

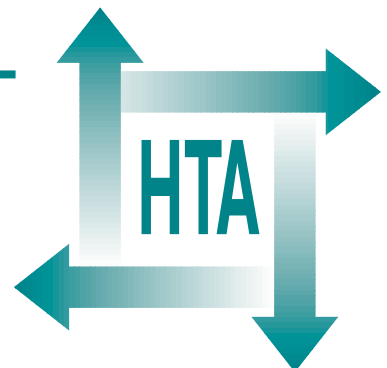
Preschool vision screening

Sarah K Snowdon

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**Health Technology Assessment
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Preschool vision screening

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NHS R&D HTA Programme

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This report is one of a series covering acute care, diagnostics and imaging, methodology, pharmaceuticals, population screening, and primary and community care. It was identified as a priority by the Population Screening Panel (see inside back cover).

The views expressed in this publication are those of the authors and not necessarily those of the Standing Group, the Commissioning Board, the Panel members or the Department of Health.

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Glossary and list of abbreviations

Technical terms and abbreviations are used throughout this report. The meaning is usually clear from the context but a glossary is provided for the non-specialist reader. In some cases usage differs in the literature but the term has a constant meaning throughout this review.

Terms relating to vision

Amblyopia Reduced visual acuity in the absence of organic disease, which cannot be improved by spectacles. It is usually unioocular. Amblyopia is held to be reversible up to the age of about 8 years. Children presenting with amblyopia will be treated with occlusion or other therapies in order to reverse the visual loss. It is thought to be caused by hypermetropia and/or anisometropia as well as by the various types of squint. Some practitioners treat these refractive errors in preschool children to prevent the development of amblyopia; others follow-up these children and intervene as soon as the amblyopia appears.

Anisometropia A difference in refractive error between the two eyes.

Binocular single vision The simultaneous use of both eyes so that each eye contributes to a common singular perception. There are grades of binocular single vision. In the highest form the object is fixated at the centre of the retina in both eyes and fusion of the two images allows depth perception (stereopsis).

Cover-uncover test A test used to detect squint, in which each eye is covered in turn while the child fixes on a specified target, and the tester observes the movements of the eyes.

Cycloplegic drugs These drugs block the action of the ciliary muscle, preventing accommodation. In addition, pupillary dilation occurs.

Dioptre (D) Unit of measurement of the power of a lens.

Diplopia Double vision or seeing two images of one object simultaneously.

Hypermetropia Refractive error where the principal focus is behind the eye (so-called 'long sight').

Intermittent squint There is a manifest squint at some times or distances but the visual axes are aligned at others. Children with intermittent squints may respond to spectacle correction alone if they are also hypermetropic. They may be followed-up and undergo surgery if the squint becomes less well controlled, in order to prevent the loss of binocular vision and the development of a cosmetically obvious squint.

Latent squint (heterophoria) With both eyes open the visual axes are aligned. When one eye is covered, the eye under cover deviates; when the cover is removed, it comes back into alignment. A small heterophoria is present in the majority of people without ocular symptoms. Small latent *divergent* squints are regarded as common in children aged 3–4.5 years and are not thought to be associated with any adverse effects. No intervention is recommended. Small latent *convergent* squints are often accompanied by hypermetropia, for which spectacle correction is prescribed with the aim of preventing further deterioration of the squint.

LogMAR scale Scale used to measure visual acuity (see below).

Manifest squint (heterotropia) With both eyes open the visual axis of one eye is deviated from the point of fixation. It may be constant or intermittent.

continued

Microsquin (microtropia) A small angle heterotropia usually of 10 dioptres or less. These are associated with abnormal binocular function but cannot be treated. They are often associated with anisometropia and both of these conditions are thought to predispose children to developing amblyopia. Children with microtropias are prescribed spectacles if they are anisometric and they are followed up to allow incipient amblyopia to be detected and treated early.

Myopia A refractive error where parallel rays of light focus in front of the retina when the eye is at rest (so-called 'short sight').

Occlusion Obscuring the vision of one eye, either totally or partially, to prevent or reduce visual stimulation.

Refractive error An abnormal refractive index.

Snellen scale Scale used to measure visual acuity (see below).

Squint The lay term for strabismus.

Stereopsis The image seen by each eye is slightly different; the fusion of these two images allows perception of depth.

Strabismus The misalignment of the visual axes of the two eyes. It may be manifest or latent.

Visual acuity The limit of spatial visual discrimination, commonly measured using letters or other geometrical forms (opto-types). Two of the scales used to measure visual acuity, the Snellen and LogMAR scales, are given below.

Snellen	LogMAR	Snellen	LogMAR
6/60	1.0	6/12	0.3
–	0.9	6/9	0.2
6/36	0.8	6/7.5	0.1
–	0.7	6/6	0.0
6/24	0.6	6/5	–0.1
6/18	0.5	6/4	–0.2
–	0.4	6/3	–0.3
NB Many Snellen charts stop at 6/5.			

