

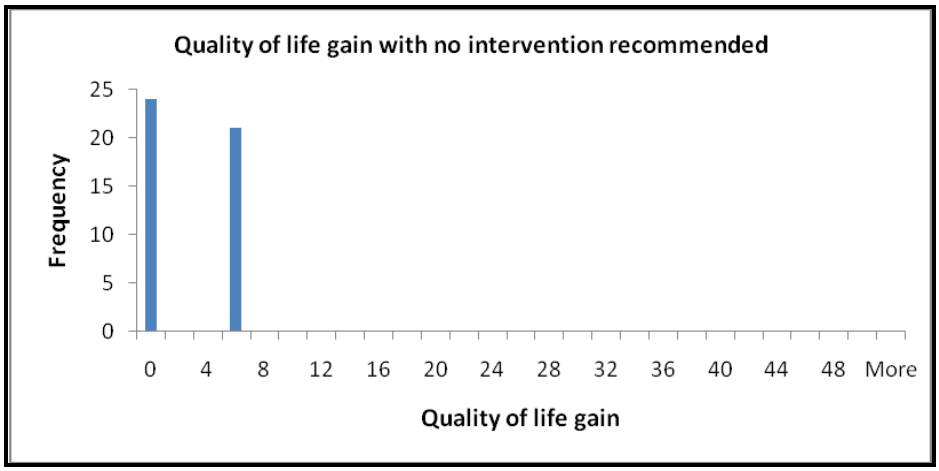


Figure 11.1The above histograms show the gain in quality of life in 3 groups of participants; a) where spectacle intervention was accepted, b) where no intervention was accepted c) where intervention was not recommended

A Kruskall-Wallis test was used to investigate the gain in quality of life in the three groups outlined in Table 11.2 and revealed that the gain differed significantly amongst the groups ($p<0.001$). Pairwise comparisons with the Mann-Whitney U test showed that the “no intervention” group improved (median 0 in both groups) significantly ($p<0.001$) less than the “spectacles” group (median 12), but the degree of gain in the “no intervention required” group was not significantly ($p=0.88$) different to the gain in the “no intervention accepted” group.

The following key points can be derived from the histograms in Figure 11.1:

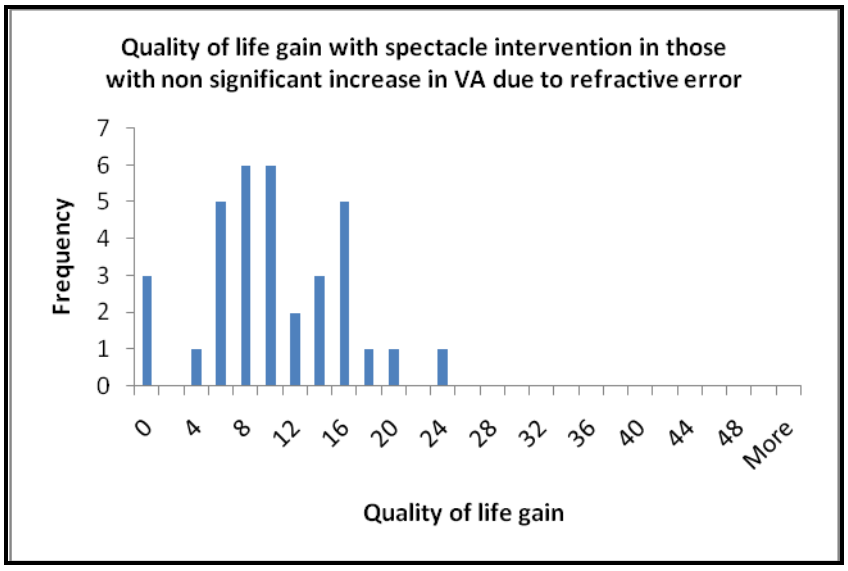
- More patients had an overall gain in QoL with spectacle intervention (75 participants) than in the group where intervention was recommended but not accepted (21 participants)

- In the group that did not accept intervention, 11 out of 21 (52%) patients had a gain between 0-2 points, whereas only 3 out of 75 (4%) had a gain between 0-2 points in the spectacle intervention group. This is because the spectacle intervention group had higher gains in QoL scores compared with the group that did not accept intervention

- In the group that did not accept intervention, there were no participants that had a gain of over 8 points compared to 53 participants (71%) in the spectacle intervention group that had a gain of over 8 points.
- An increase in quality of life was also seen in the group that required no intervention. The patients in this group benefited from the question that dealt with the explanation of ocular health discussed earlier in this section. It could be argued that this highlights the importance of frequent eye examination regardless of whether ocular health is normal and spectacle intervention is not necessary.

Having established from the above graphs that the group with the spectacle intervention had a more significant increase in QoL than the group in which no intervention was accepted, the spectacle intervention group will now be further evaluated. In particular, was the magnitude of change in spectacle prescription correlated with the gain in quality of life? The histograms below look at the spectacle intervention group and show the gain in quality life in those patients that were found to have a significantly improved acuity (i.e. 0.2 LogMAR increase as defined in Chapter 4) following new spectacles after the gold standard eye examination compared to those who were found to have no increase in acuity or those whose gain in acuity was not significant.

(a)



(b)

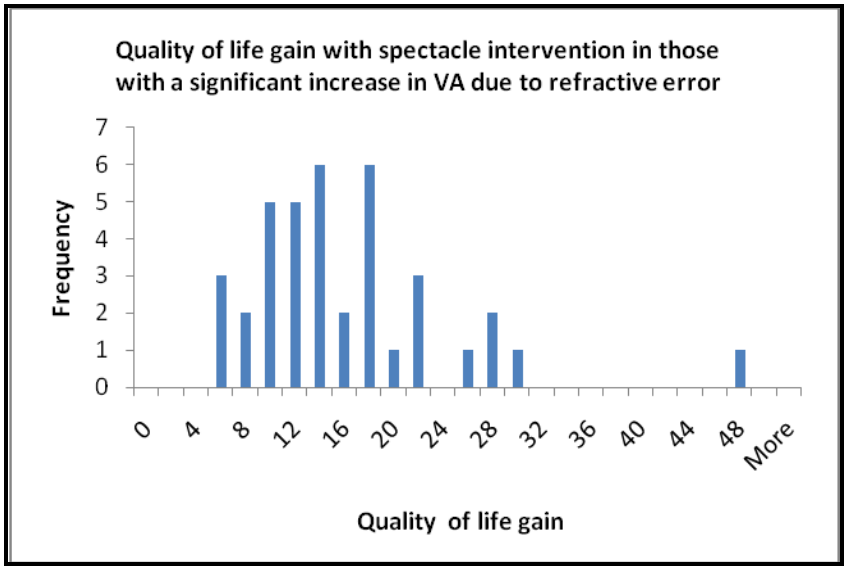


Figure 11.2 Graphs showing quality of life gain with spectacle intervention in a) patients that did not have a significant increase in acuity due to refractive correction and b) patients with a significant gain in acuity with refractive correction.

The graphs above show that in the group that did not have a significant increase in VA there are more patients with a small gain in QoL compared to those that have a significant gain in acuity where the gain in QoL is less at the lower values and more at the higher values. The graphs above show the gain in QoL in patients who had

significant gain in VA compared to those who did not have significant VA gain in the spectacle intervention group. The scatter plot below shows the average gain in VA (from the gold standard eye examination) against the gain in QoL.

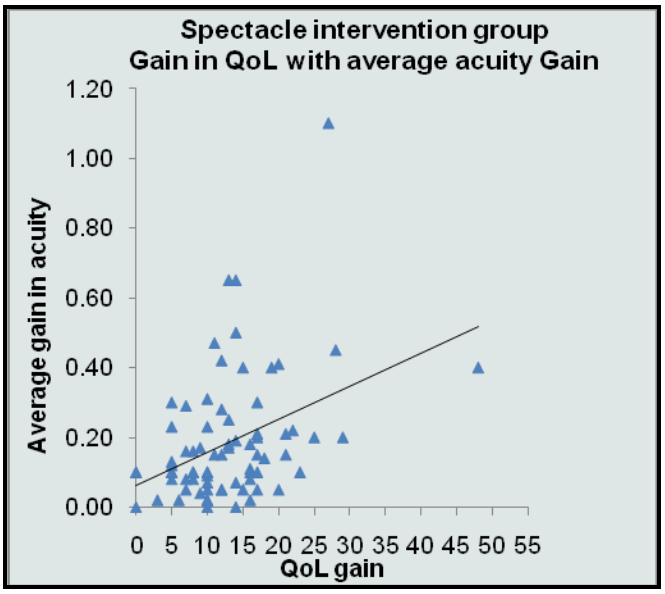


Figure 11.3 Average gain in VA from the gold standard eye examination (calculated from RE gain in VA and LE gain in VA) against the gain in QoL.