Epidemiological terms

False-negatives Individuals with a negative test result but who actually have a target condition.

False-positives Individuals with a positive test result but who do not have a target condition.

Negative predictive value The proportion of individuals who test negative who do not have a target condition.

Positive predictive value The proportion of individuals with a positive test result who have a target condition.

Screening The presumptive identification of unrecognised disease or defect by the application of tests, examinations, or other procedures which can be applied rapidly to a whole population. Screening separates apparently well people who probably have a disease/defect from those who probably do not.

Sensitivity (true-positive rate) The proportion of individuals with the target condition in a population who are correctly identified by a screening test.

Specificity (true-negative rate) The proportion of individuals free of the target condition in a population who are correctly identified by a screening test.

Surveillance On-going observation of the health of individuals or populations.

Yield The proportion of individuals in a screened population who are found to have a target condition.

Abbreviations

CCT	controlled clinical trial
CI	confidence interval
CMO	Chief Medical Officer
GP	general practitioner
RCT	randomised controlled trial



Executive summary

Objectives

- To undertake a systematic review of the effectiveness of preschool vision screening.
- To provide evidence on which decisions about the future provision of this service can be made.
- To indicate areas for further research.

How the research was conducted

Study selection

The Centre for Reviews and Dissemination guidelines for systematic reviews were used. The research questions were formulated using the Wilson and Jungner criteria for evaluating screening programmes. They concerned prevalence, natural history, disability, treatment and screening in relation to three target conditions: amblyopia, refractive errors and squints which are not cosmetically obvious.

Studies were considered for inclusion according to pre-determined criteria for the age group studied, the outcomes measured and the study design. The following types of study design were considered: cross-sectional studies of prevalence, cohort studies of natural history, any type of study (e.g. cross-sectional surveys, case-series, qualitative studies) of disability attributable to a target condition, controlled trials, observational studies and audits of screening programmes, and prospective controlled trials of treatment.

Data sources

The following electronic databases were searched: Biological Abstracts, CINAHL, Embase, ERIC, IAC Health Periodicals, IAPV, Medline, Psychlit, Science Citation Index, System for Information on Grey Literature in Europe, DHSS-Data, Faculty of Public Health Medicine Database of Dissertations, Index of Scientific and Technical Proceedings, Dissertation Abstracts, Index of Theses, NHS Research Register, Public Health Information Sharing Database. A limited amount of handsearching was undertaken. Reference lists were scanned to identify other relevant studies, and requests for unpublished data were made to people working in the field.

Data extraction

Data was extracted by the first author and then checked by the second.

Data synthesis

Quantitative analysis was undertaken where possible. Qualitative analysis was performed where studies were too heterogeneous for the data to be combined, or for research questions that were not suitable for quantitative synthesis.

Research findings

The electronic search yielded over 5000 references, and over 500 abstracts were downloaded from the databases for further scrutiny. A total of 85 studies were included in the main analysis.

Prevalence

No studies were found with the primary aim of establishing the prevalence of visual defects in preschool children. Data from studies of screening programmes report a range of yields for all the target conditions combined of 2.4–6.1%.

Natural history

No studies designed with the intention of documenting the natural history of the target conditions in children aged 3 or 4 years were found. Other studies that provide some natural history data suggest that mild degrees of amblyopia may resolve spontaneously. In the absence of information about natural history it is impossible to estimate the effect of treatment from studies without a control group that was not treated.

Disability

A total of 21 studies exploring disability in relation to the target conditions were included. The literature provides a reasonable basis for generating plausible hypotheses about the ways in which the target conditions might disable people, but is insufficient to draw any firm conclusions about their impact on quality of life. The research to date is not sufficient to determine appropriate outcomes for controlled trials of treatment.

Treatment

Five randomised controlled trials of treatment and six prospective controlled trials without randomisation were found. No studies compared treatment with no treatment. Most of the studies were methodologically flawed.

Screening programmes

One prospective controlled trial and 16 retrospective studies (observational studies and audits) of different screening programmes were found. They showed that orthoptic screening programmes perform better than health visitor or general practitioner (GP) screening in terms of programme yield and positive predictive value. The mean uptake rate was 64.8%. The mean referral rate was 6.7% for primary orthoptic screening programmes and 3.9% for screening by health visitor or GP. The positive predictive value ranged from 47.5% to 95.9% for orthoptic screening and from 14.4% to 61.5% for screening by health visitor or GP. Only two studies were found which reported numbers of false-negative cases. The findings of the one prospective study do not support the belief that identifying children with amblyopia in the preschool period reduces the prevalence of this condition in children aged 7 years.

Conclusions

There is a lack of good quality research into the natural history of the target conditions, the disabilities associated with them, and the efficacy of available treatments. This evidence is essential to support a screening programme for a non-fatal condition for which there have been no rigorously controlled trials. An invitation to preschool vision screening carries with it the implicit assumption that screening is going to benefit the child. In the absence of sound evidence that the target conditions sought in these programmes are disabling and that the interventions available to correct them do more good than harm, the ethical basis for such interventions is very weak.

Recommendations

Clinical practice

Purchasers and providers are advised not to implement new preschool vision screening programmes unless they have been rigorously evaluated.

The National Screening Committee should consider whether to recommend that existing vision screening programmes be discontinued, unless they are part of a controlled trial of treatment.

Research recommendations

There is a need to research the following areas.

- The extent of disability attributable to the target conditions.
- The prevalence of blindness or partial sight attributable to amblyopia in the UK.
- The prognosis for vision in the amblyopic eye following loss of vision in the better eye.
- The impact of orthoptic treatment on family life and the psychological well-being of the child.
- The effectiveness of orthoptic treatment for amblyopia on vision and quality of life. This should be a randomised controlled trial in which the control group is not treated, using health outcome measures defined in studies of disability. This would also provide data on the natural history of amblyopia. Trials undertaken in groups of children aged 3–4 years and 5–7 years would determine whether treatment in the preschool years confers any benefit over treatment at school entry.
- The effectiveness of treatment of non-cosmetically obvious squints and refractive errors in this age group.

Chapter I

Background

Vision screening of children aged 3–4 years was developed in the context of the UK child health surveillance programmes during the 1960s and 1970s, in response to a need perceived by health professionals. By the 1980s, a variety of different programmes were practiced in different parts of the country.¹

Aim of vision screening

There is some uncertainty in the literature about the precise aims of programmes to screen children's vision at this age, as they have the potential to identify a range of visual problems. This is in contrast to other screening programmes where the aim is to identify a single disease. The primary aim of vision screening at this age is to identify the less severe common defects, called here target conditions – amblyopia, refractive errors, and non-cosmetically obvious squints which cannot be detected without screening (latent and intermittent squints and microtropias).

Target conditions

Amblyopia has been defined as a unilateral or bilateral decrease of vision, for which no cause can be found on physical examination of the eye.² It can be present at varying levels of severity and usually affects one eye only.

Refractive errors describe the situation in which light rays cannot be focused on the retina and a blurred image is formed. The image can almost always be focused with the help of spectacles.

Squint (strabismus) is a condition in which the two eyes are not aligned. In cosmetically obvious squint one eye is obviously looking in a different direction from the other. In small angle or micro-squint the deviation is not obvious and is revealed with the cover test. Latent and intermittent squints are only present under certain circumstances and can be revealed with the uncover test. These may develop into cosmetically obvious squints.

None of the target conditions (amblyopia, refractive error and non-cosmetically obvious squint) are

clinically obvious. They are associated with one another but the relationship is complex and its precise nature is uncertain.^{3,4} Refractive errors (particularly anisometropia and hypermetropia) may strain ocular muscle balance and cause squints. Squints may also arise independently of refractive errors. Both are thought to predispose to childhood amblyopia because vision in one eye may be suppressed (the eye may become amblyopic) to prevent diplopia (double vision), in which the ocular muscles cannot keep both eyes focused on a single image. Experimental evidence from animal studies and clinical experience in humans suggests that there is a sensitive period in the human child up to the age of about 8 years when this process may occur but may be reversible. It would appear that vision is important for normal growth and development of the eye. Loss of vision in one eye may result in loss of oculomotor balance and squint.

Conditions other than the target conditions which may be detected by screening

Cosmetically obvious squints should, by definition, be identifiable by parents or health professionals without a screening programme and most children with squints present by this route.^{5–7} From time-to-time, a child with a cosmetically obvious squint will present through screening who has 'slipped through the net' of child health surveillance. Although the frequency of this is unlikely to be sufficient to justify a screening programme in its own right, the identification of these children is an added benefit of the programme. Clinicians sometimes justify these programmes on the basis of identifying the rare childhood conditions that cause partial sight or blindness. Visual impairments are often detected in the first weeks of life by simple inspection;⁸ these children present spontaneously because their parents notice that they cannot see.⁹ Very occasionally, however, a child will turn up for screening with a serious problem, such as retinoblastoma or a cataract, which has not been noticed by the parents. Such instances are too rare to be used to justify the screening programmes but, as with cosmetically obvious squints, their detection during screening is an added benefit. A true cost-benefit analysis of screening should take both into account.

The effect of target conditions on visual function and quality of life

Amblyopia

Visual acuity

The human eye is a very complex organ performing many different types of visual function. Traditionally, visual acuity (the limit of spatial visual discrimination, commonly measured using letters or other geometrical forms) has been the most clinically valued characteristic in describing quality of vision.¹⁰ In adults, it is usually tested with a letter chart at 6 metres. In young children, the method of testing must be appropriate to the age of the child; hence, for preschool children there are a variety of visual acuity tests. Visual acuity testing is the main screening method used to identify the target conditions, with amblyopia defined by reduced visual acuity not justified by other organic defects.¹¹ Accordingly, if visual acuity screening is carried out accurately, all children failing could be regarded as disabled. However, children with amblyopia may have very good acuity in the unaffected eye and only have a visual acuity deficit with one eye closed.