The trendline indicates that there is a positive correlation between average VA gain found in the gold standard eye examination and the gain in quality of life after spectacle intervention. The R-squared value is 0.154. This indicates that approximately 15% of the variability in the data can be explained by the association between average gain in acuity and gain in quality of life.

The quality of life results indicate that the screening tools and eye examination had a positive impact on the quality of life of the participants. An example of a case scenario showing the positive impact on the quality of life score can be seen in Table 11.3

Table 11.3 Case study of a participant in the research who benefited from refractive correction. The participant is a 75 year old man seen at a community day centre.

Variable	Before	After
Symptoms	None reported. No prescribed spectacles, just ready-readers. Last eye examination 4 years ago.	
CVS2 result	Failed	
FVS result	Failed	
Management	New spectacles	
QoL	103	121
Presenting vision	R 6/20+ L 6/9.5	R 6/9.5+ L6/9.5+

This chapter has presented the results from the quality of life questionnaires. The results from the main study have now been presented and the following chapter will discuss the main aspects of the results and address several key topics in order to derive conclusions from the present research.

Chapter 12

Discussion

This chapter will summarise and discuss the main outcomes from each section of the study. The main features of the results will be discussed together with the limitations of the research. This will then lead to a consideration of the key questions surrounding the validity and usefulness of the screening tools in the detection of the target conditions. The detection of glaucoma will be discussed in the context of the prediction at the start of the study (Chapter 4) that the screeners would not be good at detecting glaucoma. This will then lead on to a discussion on the ethics of screening. Ideas for future research will be discussed at the end of the chapter.

12.1 Participants, descriptive data, and prevalence of visual problems.

The descriptive data comparing the characteristics of the subjects participating in the two phases of the project can be found in Chapter 7, Table 7.1. The table shows that the two populations were generally similar and this is particularly evident when looking at the overall prevalence of significant cataract (31.7% in Study 1 and 30.7% in Study 2). The average and median ages of the two populations were identical with a small difference in the age range of the participants. There were differences in some variables such as the prevalence of significant macular degeneration and the prevalence of uncorrected refractive error.

Table 7.1 shows that the number of male participants was greater in Study 1 than in Study 2. The data also shows that this difference was not due to age because the average and median ages for both studies were the same. The difference may be due to the fact that Study 2 was more community-based; this may have resulted in more females participating in the study as they may be more likely to attend community venues such as day centres. This is supported by research of the

Economic and Social Research Council in 2005 where it was found that men were less likely to attend day centres than females (Arber, 2007).

The types of spectacles worn was similar in both studies especially with regard to multifocal spectacles. There were a slightly greater number of participants with no spectacles in Study 2 than Study 1.

The prevalence of the target conditions as detected by the gold standard eye examination, including significant macular degeneration was less in Study 2 than Study 1. This may seem counter-intuitive as the prevalence of the target conditions might have been expected to be higher in the community away from clinic based settings. There are a number of possible explanations for this; firstly those with visual problems are less likely to be mobile and so may not attend places like day centres or GP surgeries. Secondly, those older people that do attend community venues may be likely to be those who do not have eyecare needs or those that have eyecare needs that are being met already. The prevalence of correctable visual loss (cataract and/or significant refractive correction) is over 50% for both studies which highlights the significance of undetected correctable visual loss among older people regardless of whether the study is based in the community or in a clinic based environment.

Both studies had a large sample size from a variety of venues and so are likely to be reasonably representative of older people in general. However, a limitation of the present research is that individual residences were not targeted, which probably means that the present research has underestimated the overall prevalence of undetected visual loss among older people. Taking the study into individual residencies would have enabled certain areas to be targeted, for example areas with a concentration of people with low incomes. For the present research, this would have been logistically difficult, expensive and would have raised a number of health and safety issues. The flipchart screening tool would be a very quick, easy and cost effective way of screening older people in their homes and it would be feasible for community health care staff to use when making home visits.

12.2 Supplementary studies

The supplementary studies outlined in Chapters 5 and 6, will now be briefly discussed before the screening tools are discussed in the next section.

12.2.1 Provision of NHS eyecare in South London

This preliminary study investigating the provision of NHS eyecare and NHS funded eyewear in South London raised awareness among older people about their entitlement to NHS spectacles. The information resulting from the study was used to provide the patients in the two main research studies with a list of community optometric practices that provide spectacles whose cost is fully covered by the NHS optical voucher scheme for eligible patients.

The study showed that in the South London area, almost a third of practices that responded to the survey do not provide voucher value spectacles (VVS), which are spectacles whose cost is fully covered by the NHS optical voucher. It is thought that in other areas that are perhaps more affluent, optical practices may be less likely to supply VVS than those in South London. The study also highlighted that often the practices that supply VVS have a very limited selection of frames that are suitable for older people.

Although raising awareness among older people of their entitlement to VVS is crucial in improving the uptake of community eyecare services, it is of limited value if VVS are not readily available. Quite often it is not feasible for older people to 'shop around' to find a practice that provides VVS and it is thought that this may deter older people from updating their spectacles even though this would improve their vision.

Despite the limitations of this preliminary study including the modest sample size and the possibility of respondent bias (discussed in Chapter 5), the results do highlight the potential difficulty that older people face when needing to purchase spectacles. It is thought that the limited availability of VVS together with the lack awareness of the entitlement to VVS may be one of the reasons why a significant proportion of older people have poor vision due to under-corrected refractive error.

12.2.2 Cataract grading

It was necessary to implement this supplementary study early on in the research because the outcome would influence the choice of venues for Study 2. The results indicated that the portable slit lamp biomicroscope gives comparable results to the table top slit lamp biomicroscope for the grading of cataracts with the LOCS III grading system. The results showed not only a good inter-instrument repeatability but also a good inter-observer repeatability.

The results from this study meant that the venues chosen for Study 2 could be community based using the portable slit lamp to grade cataract for the purpose of the gold standard eye examination. The table top slit lamp would have been difficult to transport between venues and would have limited the number of venues used in Study 2.

The limitations of this supplementary study have been outlined in Chapter 6 and include issues surrounding the size of the grading steps used. The original paper on the LOCS III recommended a decimal scale (Chylack, Jr. *et al.*, 1993a) and from a theoretical perspective finer step sizes would have resulted in improved accuracy of results. However, from a practical perspective, this is difficult to implement and it was felt that the fine clinical judgements were impractical in a community setting where variables such as lighting cannot be controlled as precisely as in a clinic.

12.3 Are the screening instruments valid?

Before the validity of the screening instruments is discussed a brief summary of the screening tools will be given. The first version of the computer screener (CVS1) contained a near acuity test (binocular), visual field test (monocular), fixation disparity, stereoacuity, high contrast distance acuity (monocular) and low contrast acuity (monocular). In the refined computer vision screener (CVS2), tests of stereoacuity and fixation disparity were eliminated because these tests were not found to be useful in the detection of correctable visual loss. Tests of near acuity (binocular), visual fields (monocular), high contrast distance acuity (monocular) and low contract acuity (monocular) were included in CVS2. The flip chart screener

incorporated the key acuity tests from CVS2. This included near acuity (binocular), high contrast acuity (monocular) and low contrast acuity (monocular).

The validity of the computer vision screener and the flipchart screener can be evaluated by comparing the results of the acuity tests from the screening tools with the tests from the gold standard. To give an accurate estimate of the inter-test agreement between the acuity tests of the screeners and the gold standard tests, Bland and Altman graphs (Bland and Altman, 1986) were plotted based on the central range of data, for which the tests are comparable.

The results from study 1 and study 2 were pooled together for the Bland and Altman plots in Chapter 7 evaluating the data from the computer vision screeners. For high contrast acuity (Figure 7.15 and Figure 7.16), the mean difference between the two measurement methods (CVS and gold standard) is 0.018 for the right eye and 0.039 for the left eye and the 95% limits are approximately two lines for each method. The Bland and Altman plots in Chapter 10 evaluate the HCVA test with the flipchart screener in Study 2 (Figure 10.3 and Figure 10.4) and the mean difference between the two measurement methods (FVS and gold standard) is 0.072 for the right eye and 0.059 and the 95% limits are also approximately two lines for each method. This finding is fairly consistent with the literature. More sophisticated measures of visual acuity, which are more time consuming than the screener, can achieve 95% confidence limits of 0.10 to 0.15,(Cho & Woo, 2004;Ruamviboonsuk *et al.*, 2003;Woods *et al.*, 1998d) but test-retest variability increases as visual performance declines (Woods, 1993). In advanced eye disease the 95% confidence limits of test-retest visual acuity are 0.20 (Kiser *et al.*, 2005). Since the two test methods were different, 95% limits of approximately ±0.20 in the present populations are not surprising.

It is interesting to note that the mean difference between screening and gold standard results for high contrast acuity is greater with the FVS than with the CVS and this may be because the gold standard test of visual acuity was a computerised method and in this respect was more similar to the CVS than the FVS. The mean differences for both screening tools were positive values and this indicates that the gold standard was measuring slightly worse acuities (higher

LogMAR values) than the screening tools. This could possibly be due to a difference in crowding as both the FVS and CVS have a linear layout in contrast to the chart layout implemented in the gold standard eye exam.