Stereopsis

Children with amblyopia may suffer another type of visual disability – lack of binocular function. Two eyes focusing on an object from a slightly different angle allow the perception of depth (stereopsis). If one eye cannot see at all this cannot happen. Stereopsis is not an all-or-none phenomenon; people may have partial stereoscopic function measured in seconds of arc. The extent to which amblyopia affects stereopsis is therefore important in assessing visual disability caused by amblyopia.^{3,12}

Other visual functions

Complete lack of vision in one eye would cause visual disability by reducing the visual field (the area which an individual can see without moving their head). Complete lack of vision is, however, unusual in amblyopia. Other aspects of visual function include perception of both colour and movement. These are not generally thought to be influenced by the target conditions.

Refractive errors

Refractive errors create a blurred image on the retina and thus also reduce visual acuity. A degree of hypermetropia (long sight) is normal in young children⁴ and, because most children have strong powers of accommodation, visual acuity may not be affected. However, the effort of accommodation in the presence of hypermetropia is thought to

predispose to the development of squint. Hypermetropia and other refractive errors (myopia or short sight, anisometropia or unequal refraction in the two eyes, and astigmatism) should be correctable with spectacles, with no residual disability other than the need to wear them.

Impact of amblyopia and refractive error on everyday life

It has been suggested that amblyopia and uncorrected refractive error may interfere with a child's development, educational performance and sporting ability. As a consequence of educational failure, there may also be a long-term disabling effect on adults. Adults suffering from amblyopia may have a problem with a number of activities, such as racquet sports, driving, or jobs requiring fine motor coordination. Imperfect vision may be a reason for refusing entry to the armed forces or to pilot training programmes. People with amblyopia are at greater risk of blindness as a result of injury or disease in the non-amblyopic eye than those with two good eyes.

Squint

Non-cosmetically obvious squints may progress to become obvious and unsightly, and may, as a consequence, cause psychological problems. If these squints cause amblyopia they may be associated with poor stereoscopic function. They are thought to cause eyestrain (pain brought on by ocular muscle spasm) and headaches.

Treatment of target conditions

Traditionally, amblyopia has been treated by occlusion of the non-amblyopic eye by covering it with a patch; this is the only method currently in use in the UK. Patching deprives the child of vision in the good eye and encourages use of the amblyopic eye to prevent loss of vision. Regimes for patching vary from one orthoptic department to another. In recent decades, alternative treatments have been tried. Penalisation, or selective fogging of one eye using spectacles or cycloplegic drugs, is one such method. Systems designed to stimulate the amblyopic eye – pleoptics (dazzling light flashes) and CAM stimulation (high contrast grating patterns) – are others. Children in whom amblyopia has been identified are treated with intermittent patching of the good eye to force continued use of the amblyopic eye, thus preventing loss of vision.

A refractive error may be treated to effect an immediate improvement in visual acuity or

because it is thought to be contributing to the development of amblyopia or a squint. In the latter case, a refractive error may be treated at a level of severity that would not be considered warranted as treatment in its own right. Squints that progress to become clinically obvious may be treated by surgery to the extra-ocular muscles, in order to restore binocular single vision by re-aligning the visual axis or to improve cosmesis in the absence of binocular single vision.

Types of preschool vision screening programmes

In the past, UK child health surveillance programmes have incorporated a great variety of preschool vision screening tests undertaken at various ages.¹ Traditionally, health visitors or clinical medical officers carried out these tests as part of routine child health surveillance. The commonest tests at age 3–4 years are inspection of the eyes for cosmetically obvious squint and other visual or ocular abnormalities, the cover-uncover test for squint, and a test of visual acuity, most commonly the Sheridan–Gardiner test. In the last two decades, programmes have been established by orthoptists in which children are invited to attend clinics specifically to have their vision screened using a battery of orthoptic tests, including visual acuity, cover-uncover test, further tests of ocular muscle balance and tests of stereopsis. In some health districts in which there is no primary orthoptic screening, orthoptists have set up community clinics or secondary screening clinics to which health visitors, general practitioners (GPs) and clinical medical officers (CMOs) can refer children who are of concern either as a result of a primary screen or as a result of a clinical consultation. In other districts, referrals are made directly by health visitors and CMOs, and in some places the referral has to be made via the GP. Orthoptists may also aim to invite and screen all high-risk children (those with a family history of visual problems or those with congenital defects).¹³ The range

of possible programmes extends therefore from no screening by anyone and referral to an ophthalmologist of children who present clinically through surveillance by health visitors, GPs or CMOs, to screening with the cover-uncover test, with or without visual acuity, by health visitors, GPs or CMOs, a limited orthoptic screen of high-risk children, and a full population primary orthoptic screen. All but the last of these models may be provided with or without a community orthoptic clinic.

Previous reviews of preschool vision screening programmes

In 1989, a UK national working party undertook a review of the effectiveness of these programmes as part of an overall review of preschool child health surveillance. The working party concluded that there was no evidence to support screening at any age other than at 3–4 years, and that the efficacy of this screen was questionable.¹⁴ The study identified a number of research issues that needed to be answered before a national screening programme could be recommended. In contrast, in both Canada and the USA, reviews of the evidence relating to preschool vision screening have led national bodies to conclude that screening at 3–4 years of age is effective and efficient, and should be available to all children.^{15,16}

The need for evidence of effectiveness

In a recent Executive Letter, the Department of Health stated that shifts in investment are expected away from ineffective and less effective interventions towards those that have been shown to be effective.¹⁷ The need for evidence of effectiveness is underlined again in the NHS Executive programme, *Promoting Clinical Effectiveness*.¹⁸ In this review the fundamental questions that remain about the efficacy of preschool vision screening are addressed.

Chapter 2

Criteria for evaluating screening programmes

The basic principles of screening and the criteria by which the effectiveness of screening programmes may be judged were defined by Wilson and Jungner in 1968.¹⁹ The criteria may be summarised as follows.

The condition:

- is common and disabling
- has a known natural history
- has a recognisable latent or pre-symptomatic phase.

The screening test:

- is reliable, valid and repeatable
- is acceptable, safe and easy to perform
- has a high positive predictive value
- is sensitive and specific
- has a cost which is commensurate with the benefits of early detection.

Treatment:

- is effective and available
- service provision is adequate to treat the children identified by the screening programme

- policy regarding who will be treated has been agreed.

Failure to fulfill any one of these criteria calls into question the validity of the screening programme. All of the criteria can, in theory, be evaluated in a single study if that study starts by allocating children to be screened or not screened, and the entire population is followed-up for several years to identify false-negative cases and to measure the benefits in children who have been screened. In the absence of such studies, however, it is useful to evaluate the extent to which each of the criteria is fulfilled. Although the criteria are usually presented in the above order, it is more logical to address questions relating to treatment before those relating to the efficacy of screening. If there is no effective treatment for a condition, the questions on the efficacy of the screening programme become superfluous. Hence, the research questions for this review have been formulated using the Wilson and Jungner criteria¹⁹ but in this more logical order.

Chapter 3

Research questions

The conditions

Prevalence

What is the prevalence of the target conditions (amblyopia, refractive errors and non-cosmetically obvious squints) in children aged 3–4 years? What proportion of children with cosmetically obvious squints and partial sight and blindness fail to present spontaneously?

Natural history

What is the natural history of the three target conditions?

Disability

What are the consequences of the primary target conditions, in terms of disability at that time or later, as measured by various outcomes such as visual acuity, stereopsis, educational achievement and the performance of everyday activities?

Treatment

What is the effect of treatment of the primary target conditions in children aged 3–4 years on visual function and current and future disability?

Is there evidence that this is more effective than treating the same conditions in children aged 5–7 years? If treatment is as effective at 5–7 years of age, then screening could be carried out at school entry.

Screening

What is the uptake of screening following invitation? Is there evidence that these screening programmes can identify the target conditions efficiently?

The parameters of a screening programme that predict its performance are the sensitivity, specificity, positive predictive value and yield (see box).

Potential research questions not included in this review

No attempt has been made to identify and critically appraise all the literature pertaining

Measuring the efficiency of screening

	Target condition present	Target condition absent
Test positive	a	b
Test negative	c	d

a = true-positive cases; **b** = false-positive cases;
c = false-negative cases; **d** = true-negative cases.

$$\text{Yield} = \frac{a}{a + b + c + d}$$

$$\text{Positive predictive value} = \frac{a}{a + b}$$

$$\text{Negative predictive value} = \frac{d}{c + d}$$

$$\text{Sensitivity} = \frac{a}{a + c} \quad \text{Specificity} = \frac{d}{b + d}$$

to the performance of the numerous vision tests that could be used in this age group. The search has been restricted to tests that have been used in population screening programmes. This is necessary before a test can be recommended for use in a screening programme, as the results of testing in experimental conditions are not always replicable in practice. The reliability, validity and repeatability of a test determine the sensitivity, specificity and positive predictive value of the test's performance in a screening programme, and tests which have been shown to score highly on the latter must therefore perform reasonably on the former. Visual acuity charts in which the lines are scaled in a logarithmic fashion (LogMAR charts), and which can be scored by letter rather than by whole lines, seem to have advantages over the Snellen scale, including greater accuracy and better test-retest reliability^{20,21} but, in the UK, they are only used at present in research.