The Bland and Altman plots for low contrast acuity with the CVS (Figure 7.21 and Figure 7.22) show that the mean difference between the two measurement methods (CVS and gold standard) is 0.060 for the right eye and 0.063 for the left eye. Evaluation of the low contrast acuity test with the FVS (Figure 10.7 and Figure10.8) shows that the mean difference between the two measurement methods to be -0.014 for the right eye and -0.007 for the left eye. These negative values indicate that the FVS is measuring worse acuities (higher LogMAR values) than the gold standard technique. The gold standard technique was a computerised chart and this may account for the negative mean difference as the internally illuminated computer screen may have helped patients to achieve better low contrast acuity (lower LogMAR values) than the FVS which may have been subject to too little lighting or shadows.

Throughout the results chapters both HCVA and LCVA have been shown to be of value in the detection of correctable visual loss both as tests on their own and in combination with other tests. The Bland and Altman plots have shown the tests to be valid and the usefulness of the screening tools will be discussed further on in this chapter. With regard to near acuity, the results chapters have shown that near acuity testing is not as efficient as distance acuity testing in the detection of correctable visual loss as a test on its own. It has shown to be of some value when used in combination with other tests but both screening tools have shown near acuity testing to be less efficient than distance acuity testing. This may be because reduced near acuity is affected by many different ocular conditions and also environmental factors such as lighting and glare, possibly affecting near acuity to a greater extent than it would distance acuity. For near visual acuity, a Bland and Altman plot reveals that the mean difference between the gold standard and the FVS (Figure 10.9) is 0.118 (N=46). This difference is considerably greater than that obtained with the distance acuity tests, but this is true for a smaller N value of 46 for near compared with 56 for distance. Also, as mentioned earlier, the near vision

screening test on the FVS does not attempt to measure near acuity but rather the minimum size required for comfortable vision and because of acuity reserve, this is bound to be a larger font size than a near acuity measurement. It may be argued that the ease at which older people can read different size fonts is a more relevant measure of near vision than near acuity.

12.4 Overview of results for computerised vision screener

CVS1 was the first version of the computerised screener and it proved that correctable visual problems in the older population can be detected by computerised screening methods. CVS 2 built on the results from CVS 1 to develop a refined computerised tool that contained the tests that would be most appropriate for detecting correctable visual loss. Analysis of results from CVS 1 showed that tests of stereoacuity and fixation disparity added little value to the screening and so were omitted in CVS 2.

Initial analyses of results from Study 2 showed that the sensitivity values were considerably lower than in Study 1 and the specificity values in Study 2 were higher than in Study 1. This occurred despite the fact that the cut-off values derived from the ROC curves were the same in Study 1 and 2. Possible explanations for these differences in sensitivity and specificity between the two studies are now discussed.

First, the difference in sensitivity and specificity values between the 2 studies for each of the main target conditions are given in Table 12.1 a and b.

Table 12.1 Comparing sensitivity and specificity values obtained for a) HCVA and b) LCVA for predicting the presence of the target conditions. The large difference in the sensitivity values between the two studies can be seen with the highlighted cells. This is discussed below.

(a) High contrast visual acuity

	SENSITIVITY		SPECIFICITY	
HCVA	**STUDY 1**	**STUDY 2**	**STUDY 1**	**STUDY 2**
CATARACT	86.5 (72-94.1)	64.4 (49.8-76.8)	51.4 (43.2-59.6)	59.4 (51.5-66.8)
REFRACTIVE ERROR	79.6 (67.1-88.2)	72.5 (57.2-83.9)	53.7 (44.9-66.2)	60.6 (52.9-67.9)
CVI	78.7 (68.1-86.4)	64.9 (53.5-74.8)	59.8 (50.1-68.8)	65.1 (56.4-72.8)

(b) Low contrast acuity

	SENSITIVITY		SPECIFICITY	
LCVA	**STUDY 1**	**STUDY 2**	**STUDY 1**	**STUDY 2**
CATARACT	78.4 (62.8-88.6)	64.4 (49.8-76.8)	55 (46.7-63)	64.5 (56.7-71.6)
REFRACTIVE ERROR	68.5 (55.3-79.3)	70 (54.6-81.9)	55.3 (46.5-63.8)	65 (57.3-72)
CVI	66.7 (55.4-76.3)	63.5 (52.1-73.6)	58.8 (49.1-67.9)	70.6 (62.2-77.9)

The tables above indicate that there is a marked difference in the sensitivity values in the two studies for the detection of cataract. Refractive error also shows a difference but this is smaller than that found with cataract. In order to investigate this further, the raw data provided information on the various types of cataract found in both studies. The table shows the total number of each type of lens opacity (i.e. the sum of the number of opacities in the right eye and the left eye). The data showed that the number of patients with nuclear sclerosis was markedly higher in Study 1 than in 2 and the number with cortical lens opacities was higher in Study 2 compared to Study 1. The difference in the type of cataract found can be clearly seen in the table below using the raw data from the right eye and left eye.

Table 12.2 Types of cataract (NS-nuclear sclerosis, C-cortical, PSC-posterior subcapsular cataract)

Type of cataract	NS	Cortical	PSC
Study 1	25	40	38
Study 2	11	72	36

It is known that vision is more significantly affected by nuclear and posterior sub capsular lens opacities than with cortical lens opacities (Kanthan *et al.*, 2008). This may explain why in Study 2, more patients were passing the acuity test on the vision screener despite having significant cataract and this would account for the decrease in sensitivity in detecting cataract in study 2. The decrease in sensitivity in Study 2 would have been due to an increase in the number false negatives (the number of individuals who have significant cataract according to gold standard, but that pass the vision tests during screening).

Although there was a similar prevalence of cataract in both studies, there was a clear difference in the distribution of the types of cataract. This has had an impact on the ability of the screener to detect certain types of cataract, in particular those patients with cortical lens opacities that may not affect vision as significantly as nuclear sclerosis or posterior subcapsular cataract. The tables above (Table 12.1) show that there is a degree of overlap of the confidence intervals between the 2 studies. This indicates that the sensitivity values and the specificity values are not significantly different with probability <0.05.

In summary, the detection of significant cataract in the gold standard examination was based on anatomical appearance, which detected all types of cataract, whereas detection of cataract by the screener was based on visual function, which was more likely to be reduced for nuclear and posterior subcapsular lens opacities. The usefulness of the screening tools in the detection of cataract is discussed further in Section 12.6.2

Analyses of CVS2 showed that a number of test combinations give good sensitivity for detecting the target conditions. The test combinations that give the best compromise between sensitivity and specificity for detecting significant acuity

impairing eye conditions (SAIEC) are given below. This table is derived from Chapter 9 (Table 9.28) and contains the key combinations in the detection of SAIEC.

Table 12.3 Summary of best combinations from CVS2 for detecting SAIEC

Combination	Sensitivity	Specificity	Comment
HCVA	77 (68.8-83.6)	73.1 (62.3-81.7)	The single best test to use for screening of visual loss is HCVA which provides both a high sensitivity and specificity.
HCVA or NVA	79.5 (71.5-85.7)	67.9 (57-77.3)	The addition of near acuity provides a slightly higher sensitivity and may be useful in a situation where it is important to detect as many people as possible with visual loss.
LCVA	71.3 (62.7-78.6)	76.9 (66.4-84.9)	In a country where there are few optometric services (e.g., developing countries), specificity may be more important than sensitivity and in this case low contrast VA alone may be a simple screening tool that it is appropriate. This single test provides the best specificity out of all the combinations.
HCVA or LCVA or NVA	80.3 (72.4-86.4)	66.7 (55.6-76.1)	Combining all the tests together increases the chances of detecting visual loss (i.e. a high sensitivity value) but the high number of false positives results in a low specificity value.

If the screening tool is to be used to detect glaucoma as well as SAIEC then the addition of the visual field tests in an OR combination with HCVA or LCVA provides the best combination. The introduction of the visual field test results in an overall increase in sensitivity but a reduction in specificity. The ability of the screener to detect glaucoma will be discussed later in the chapter (Section 12.6.4).

As discussed in Chapter 3, one of the benefits of computerised screening is that tests can be excluded or included depending on the situation. Table 12.3 illustrates how this approach would be useful depending on the following factors: aims of the screening programme, target conditions, screening venue, and resources that are available after the screening has taken place. The importance of adapting the screening tools to take into account the aims of the screening programme is returned to in Chapter 13.

12.5 Overview of results for flip chart screener

The key tests from CVS1 were incorporated into a flip chart to provide a rapid screening tool that was evaluated alongside CVS2. The test combinations that provided the best compromise between sensitivity and specificity in the detection of SAIEC were the same combinations found using the computer vision screener and these have been summarised below.

Table 12.4 Summary of best combinations from flip chart screener for detecting SAIEC

Combination	Sensitivity	Specificity
HCVA or NVA	75.4 (67.1-82.2)	69.2 (58.3-78.4)
HCVA	73 (64.5-80)	74.4 (63.7-82.7)
LCVA	75.4 (67.1-82.2)	76.9 (66.4-84.9)
HCVA or LCVA or NVA	82 (74.2-87.8)	61.5 (50.4-71.6)

The sensitivity and specificity results obtained are similar to those from the computer vision screener in Table 12.3. The results show that in the flip chart format, LCVA fares better than HCVA as a single test to use for screening of visual loss. The single most useful test with the CVS2 was HCVA whereas LCVA showed the best sensitivity and specificity as a single test for the FVS. It is tempting to attribute this to properties of the computer monitor, but this had been carefully

calibrated. The 95% confidence limits for these differences overlap, so these results may be attributable to chance.

The chapter so far has given a summary of the results from the present research. The next section will take an overall look at the usefulness of the screening tools in detecting vision loss.

12.6. Are the screening instruments useful?

The present research supports previous findings (Reidy *et al.*, 1998b) that there is a high prevalence of correctable visual loss in older people. The notion that older people with visual problems will fully engage in eyecare services is clearly nothing more than an ideal and this supports the need for methods that will encourage older people to seek regular eyecare. The screening instruments that have been investigated here are reasonably efficient at detecting people with visual problems and it was found that when participants were given personal advice that they would be likely to benefit from an intervention then most were keen to follow this advice.

The usefulness of the screening tools in the detection of the target conditions will now be discussed. This will be addressed in three ways. Firstly the ability of the tools to detect the target conditions in combination will be discussed. The combination of the target conditions has been categorised as significant acuity impairing eye conditions (SAIEC) and this has been defined as binocular gain in NVA through refractive correction or a monocular gain in distance acuity through refractive correction or significant cataract in either eye or the risk of rapid progression MD in either eye. Secondly the ability of the tools to detect the target conditions individually will be addressed. As mentioned in previous Chapters the evaluation of each of the target conditions in isolation was essential in deriving the cut off values from the ROCs but there are limitations to this approach. One limitation is that the ROCs for certain target conditions attempted to correlate structure with function; for example relating the appearance of cataract using the LOCS grading scale with visual acuity measurements. Also, many different conditions influence measures of visual function (e.g., visual acuity) and this too is a limitation of the ROC analyses. It could be argued that a more valid measure of

screener performance is to evaluate whether it detects those cases which an optometrist would be likely to feel needed an eye examination. This will be discussed in the third approach that will be taken to evaluate the usefulness of the screening tools and will involve summarising the overall performance of the screeners in detecting the need for optometric eyecare.

12.6.1 Detection of significant acuity impairing eye conditions

The results show that the screening tools have proved to be useful in the detection of significant acuity impairing eye conditions. The simple HCVA test in CVS2 detected 75% of cases of uncorrected refractive error or cataract or AMD. By combining tests in the screener a sensitivity of over 80% can be achieved, although the specificity drops. A specificity of about 70% was possible and the best test combination was obtained by selecting participants who failed the high contrast VA or near VA tests.

The FVS performed similarly to CVS2. For detecting cataract, correctable refractive error, and significant AMD a sensitivity of about 80% could be achieved with a specificity approaching 70%. These values were obtained by selecting people who failed either the high contrast or low contrast distance VA tests, and 79% of people who failed one of these tests had one of these conditions.

It is interesting to note that the results show that the best single test on the rapid flipchart tool is LCVA. This achieves 75% sensitivity and 77% specificity for the detection of SAIEC and 84% of patients that failed the LCVA test on the FVS had one or more of the target conditions (the positive predictive value). It is particularly interesting to note that LCVA fares better than HCVA as a single test to detect SAIEC in the flipchart format. With the CVS2, LCVA alone provided the best specificity (77%) of all the combinations for the detection of SAIEC in CVS2. However, the single best test to use for the detection of SAIEC when using CVS2 is HCVA. This achieves a sensitivity of 77% and specificity of 73% and 82% of patients that failed the HCVA test on CVS2 had one or more of the target conditions as defined by SAIEC (the positive predictive value).

It can be seen that the screening tools are useful in the detection of SAIEC and even a single test can be reasonably efficient at detecting those with vision loss that may be correctable. Combining tests to detect SAIEC always has the effect of increasing the sensitivity but reducing the specificity. When using CVS2, the sensitivity and the specificity of the screening tool can be manipulated by eliminating or adding tests depending on where the screening programme is being implemented and the availability of eye care services in that area. In some situations it may be appropriate to have a high specificity even though it may mean a reduced sensitivity and this may mean only screening with one or two tests. In other situations it may be better to have a high sensitivity with low specificity by using all the tests in the screening package. In the majority of situations a compromise between sensitivity and specificity will be needed and tests can be easily eliminated or added using CVS2 to achieve the desired sensitivity and specificity values.

The next section will look at the target conditions in isolation before the usefulness of the screening tools will be discussed in terms of their overall performance in detecting the need for optometric eyecare.

12.6.2 Detection of cataract

The gold standard eye examination assessed cataract by using the LOCS III grading system as described in Chapter 4.The type of lens opacities present in the population had an effect on the ability of the screener to detect significant cataract as outlined earlier in the chapter. The detection of significant cataract in the gold standard examination was based on anatomical appearance, which detected all types of cataract, whereas detection of cataract by the screener was based on visual function, which had a predisposition to the detection of nuclear and posterior subcapsular lens opacities. The sensitivity and specificity values for the detection of cataract by acuity tests of the computer vision screeners can be seen in Table 12.1 and by the flipchart screener in Chapter 10 (Table 10.4)

It may be argued that as cortical lens opacities have less of a detrimental effect on vision then it may not be as vital for the screener to detect this type of lens opacity

compared to nuclear sclerosis and posterior subcapsular opacities. When cortical lens opacities reach advanced stages then the screener would be able to detect this because visual function would be affected. Although anatomical appearance of cataract is an important factor in determining whether it is appropriate for a cataract procedure to be conducted, functional vision is even more important. Even if a significant lens opacity was present (as anatomically determined by the gold standard), but functional vision was not significantly impaired and the patient was not experiencing problems it may be thought inappropriate to refer for cataract extraction. However, a full eye examination might detect detrimental effects of cataract on vision other than visual acuity, such as poor night vision or glare.

It is recognised that the grading system and method used in the gold standard to assess cataract may not be commonly used in everyday optometric practice. In a normal eye examination it is likely to be mainly a combination of the appearance of cataract and the visual acuity that influences whether referral is indicated. Also, cataract referral is very much dependent on whether the patient is finding it difficult to perform everyday tasks that they would like to. It is likely therefore that the use of LOCS III as a gold standard means that the sensitivity obtained for the screeners in the present research is likely to be conservative.

12.6.3 Detection of refractive error

The HCVA test on the computer vision screener proved to be effective at detecting uncorrected refractive error as can be seen in Table 12.1. LCVA is also a good predictor of uncorrected refractive error achieving a sensitivity and specificity of 70% with FVS.

The near VA test did not fare so well, only achieving a sensitivity of 48% (with CVS2) and 58% (with FVS) for detecting uncorrected refractive error at near. This particular test had even worse ability to detect cataract with both screening tools, and therefore was not valuable at detecting correctable visual loss (either of these two conditions). However, this only reflects the value of this test when considered in isolation and, it was found to be of some value when its results are taken in combination with other tests. Furthermore, the objective of the screening tools was

not to measure near acuity but to give an indication of the ease at which older patients could read small print.

12.6.4 Detection of glaucoma

It was anticipated from the outset (Chapter 4) that the screening tools would not have a high sensitivity or specificity for detecting glaucoma and this was found to be the case. Even in a gold standard eye examination where three or more glaucoma tests are available, the detection of glaucoma is challenging (Weinreb & Khaw, 2004).

Harper and colleagues indicated that the most predictive measures for glaucoma were visual field screening, optic disc cupping and intraocular pressure (Harper & Reeves, 1999). However as discussed in Chapter 4, it would not be possible to implement all three tests in a screening programme. Harper and colleagues stated that although single tests do not provide sufficiently good discrimination, the visual field test was the best single predictor of glaucoma (Harper & Reeves, 1999). As such, this test seemed the most appropriate to include in the computerised screening tool. The visual field in CVS2 detected 15 of 19 cases who had or were at risk of glaucoma, but this greatly reduced the specificity of the screener causing it to 'fail' about three-quarters of those who were visually normal. This indicates that although the specificity of the visual field test was poor, the sensitivity was approximately 80% (15/19). This sensitivity value is in the same range as that obtained for the other target conditions.