We have not looked for studies of the safety of these tests. All are non-invasive and have been in use for decades; hence, it seems reasonable to assume that they are safe. Nor have we looked for studies of their acceptability. To some extent, a high uptake rate can be regarded as a proxy measure of acceptability by a community.

No attempt has been made to assess the adequacy of current service provision. This would need to be undertaken before a screening programme such as this was implemented.

No attempt has been made in this review to assess the effectiveness of screening at 3–4 years

of age relative to alternative strategies for the identification and treatment of visual defects in children. These include the identification and treatment of risk factors for amblyopia and squint in infants by various methods of refraction, and screening at school entry.

Chapter 4

Review methods

The guidelines from the NHS Centre for Reviews and Dissemination, *Undertaking Systematic Reviews of Research on Effectiveness*,²² were consulted, and the Director of the NHS Centre, Trevor Sheldon, offered advice and support on all aspects of the review.

Advisory group

A multi-disciplinary group of researchers and practitioners with diverse opinions were invited to help identify literature, comment on the protocol, check the authors' interpretation of the literature, and offer peer review of a draft report and advice on the implications of the study (see Appendix 3 for group membership). One meeting of the group was held to discuss an early version of the report. The group did not determine the content of the review.

Search strategy

The Medline database was searched from its start date in 1966; other databases were searched from 1975. Studies in any language were considered for inclusion.

Studies that focused on children with severe disabilities and who also had visual defects were excluded.

Electronic searching

The electronic search strategies were devised with the help of Anne Lusher, Cairns Library, Oxford, and Julie Glanville, NHS Centre for Reviews and Dissemination.

The search strategy was modified to meet the requirements of each database. For those which code the research designs, separate searches were undertaken to identify (a) randomised controlled trials (RCTs), (b) controlled clinical trials (CCTs) and (c) other study designs. The search strategies are included in Appendix 1.

The following databases were identified by a CROS search (Appendix 2) as being those with the greatest number of references relating to the broad topics of the review:

- Biological Abstracts
- Medline
- Embase
- SciSearch
- Psychlit
- IAC health periodicals
- CINAHL (Citation Index for Nursing and Allied Health and Sociofile)

In addition, the ERIC (an educational database) and IAPV (Incidence and Prevalence) databases were searched for relevant material.

Hand-searching

The results of the hand-searches undertaken by Jennifer Evans and Richard Wormald at Moorfields Eye Hospital for the Cochrane Collaboration were made available for the purposes of the study. The following journals were searched for RCTs and CCTs of both screening and treatment:

- *British Journal of Ophthalmology*, 1948–95
- *Ophthalmic and Physiological Optics/British Journal of Optometry and Physiological Optics*, 1948–95
- *British Orthoptic Journal*, 1985–95
- *Clinical Vision Sciences*, 1986–95
- *European Journal of Implant and Refractive Surgery*, 1989–95
- *Experimental Eye Research*, 1985–95 (some issues missing 1994–95)
- *Journal of the British Contact Lens Association*, 1985–92
- *Progress in Retinal Research*, 1985–95 (one issue missing 1994)
- *Vision Research*, 1961–1970, 1975, 1980, 1985, 1990, 1992, 1995
- *Visual Neurosciences*, 1988–95
- *Journal of Paediatric Ophthalmology/Strabismus*, 1964–94 (except 1978 and 1980; some issues missing in 1994).

We were notified of potentially relevant RCTs and CCTs identified by the Baltimore Cochrane Centre for inclusion in the Vision Trials Register.

The *British Orthoptic Journal*, 1976–96 was searched by hand for any studies relating to the research questions.

Other sources

Requests for unpublished data were sent to departments of ophthalmology, vision sciences and orthoptics and to known researchers in the field. An announcement of the review and a similar request was made in the following publications: *British Orthoptic Society Newsletter*, *Optician*, and *Optometry Today*.

The reference lists of retrieved articles were scanned to identify other studies that might be relevant.

The following 'grey literature' databases were searched:

- SIGLE (System for Information on Grey Literature in Europe)
- DHSS-Data
- Faculty of Public Health Medicine database of dissertations
- Index of Scientific and Technical Proceedings
- Dissertation Abstracts
- Index of Theses
- NHS Research Register
- PHISH (5-counties Public Health Information Sharing database)
- MSc theses from Departments of Community Paediatrics at UK universities.

Inclusion criteria

Studies were considered for inclusion on the grounds of subject relevance, outcome and design. For some of the research questions, the range of study designs included is far greater than those usually included in systematic reviews, which are often confined to controlled trials or RCTs. The inclusion criteria for studies on disability were particularly wide. It was deemed important to identify the literature on which clinicians base their views on disability and to appraise the extent to which it supports those views.

Studies that met the inclusion criteria are tabulated. Those that were rejected on one or more of the criteria are listed at the end of the References. Some which did not meet the inclusion criteria still provided useful contributory information, and are referred to in the text.

Prevalence studies

- Subjects: a representative population of children aged 3–4 years.