Harper and colleagues show that sensitivities and specificities of more than 90% can be obtained for detecting glaucoma when visual field screening, optic disc cupping and intraocular pressure were combined. The College of Optometrists advises the public that those aged over 40 years should receive a combination of at least two of the three predictive tests (College of Optometrists., 2008). Harper and colleagues show that when a two test combination of intraocular pressure (cut off value >22 mmHg) or optic disc cupping (cut-off value >0.6) is used in the detection of glaucoma the sensitivity and specificity of approximately 85% is achieved.

Screening tools for the detection of glaucoma need further investigation (see section 12.10) and the screening tools in the present study are not appropriate for screening for the presence of glaucoma due to the low specificity achieved with the visual field test.

The screening tools in the present study do not replace the need for regular eye care and this would be important to explain to patients who undergo vision screening. Patients who pass the screening test still need to have regular eye examinations so that conditions such as glaucoma can be detected. However, a scenario may arise where an undiagnosed glaucoma patient passes the vision screening and as a result does not feel it necessary to attend for an eye examination, even if this conflicts with advice given at the time of screening. This raises the issue of whether it would be ethical to use the screening tools from the present research. The ethical issues surrounding screening will be discussed further on in this Chapter.

12.6.5 Evaluating the screening tools from an optometric perspective

The section above has focused on the ability of the screening tools to detect the target conditions based on various cut-off values derived from ROC curves. As noted in Chapter 8, 9 and 10, although the ROCs are necessary to select the optimum cut-offs for the screener, this method of evaluating the screening tools may be viewed as overly critical of the screener performance. This is because many of the ROCs in this study compare a grading of the appearance of an ocular condition (e.g., cataract or AMD) in the gold standard examination with the functional status of the eye (e.g., high contrast visual acuity) as measured with the screener. The ROCs will also be limited because many different conditions influence the functional measures (e.g., visual acuity). It could be argued that a more valid measure of screener performance is to evaluate whether it detects those cases which an optometrist would be likely to feel needed an eye examination. This could be defined, in a pragmatic operational way, as reduced high contrast visual acuity in one or both eyes and those who have not attended for an eye examination in the last year. Alternatively, it could be argued that optometrists may feel it appropriate to conduct an eye examination on those with

reduced high contrast acuity or those who have not had an examination within the last year. This evaluation was carried out for both versions of the computer screener (Chapters 8 and 9) and also the rapid flipchart screener (Chapter 10).

Table 12.5 Summary table: Performance of screening tools from an optometric perspective

Performance of screener from an optometric perspective	CVS1		CVS2		FVS	
	Sensitivity (%)	Specificity (%)	Sensitivity (%)	Specificity (%)	Sensitivity (%)	Specificity (%)
HCVA >0.19 and no eye examination in the last year	82.2 (73.6-88.4)	82.9 (72.9-89.7)	81.8 (73.1-88.2)	94.1 (87.6-97.2)	76.8 (67.5-84)	95.0 (88.9-97.9)
HCVA>0.19 or no eye examination in the last year	97.6 (93.9-99.1)	75 (46.8-91.1)	94.6 (90.3-97)	93.8 (71.7-99.7)	94.0 (89.6-96.6)	87.5 (64-96.5)

This approach to assessing the screening tools has shown that they have a very good ability to detect those older people who an optometrist would be likely to feel needed an eye examination. A summary of the results from this approach to assessing the tools can be seen in Table 12.5.

This section has demonstrated the value of the screening tools in the detection of the target conditions collectively, individually and in a more pragmatic way. It is noted however, that the screening tools do not achieve 100% sensitivity and specificity and also are not very effective in the detection of glaucoma. This raises issues surrounding the ethics of screening, which will now be discussed.

12.7 Ethics of screening

In this context, the primary purpose of screening is to encourage participants to have regular eye examinations, particularly those with poor vision. However, there is a risk that those who pass the screening feel reassured and become less likely to have a full eye examination. For this reason it is very important that people who undergo vision screening receive verbal and written information stressing that a 'pass' in the vision screening test should not be seen as an alternative to regular professional eyecare. This is particularly important in cases of glaucoma where a full eye examination is vital for its early detection. It is also important for people with diabetes who have photographic screening for diabetic retinopathy, but should

still have professional eyecare to check for other conditions (e.g., glaucoma). But the present research indicates that these screening methods are an effective way of encouraging many older people to re-engage with eyecare services.

Screening programmes are becoming increasingly popular. Quite often, screening programmes can be expensive to implement and the treatment following screening can also be expensive. The screening itself may lead to side effects and harm if the screening procedure is invasive; there is also a risk of unnecessary intervention for inconsequential disease which may never become clinically significant or life-threatening. Screening has also been criticised for increasing anxiety in the public about healthcare issues. Vision screening does not pose these concerns to same extent as some other forms of screening. The tools used in the present research are not expensive to operate and can be administered by lay personnel and are likely to be reasonably cost effective. The treatment following screening is also relatively inexpensive. Patients who fail the screening would be alerted to have an eye examination and so the risk of unnecessary intervention is reduced. Since the emphasis of the vision screening is on detecting correctable visual problems, in most cases it leads to a positive outcome which is unlikely to cause excessive anxiety.

Although screening tests cannot guarantee the detection of all 'abnormal' cases, and will lead to false reassurance for some, this disadvantage needs to be weighed against the potential benefits. The gain in quality of life through the detection of previously undetected correctable visual loss is significant and vision screening may play a central role in reducing the prevalence of visual loss among older people. If the correct verbal and written information is given to patients then the use of the screening tools can be two fold; firstly to detect those patients that have reduced vision that may be improved through simple intervention and secondly to increase awareness among the older population about the need for regular eyecare. The CVS is particularly well-suited to producing appropriate written advice after screening, since it is possible for a computer to produce personalised reports, with an appropriate font size, stressing the continued need for routine eyecare in all cases.

On balance, it is concluded that the benefits of vision screening outweigh the possible disadvantages, as long as care is taken to ensure that participants understand that the screening does not obviate the need for regular eyecare.

12.8 Have the research objectives been met?

The chapter so far has shown how the primary objectives in Chapter 3 have been met. These objectives relate to the battery of tests suitable for screening in older people and appropriate test combinations. The study has shown the suitability of various tests for older people and has also shown how these can be incorporated in a screening tool to detect correctable visual loss in the older population. The research has shown that both screening tools are suitable for different situations and the advantages and disadvantages of the two tools are summarised in Table 12.6.

Table 12.6 Summary of suitability of screening tools

	Advantages	Disadvantages
Computer Vision Screener	Tests can be excluded or included depending on the aims of the screening programme	May not be suitable in situations where computerised screening is too complex for the person administering the screening
	The results are automatically analysed and a report can be printed summarising the results.	May not be suitable for use in situations where there are logistic constraints on the use of computers (e.g., security, mains power)
	The inclusion of the visual field test may be useful in locations where a high prevalence of glaucoma is suspected.	May not be suitable for use in situations where the cost of running a computerised system is too high
Flip chart screener	Cost effective to manufacture	The results from the flip chart need to be manually recorded
	Even more portable than the computer screener	The flip chart screener does not contain a visual field test and can play no role in the detection of glaucoma
	Suitable in situations where computer screening is not ideal	The flip chart does not have the flexibility of test choice as with the computerised screener

The secondary objective was to determine whether people whose visual problems are detected with screening do, as a result of the screening, receive treatment for their visual problems and appropriate support. The quality of life data evaluated in Chapter 11 does give an indication of the proportion of those screened where an intervention was recommended and the proportion of these individuals who actually received an intervention based on the gold standard data. It also illustrates the increase in the quality of life in those patients that took up the intervention. However, the screening and the gold standard eye examination were conducted on all participants. So it cannot be said with certainty that if older patients were only screened, they would as a result of the screening attend for an eye examination and then receive treatment of their visual problems. This would

require further research and will be discussed later in this Chapter. The quality of life data is discussed further below.

Apart from the objectives, it was thought that when conducting the study additional observations may be made on the suitability of different venues for screening vision in older people (Chapter 3). Both screening tools were easy to use in the venues chosen for the present study. It is thought that the computer screener is best suited for a formal vision screening programme or as part of a wider health screening programme for older people. The flip chart screener is better suited to community settings for example when at Woodlawns day centre and would be ideal to use when making home visits or in the developing world. In the UK it could, for example, be used by a community nurse or occupational therapist when visiting patients at home, for example after a fall.

The second additional observation outlined in Chapter 3, was to comment on the characteristics of older people with poor vision in South London. In particular, to make observations on the relationship between ethnicity/poverty and correctable visual loss. As discussed in the preliminary study of the provision of NHS eyecare (Chapter 5), South London has a number of areas associated with deprivation and poverty. The population is from a diverse range of ethnic backgrounds and socio-economic status and this was particularly evident in Study 2 where the screening tools were taken into the community. The study showed that 18.5% of participants from Study 2 were from an ethnic minority. This was determined from the names of patients; this technique is sometimes used in health research to increase the number of persons from racial and ethnic groups represented in surveys. Although this achieves the goal of identifying those from ethnic origin (Davern *et al.*, 2007) it is understood that this technique is not optimal for detailed statistical evaluation.

Although a detailed analysis of the effects of ethnicity and poverty on visual problems was beyond the scope of the present research, studies have shown that correctable reduced vision is likely to be particularly prevalent amongst people who suffer from the effects of poverty (Reidy *et al.*, 1998a) and/or are from ethnic minorities (Lindesay *et al.*, 1997;Pardhan & Mahomed, 2002). The present research has demonstrated the efficacy of the vision screening tools and it seems

likely that these could be used in future research to improve the ways in which people from ethnic backgrounds and those who are suffering the effects of poverty can better access eye care services.

12.9 Quality of life and Hawthorne effect

This section discusses the Hawthorne effect with respect to the quality of life data presented in Chapter 11. The quality of life data does give an indication of the number of people that were recommended intervention and those that actually received intervention based on the gold standard data. It also illustrates the increase in the quality of life in those patients that took up intervention.

The Hawthorne effect was first reported in industrial research, but it has significant implications for clinical research and routine practice (McCarney *et al.*, 2007). The Hawthorne effect is a component of the non-specific effects of trial participation, but is not controlled for by usual controlled trial designs. The Hawthorne effect on clinical trial results indicate that patients in clinical trials appear to fare better than those in routine practice by virtue of their participation (McCarney *et al.*, 2007).

The Hawthorne effect is important to consider when evaluating Quality of Life because if there is a demonstrable benefit from participating in clinical research, *for whatever reason*, then this has implications for good clinical practice and for improving care. It may be argued that if the quality of life gain was due to the Hawthorne effect then it is likely that the very act of older people having a regular eye examination would produce a similar effect. The reason for this is because the tests and procedures used in the study are very similar to those implemented in community-based optometric care. However, we cannot rule out an improvement in quality of life resulting from participants' awareness of being involved in a research study, over and above an effect from the clinical tests. To investigate this further a study would be needed to evaluate if the same gain in QoL was produced if a patients were to attend an eye examination when not participating in the study. However, it is unlikely that the QoL results obtained can be solely attributed to the Hawthorne effect because the group in which no intervention was required did

have a lower quality of life gain that the spectacle intervention group. This can be seen in Table 12.7.

Table 12.7 Direct comparison between QoL scores from patients in spectacle intervention group and those in the no intervention required group for three variables: initial QoL, Post QoL, and Gain (individually calculated as Post-Initial)

Spectacle Intervention N= 75 No intervention required N= 46	Median	Median	Minimum	Minimum	Maximum	Maximum
Initial	108	120	54	96	125	125
Post	120	123	68	96	125	125
Gain	12	0	0	0	48	5

The above table shows that although the initial quality of life is higher in the group that required no intervention, the gain in quality of life is higher in the spectacle intervention group. It is appreciated that the Hawthorne effect is an important potentially confounding variable that needs to be considered in relation to our quality of life data. Further research would be required to investigate this fully.

12.10 Suggestions for future research

The present research has highlighted the need for further studies in a number of areas and these areas will now be discussed.

The preliminary study on the provision of NHS funded primary eyecare and NHS funded spectacles in South London (Chapter 5) could be extended to include a larger sample size, on a national scale. It would be interesting to investigate geographical variations concerning the provision of NHS funded spectacles for older patients on low income.

The supplementary study on cataract grading (Chapter 6) raises questions about why cataract grading is not used more often in clinical practice. This could be investigated further, for example to detect whether cataract grading is possible without pupillary dilation and what grading step sizes are appropriate for clinical use.

As predicted in Chapter 4, and noted in the above section the screening tools that have been investigated in this project perform quite well at detecting all common eye disorders in older people except for glaucoma. There are a number of promising techniques under development which may lead to new screening instruments specifically aimed at early glaucoma detection (Cordeiro *et al.*, 2004;Bach, 2006;Bach *et al.*, 2006). Another area for future research could be to investigate the use of one or more of these new techniques in conjunction with one of the two screening tools that have been used in the present research. This research has investigated various test combinations and future research can build on this by further exploring the optimum algorithm for combining test results, especially if new glaucoma screening technology could be incorporated into the battery of screening tests researched in this study.

In order to investigate the direct impact of screening on the uptake of eyecare services it would be interesting to carry out an interventional study, using three groups. One group would receive vision screening, like that used in the present research. A second group would receive publicity alerting them to the need for optometric eye care and the third group would have no intervention. The cohorts could then be compared, after perhaps three months, to see if visual screening of older people has a greater impact on the uptake of eye care services than general publicity or no intervention. It would also be interesting to evaluate whether or not the computerised or flip chart screener would be successful in alerting older people to have eye examinations if it was implemented as part an overall health screening programme.

Stereoacuity was not found to be a valuable test in the initial computerized vision screener, but this may be because the study was not specifically designed to detect the risk of falls. It would be interesting for future research to investigate a stereoacuity test, and possibly other tests of binocular function, as predictors of falls. This research would probably to be longitudinal and may require a larger sample size.

As noted in Section 4.3.2, lighting was not controlled with the flip chart screener because a goal of the research was to investigate the screener under conditions

that are similar to those in which it may ultimately be used. It is assumed that most testing environments would be able to provide a level of lighting which would not greatly influence the results, since Bennett and Rabbetts (1998) suggest that as long as the luminance is above about 80cd/m2, VA is reasonably independent of luminance. Further research could investigate this assumption.

This Chapter has given an overview of the results and discussed key aspects of the study as well make recommendations for future research. The next Chapter will look at what conclusions can be drawn from the present research

Chapter 13
Conclusions

13.1 General conclusions

There are number of general conclusions that can be drawn from the present research. The first is that there are a significant number of older people in South London that have undetected vision loss. Approximately one third of older people in South London were found to have significant cataracts, about a third to have under corrected refractive error, and over half to have at least one of these conditions.

Conclusions can also be drawn about the provision of NHS eyecare services. The preliminary study has shown that although NHS eyecare is easily accessible, the provision of voucher-value spectacles (VVS) is variable. Anecdotally, the research noted during the studies reported in this thesis a lack of awareness among older people about their entitlement to VVS. Optometric practices may be reluctant to offer VVS because of the uneconomic voucher values and this in turn may be a significant barrier to the uptake of eyecare services among older people.

The study has shown that vision loss in older people can be readily detected with screening tools such as a computerised vision screener that can be administered by lay people with minimal training. The gold standard eye examination has shown that in a significant number of older people these cases of undetected reduced vision can be readily corrected. Vision screening of older people can also be successfully implemented using a rapid flip chart tool which can be used when computerised screening is not appropriate. The computer screener and flipchart tool were both good at detecting significant cataract and refractive errors. About 80% of cases of visual loss due to these problems or due to AMD could be detected with either of the screening tools. Using a pragmatic operational criterion, the screening tools detect about 94% of cases who might be considered by an optometrist to be in need of an eye examination (either overdue or reduced visual

acuity). Glaucoma is a difficult disease to diagnose and it was found, as expected, hat neither screening instrument was very good at detecting glaucoma.

The research has also revealed when older patients accept the recommended intervention to improve their vision after an eye examination there is an increase in their quality of life. This is most significantly noticed in patients that accept a spectacle intervention to improve their vision. This strongly indicates that if NHS provision for VVS was readily accessible to older patients and this barrier to eyecare was eliminated or at least reduced then older patients would benefit from a better quality of life as a result of obtaining spectacles necessary to improve their vision.

It is concluded that the high prevalence of correctable but uncorrected vision problems in older people requires action. Vision screening does not replace the need for professional eyecare, but acts as a tool to better inform the public of the need for regular eyecare, to detect problems requiring urgent attention, and to raise awareness of the correctable nature of many eye problems in older people.

13.2 Considering the aims of screening

The research has shown that the tests included in a visual screening tool are very dependent on the aims of the screening programme. The more complex the aims are, the more likely it is that more tests will need to be incorporated into the screening tool which will impact on the sensitivity and specificity of the tool. Inevitably, the research has shown that with an increased number of tests the specificity is likely to increase but at the expense of sensitivity. The increased specificity may be ideal in a situation where accessing eye care is a challenge but may not appropriate in an area where eye care is easily accessible.