- Outcome: prevalence of the primary target conditions.
- Design: cross-sectional studies.

Natural history studies

- Subjects: a representative population of children in whom any of the primary target conditions were identified at age 3–4 years and whose visual defects were not treated.
- Outcome: any visual changes observed over time in children who had not been treated.
- Design: cohort studies of 20 or more children.

Disability studies

- Subjects: any children aged 3 years or more.
- Outcomes: any type of disability attributable to any of the primary target conditions.
- Design: any (cross-sectional, comparative, case control, cohort, trials of treatment, qualitative, systematic and non-systematic reviews) studies that investigated if disabilities were associated with the target conditions. In particular, we hoped to find studies in which the aim was to establish whether there was a causal relationship between visual defects and disability.

The **epidemiological criteria** for establishing a causal relationship were described by Bradford Hill in 1971.²³ They are:

- strong and consistent, statistically-significant association not accounted for by confounding factors
- a dose–response relationship
- evidence that the visual defect preceded the disability
- evidence that the disability could be reversed by correction of the visual defect.

Treatment studies

- Subjects: children aged 3–7 years who were treated for any of the primary target conditions.
- Outcomes: visual outcomes, visual complications associated with surgery, spectacle use, disability, patient-perceived outcomes, other side-effects.
- Design: prospective controlled trials, with or without randomisation.

Screening programme studies

- Subjects: children aged 3–4 years.
- Outcomes: uptake rates, referral rates, diagnostic yield, positive predictive value, negative predictive value, sensitivity, specificity, costs, visual outcomes, and patient-perceived health outcomes.

- Design: prospective controlled trials, observational studies and audits.

authors of studies were contacted if data was unclear or appeared incomplete.

Critical appraisal

The studies have been critically appraised independently by both authors of this review. The methodological shortcomings of each study are identified in the tables. Those of different study designs are discussed in the text.

Data extraction

Data was extracted from studies that met the basic inclusion criteria by the first author of this review and checked by the second. Any disagreements were discussed and resolved. Where possible, the

Data synthesis

Results from studies that provided comparable numerical data on each aspect of screening programmes are presented together in the tables. Wherever possible, the data have been pooled. If secondary calculations have been made in order to produce comparable data, this is indicated. Some studies, particularly those on screening programmes, have addressed more than one of the research questions and so appear more than once in the results tables. A qualitative approach has been used to explore those aspects of the research hypotheses not suitable for quantitative synthesis.

Chapter 5

Results – prevalence

No studies were found which were conducted with the primary aim of establishing the prevalence of amblyopia, refractive errors and squints at 3–4 years of age. Our search strategy and inclusion criteria were specific and should have been sensitive enough; hence, it seems unlikely that any study that is at present retrievable by electronic means has been missed.

Two types of study were identified which could contribute to this research question: retrospective analyses of hospital records in communities where the hospitals serve a defined catchment area, and observational studies of the yield of screening programmes for this age group (the latter are presented later in chapter 9).

Prevalence rates depend on the definition of the condition. All three target conditions may be present in varying degrees of severity. A comparison of the yield from screening programmes, that is the proportion of children in the screened population found to have a target condition, is complicated by the absence of precise definitions of the conditions in the studies (see chapter 9 later). Only one study presented a yield for micro-squints;²⁴ the other studies failed to distinguish between different types of squint when reporting yield. The level of acuity at which amblyopia is considered significant may not be defined, and the type and degree of refractive error included in prevalence estimates of these errors is not always identified. One study of screening programme yield included all children of the relevant age referred to eye hospitals²⁵ and one study recorded referrals made through screening and by other routes separately,²⁶ while the rest included only those referred from the programme. The latter studies will underestimate the prevalence of the conditions since they may exclude children presenting spontaneously, but who are not screened because they are already under the care of an eye hospital.

The studies of primary orthoptic screening programmes presented in chapter 9 (see *Table 4a* later) provide an estimate of total yield of 2.4–6.1%. One study, with a yield of 2.4%,²⁵ excluded isolated refractive errors from the target conditions. Two other studies, with yields of 5.9%²⁶ and 6.1%,²⁴ both identified 4.3% of children as

having refractive errors (including anisometropia); however, the severity of hypermetropia and myopia were not defined and may have included mild cases. The second of these studies stated that spectacles were prescribed if the refraction was more than +4 dioptres (D) but there is no indication that only children with refractive errors at this level were included in the yield. If these two studies are excluded, the range of yields reported in these programmes runs from 2.7% to 4.4%.

One survey was found of ocular and/or vision defects detected in a cohort of children born in 1984 in one health district and followed-up to age 5 years.²⁷ During this period, in this district, a secondary orthoptic screening service was provided, and 5.1% of the children were found to have an ocular or vision defect requiring treatment or surveillance between the ages of 2 and 5 years. Heterotropia was the primary defect in 2.3% of the children and heterophoria in 0.5%, while refractive error only was found in 2.1% and other pathologies (non-target conditions) in 0.2%. These figures included children who also had amblyopia, which was classified according to the putative cause (squint, refractive error or cataract).