Table 13.1below takes the aims of screening into consideration to suggest tests that would be appropriate for particular aims. It can be seen that more tests are needed when the aims are more complex or when the aims are combined

Table 13.1 Recommended tests for various screening aims

Aims of screening	Recommended tests	Suitability of CVS	Suitability of FVS
To detect those overdue for eye exam	Questioning	Very good	
To detect those with reduced HCVA	HCVA	Very good	Very good
To detect those overdue and with reduced HCVA	Questioning HCVA	Very good	Good
To detect those overdue & with HCVA or LCVA deficit	Questioning HCVA LCVA	Very good	Good
To detect those with possible uncorrected refractive error	HCVA	Very good	Very good
To detect those with possible significant cataract	HCVA LCVA	Very good	Very good
To detect those with possible correctable visual loss (uncorrected refractive error and/or cataract)	HCVA LCVA NVA	Very good	Very good
To detect those with possible correctable visual loss (uncorrected refractive error and/or cataract)	HCVA LCVA NVA	Very good Sensitivity 80.3% Specificity 66.7%	Very good Sensitivity 82% Specificity 62.5%
To detect those who are in need of an eye examination from an optometric perspective	Questioning HCVA	Very good	Good
To detect those with possible correctable visual loss (uncorrected refractive error and/or cataract) and those overdue for an eye exam	Questioning HCVA LCVA NVA	Very good	good

The computer vision screener is particularly advantageous when conducting screening in different areas where the aims of the screening programme may change from venue to venue. The tests in the computer screener can be easily added or eliminated depending on the goals of the screening programme.

13.3 Inferences for designing visual screening tools for older people

From the present research a number of conclusions can be drawn specifically relating to the design of visual screening tools for older people and these are listed below in the table with comments.

Table 13.2 Inferences for designing visual screening tools for older people

Inference	Comment
The screening tools should be able to be administered by non health care professionals	Older people are more likely to come into contact with non health care professionals such as community workers. It is important that the screening tools are not too complicated to administer.
The screening tools should be portable, so that they can be taken to patients with mobility problems	Older people are more likely to have mobility difficulties and as such it would be ideal to be able to conduct the screening by moving the screening tool to the older person rather than asking the older person to move.
The screening tests should be quick and easy to do	Incorporating lots of tests in the screening tool is likely to lead to fatigue and loss of concentration in older people.
The screening tools should contain tests of HCVA and LCVA with the option of having further tests depending on the situation	These two tests proved to be very important in the detection of correctable visual loss in older people
In a non clinic based setting a flipchart tool would be appropriate	The computerised tool is suitable in a clinic environment such as a GP clinic, but for community venues and home visits a flip chart tool is a more practical option

It is hoped that the research described in this thesis will have an impact on the detection of correctable visual problems in older people and provide the basis for future research in this area. It is also hoped that vision screening using the tools outlined in this study can be implemented in the older population, whether this be in day centres or during home visits by non eyecare professionals. It is thought that vision screening will help to increase awareness among the older population of the need for regular eye examinations.

Appendices, Supporting Published Work and References

Appendix 1

Participant Enquiry Pack

Improving vision in older people

Thank you for your enquiry about our research. Please find enclosed a participant enquiry pack, which contains:

1. Information sheet
2. Consent form
3. Questionnaire on previous eye care
4. Non participation questionnaire

The information sheet contains information on why the research is being done and what it will involve. Please take a few moments to read the information before deciding whether you wish to take part. If you would like to take part or would like to discuss any aspect of the research please contact: Zahra Jessa (0207 234 9644) or fill out the slip at the back of the leaflet and send it to Zahra Jessa at the above address.

If you decide to take part, we would appreciate it if you could sign the consent form and complete the questionnaire on previous eye care and bring these forms with to the appointment. If you do not wish to take part then we would be very grateful if you spare a few minutes to fill out the non-participation questionnaire and send it to us, a stamped addressed envelope has been provided.

Appendix 2

INFORMATION SHEET

Improving vision in older people

You are being invited to take part in a research study. Below is some information regarding why the research is being done and what it will involve. Please take time to read the following information before deciding whether you wish to take part.

Previous research suggests that many older people have vision problems that could quite simply be corrected. Many people with these problems do not seem to receive the help that they need to make their vision better.

The purpose of our research study is to see if simple vision screening tests can help to detect these problems. We will be using a computer to carry out a simple and quick vision test. One of our team, Zahra Jessa, will also carry out a detailed eye examination. The results of the computerised vision screening will be compared with the full eye examination. The screening and the eye examinatio will take approximately 1hr and 30 minutes. The eye examination will be very thorough and you will be given the time that is needed without feeling rushed, and will be offered rest periods if you wish. All the testing will involve routine tests, similar to those that you might have when you visit the optician (optometrist).

None of the tests are painful and none of the tests are likely to cause you discomfort.

One of the tests involves some drops (Tropicamide 1%), which may blur your vision for up to a few hours. It is best not to drive until the drops have worn off. These eye drops are widely used by optometrists and eye doctors and hardly ever cause any problems. Very rarely, they can cause a reaction where the eye becomes red and painful. This reaction is so rare that in one study it occurred in less than 1 in 5,000 people. If you do experience any unusual symptoms after the eye drops then you should contact us immediately (Zahra Jessa on [redacted] or Bruce Evans on [redacted]) or seek immediate medical advice.

If we discover that your vision can be improved with new glasses then we will tell you and give you a list of all the registered opticians in the area that can provide you with glasses. We will also explain your entitlement to NHS glasses.

If, as a result of the research, we discover that you have a visual problem or other health problem that should be checked by a doctor then we will discuss this with you. We will, if you agree to this, refer you to a doctor for the treatment or care that you need.

Once you have taken part in the research we will not discuss your results with anyone without your permission and you will not be identified in anything we write. We will keep you informed of the results from the study over

the 3-year period that the research is been conducted and we may contact you again if there are other research studies that we feel you may be interested in. Please inform us if you would not like to receive any further contact. We will not forward your contact details to any third party.

The study is being funded by the Institute of Optometry and has been reviewed by several ethical committees and independent reviewers.

If you are worried about any matter concerning the research please contact Zahra Jessa, whose contact details are below. If you would like time to think about taking part in this project then please take this form away and ask us if you would like any further information. If you would like us to discuss this research with any of your family, friends, or carers then please ask them to contact us. More information, including this form in large print and other languages, can be obtained from Zahra Jessa, Research Fellow, Institute of Optometry, 56-62 Newington Causeway, London, SE1 6DS; [redacted]

If you decide to take part, you will be given this information sheet to keep and be asked to sign a consent form. If you decide to take part you will be free to withdraw from the research at any time without having to explain why. Withdrawal will not affect your usual care or visual treatments in any way.

Appendix 3

Patient Identification Number for this trial:

CONSENT FORM

Improving vision in older people

Name of Researcher: Zahra Jessa,

Research Fellow,

Institute of Optometry

Please initial box

1. I confirm that I have read and understand the information sheet dated 31/01/2005 for the above study and have had the opportunity to ask questions. ☐
2. I understand that my participation is voluntary and that I am free to withdraw at any time without giving any reason, without my medical care or legal rights being affected. ☐
3. I agree to take part in the above study. ☐

_____ _____

Name of Patient Date Signature

_____ _____

Name of Person taking consent Date Signature

_____ _____

Researcher Date Signature

1 for patient; 1 for researcher; 1 to be kept with research notes

Appendix 4

Questionnaire on previous eye care

Confidential

Question 1

Have you had an eye examination within the past two years? Yes ☐ No ☐

Question 2

Do you wear any spectacles?

Yes ☐ No ☐ If yes please specify below:

Distance vision spectacles ☐

Near vision spectacles ☐

Varifocals/bifocals ☐

Question 3

Are you aware of having any eye conditions that may affect your vision?

Yes ☐ No ☐ If yes please specify below:

Cataract ☐

Glaucoma ☐

Age Related Macular Degeneration ☐

Other ☐ Please specify below:

……
……
……

Question 4

Is there a history of any eye conditions in your immediate family?

Yes ☐ No ☐ If yes please specify below:

Glaucoma ☐

Other ☐ Please specify below:

……

Question 5

Are you experiencing symptoms of reduced vision even your spectacles?

Yes ☐ No ☐ If yes please specify below:

Is it at distance? ☐

Is it at near? ☐

Is it at distance and near? ☐

Question 6

Have you been experiencing headaches recently? Yes ☐ No ☐

Have you been experiencing any other symptoms? Yes ☐ No ☐

If yes please specify below:

……

Question 7

Do concerns about cost of glasses deter you from attending your local optician?

Yes ☐ No ☐

Appendix 5

Non-participation questionnaire

Confidential

We are sorry that you are not able to take part in our research, but thank you anyway for your interest. We are keen to find out a little about people who do not wish to participate. We would therefore be grateful if you could answer the few questions below. You do not have to give your name and your responses will be kept confidential.

Roughly how long ago was your last (sight test)? Months

How happy are you with your vision (when wearing any glasses that you currently use)? Not | Satisfied | Very

Have you had a fall within the past 12 months? Yes | No

How easy do you feel the study information was to understand? Not | Moderately | Very

How much did concerns about cost of glasses deter you from taking part in the study? No | Moderate | Great

How much did the worry of possibly being advised that you shouldn't drive deter you from taking part in the study? No | Moderate | Great worry

How much did the worry of possibly being told that your eyes were "becoming worse" deter you from taking part in the study? No | Moderate | Great

Do you feel that deterioration in vision is an inevitable consequence of ageing? Yes | No

Any other comments regarding why you declined to take part in the study would be very much appreciated.

.....

A stamped addressed envelope has been provided to post the completed questionnaire.

Thank you

Appendix 6

THE LOW VISION QUALITY-OF-LIFE QUESTIONNAIRE (LVQOL)

Distance Vision, Mobility and Lighting

How much of a problem do you have:	GRADING None		Moderate		Great		
With your vision in general	5	4	3	2	1	x	n/a
With your eyes getting tired (e.g only being able to do a task for a short period of time)	5	4	3	2	1	x	n/a
With your vision at night inside the house	5	4	3	2	1	x	n/a
Getting the right amount of light to be able to see	5	4	3	2	1	x	n/a
With glare (e.g dazzled by car lights or the sun)	5	4	3	2	1	x	n/a
Seeing street signs	5	4	3	2	1	x	n/a
Seeing the television (appreciating the pictures)	5	4	3	2	1	x	n/a
Seeing moving objects (e.g. cars on the road)	5	4	3	2	1	x	n/a
With judging the depth or distance of items (e.g. reaching for a glass)	5	4	3	2	1	x	n/a
Seeing steps or curbs	5	4	3	2	1	x	n/a
Getting around outdoors (e.g. on uneven pavements) because of your vision	5	4	3	2	1	x	n/a
Crossing a road with traffic because of your vision	5	4	3	2	1	x	n/a

Adjustment

Because of your vision, are you:	No		Moderately		Greatly		
Unhappy at your situation in life	5	4	3	2	1	x	n/a
Frustrated at not being able to do certain tasks	5	4	3	2	1	x	n/a
Restricted in visiting friends or family	5	4	3	2	1	x	n/a

	Well				Poorly	Not explained
How well has your eye condition been explained to you	5	4	3	2	1	x

Reading and Fine Work

With your reading aids / glasses, if used, how much of a problem do you have:	None		Moderate		Great		
Reading large print (e.g. newspaper headlines)	5	4	3	2	1	x	n/a
Reading newspaper text and books	5	4	3	2	1	x	n/a
Reading labels (e.g. on medicine bottles)	5	4	3	2	1	x	n/a
Reading your letters and mail	5	4	3	2	1	x	n/a
Having problems using tools (e.g. threading a needle or cutting)	5	4	3	2	1	x	n/a

Activities of Daily Living

With your reading aids / glasses, if used, how much of a problem do you have:	None		Moderate		Great		
Finding out the time for yourself	5	4	3	2	1	x	n/a
Writing (e.g. cheques or cards)	5	4	3	2	1	x	n/a
Reading your own hand writing	5	4	3	2	1	x	n/a
With your every day activities (e.g. house-hold chores)	5	4	3	2	1	x	n/a

Appendix 7

Research on vision screening of older people

Thank you for participating in our research study. The results of the test suggest that you need glasses for:

- Distance vision (looking at things far away)
- Moving around
- Television
- Eating
- Reading and writing

My tests today suggest that new glasses would be likely / very likely to improve your vision for

- Distance vision (looking at things far away)
- Moving around
- Television
- Eating
- Reading and writing

Below is a prescription for these glasses. I believe that you should be able to have glasses made up whose cost is covered or contributed to by the NHS. The list on the reverse of this page gives the names of some local places where you can obtain these glasses.

OPTOMETRIC PRESCRIPTION

Patient name.....

Date of eye examination: Re-examination advised in..... months

	Sphere	Cylinder	Axis	Prism	Base	VA	BVD	Add
R						6/		
L						6/		

Additional details.....

Research optometrist: *Miss Zahra Jessa* Signed.....

Appendix 8

OPTOMETRIC PRACTICES THAT PROVIDE NHS SPECTACLES

A & I Lask	60A Brixton Road	Brixton	SW9 6BS
Anthony Ruddock (D&A Franch]	297 Walworth Road	Walworth	SE17 2TG
Brian Ashby (Opticians) Ltd	54 Lee High Road	London	SE13 5PT
Day & Elliot [D&A Franchise]	6 Astoria Parade	Streatham High Road	SW16 1PR
Dollond & Aitchison	125 Rushey Green	Catford	SE6 4AA
Dollond & Aitchison	151 Clapham High Street	Clapham	SW4 7SS
DT MacDonald	141 Dulwich Road	Herne Hill	SE24 0NG
Edgar Darter Opticians	195 High Street	Lewisham	SE13 6AA
Hatton Opticians	157 Lambeth Walk	Kennington	SE11 6EE
Hatton Opticians	4 Westbourne Terrace	Forest Hill	SE23 2ND
Insight Opticians	4 Lee Gate	Lee Green	SE12 8SS
J G Bentley	204 Southwark Park Road	South Bermonsey	SE16 3RW
J S Robin	Whittington Centre	11-13 Rutford Road	SW16 2DO
K.A. Rowland Ltd	112 Rushey Green	London	SE6 4HW
L.A. Sackwild	90 Towerbridge Road	Bermondsey	SE1 4TP
London Eye Care Centre	30 Knights Hill	West Norwood	SE27 0HY
Marratt & Ellis Opticians	50 London Road	Forest Hill	SE23 3HF
Medirex Opticians	28-29 Wilcox Close	Lambeth	SW8 2UD
Monoptics Ltd	11 Stockwell Road	Stockwell	SW9 9AU
Monoptics Ltd	25 Brockley Cross	Brockley	SE4 2AB
Nash Opticians	303 Evelyn Street	Deptford	SE8 5AJ
Nash Opticians	254 Southwark Park Road	South Bermondsey	SE16 3RN
Optical Express Southern	25 Central Mall South	Riverdale Centre	SE13 7EP
Peckham Specsavers Ltd	Unit 3, The Aylesham Centre	Rye Lane	SE15 5EW
Provision Opticians	263 Old Kent Road	London	SE1 5LU
Quinlan's Opticians	7 Bedale Street	London Bridge	SE1 9AL
R & J Optical	39-41 East Street	London	SE17 2DS
R Woodfall (Norwood)	286 Norwood Road	West Norwood	SE27 9AF
R Woodfall (Sydenham)	6 Sydenham Road	Sydenham	SE26 5QW
Realeyes Ltd	107 Streatham Hill	London	SW2 4UG
Rodney Opticians	7 Camberwell Green	Camberwell	SE5 7AF
S Squared Ltd	33 Lower Marsh	London	SE1 7RG
Specsavers Brixton	492 Brixton Road	Brixton	SW9 8EQ
Specsavers Opticians	174 High Street	Lewisham	SE13 6JL
Specsavers Streatham Ltd	192 Streatham High Road	Streatham	SW16 1BB
The Institute of Optometry	56-62 Newington Causeway	Elephant & Castle	SE1 6DS
The Sight Centre	78 Deptford High Street	Deptford	SE8 4RT
Vision Express JV	Unit 39	The Lewisham Centre	SE13 7HB

Appendix 9

Participant evaluation of screening programme

CONFIDENTIAL

1. How easy did you feel the instructio were to understand? | Not easy | Fairly | Very |

2. How easy did you find the screening tasks to do? | Not easy | Fairly | Very |

3. How easy was it to concentrate on the screening tasks? | Not easy | Fairly | Very |

4. Do you think that the screening programme took too long. | Yes | No |

5. How stressful did you feel the procedure was? | Not stressful | Fairly stressful | Very stressful |

6. How valuable do you feel the screening programme is? | Not valuable | Fairly valuable | Very valuable |

7. Would a screening programme such as this prompt you to have a full eye examination if the screening indicated that you needed it? | Yes | No |

8. Was the place where the screening was conducted a convenient location for you? | Yes | No |

Any suggestions or comments regarding the screening programme would be very much appreciated. In particular, if you have any suggestions for other venues where the screening programme could be used then please give these below.

.....

Thank you

Appendix 10

Improving the vision of older people
Questionnaire on the provision of NHS eye care in South London

CONFIDENTIAL

Thank you for completing this questionnaire. As explained in the covering letter, we plan to use this information to give older people participating in our research a list of local optical practices where they can obtain NHS eye examinations & glasses whose cost is fully covered by the NHS voucher (for those who are eligible to a voucher). We may also analyse these results & publish a paper summarising the availability of glasses covered by the NHS voucher, but no practitioners or practices would be named in such a paper.

1. *Do you provide NHS eye examinations?* *Yes* ☐ *No* ☐

2. *Do you supply complete glasses (frame and lenses) to eligible patients whose price is fully covered by the NHS voucher?*

   ☐ *Yes* ☐ *No*

3. *If your answer is "yes" to question 2, approximately how many frames are available in this range for patients to choose from?* ☐

4. *If your answer is "no" to question 2 and you do provide NHS services, does the voucher cover the complete cost of the lenses?*

   Yes ☐ *No* ☐

   If your answer is "no", what is the minimum amount needed to top up the voucher in order to obtain lenses?

Single Vision?	*Bifocals?*	*Varifocals?*
£	£	£

5. *If your answer is "no" to question 2 and you do provide NHS services, what would be the minimum cost of a frame?* £

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