In another study,²⁸ all referrals to all hospitals in Leicester were analysed in detail to identify the age-specific and cumulative incidence of amblyopia. There was no primary orthoptic screening in place in Leicester. The cumulative incidence of amblyopia up to age 3 years was 1.25% and up to 4 years 1.69%. Some 3% of the population of Leicester were diagnosed as having had amblyopia of 6/12 or worse by the time they reached 8 years of age. In theory, if preschool vision screening is effective in identifying children with amblyopia earlier than they would otherwise present, these figures from Leicester should underestimate the prevalence of amblyopia at ages 3 and 4 years.

No comparable studies of squint or refractive error prevalence in this country have been found. The lack of information on the prevalence of non-cosmetically obvious squints (intermittent squints, latent squints and micro-squints) is notable. One study²⁹ suggests that the figure may be very high. Of a group of 86 children selected as controls for

a study of dyslexic children from a whole population of second-grade children in one Swedish county, 77% were shown to have a tropia or phoria at near and 25.4% at distance. This contrasts with the much smaller number of children found to have a tropia or phoria in the birth cohort study discussed above.²⁷ That study was based on a population of children referred to an eye hospital and would not have included children in whom there was no reason to suspect any abnormality. The control group in the Swedish study approximates to a normal population and is more likely to give an indication of the true prevalence. A study of admissions to hospital for squint surgery in an English county showed that the rate had halved from 2.1 per 1000 of the population to 1.3 per 1000 over the period 1968–85. The authors suggested that this might be a result of the comprehensive primary vision screening in their district, but did not say how screening could have reduced the incidence

of squint. An alternative explanation is a change in the indications for surgery.³⁰

No studies were found which addressed the question of how many children with cosmetically obvious squints and partial sight and blindness fail to present spontaneously. The few studies that touched on the issue of spontaneous presentation of children with visual defects are discussed in the chapter on screening.

Summary

Despite the methodological limitations of the studies included in this section, and excepting the difference between the two studies mentioned above,^{27,29} the prevalence estimates are consistent. There can be no doubt that the target conditions are sufficiently common for screening programmes to be justified.

Chapter 6

Results – natural history

No studies were found that were designed with the intention of documenting the natural history of squint, amblyopia or refractive error in children aged 3–4 years. A focused search strategy was used, so it is unlikely that any correctly coded studies were missed.

Some studies were found that, although they do not fulfill the inclusion criteria for natural history studies and are methodologically limited, do provide useful background data.

One of these was set up to evaluate the effectiveness of a primary orthoptic screening programme for children aged 3–4 years in Newcastle-upon-Tyne.³¹ The prevalence of amblyopia associated with non-cosmetically obvious squints or refractive error (straight-eyed amblyopia) was significantly higher in the group who underwent orthoptic screening than it was in the other groups of children, and more of these children received treatment. This was attributed to the efficiency of orthoptic screening in finding children with amblyopia. When the children were followed up to the age of 7 years, it was expected that the prevalence of amblyopia would be higher in the group which had not been screened by orthoptists because fewer of the children with amblyopia in this group would have been identified and treated. However, the prevalence of amblyopia was found to be the same in all groups. The implication of this is that some of the cases of amblyopia identified and treated in the orthoptic screening group would have resolved spontaneously if left untreated. This study was a CCT not an RCT and the sample sizes were small, so conclusions must be drawn with caution. (A fuller appraisal of this important study is to be found in chapter 9.)

A second study³² followed-up 22 of 24 children referred to the eye department of a Swedish children's clinic following screening at 4 years of age; they had confirmed mildly-reduced visual acuity of 0.65 (decimal equivalent of approximately 6/9) in both eyes, or 0.65 in one and 0.8 (approximately 6/7.5) in the other. Distance visual acuity was tested using the HVOT chart. Two of the children had hypermetropia of $> +3.25$ D in both eyes. None of the 24 children were treated. At 5 years of age, 18 children could see 0.8 or better with each eye.

The visual acuity of the four children whose vision had not self-corrected had not deteriorated. However, the refractive error had increased slightly in two of them. These children were treated with spectacles and patching at 5 years of age and both improved. This was a small study but its findings are in agreement with those of the previous study,³¹ and call into question the need to refer or treat children with amblyopia of 6/9 at 3–4 years of age.

The third study also took place in Sweden.³³ In this study, babies whose parents reported that they or a sibling had a squint were followed-up. The vision of these children was tested at 3, 6, 12, 24 and 48 months. All the children who developed an esotropia (a convergent squint) by 4 years of age (17.6% of this group of 34 children) were hypermetropic $> +4.0$ D at 6 months of age. Half of the group with hypermetropia to this degree at 6 months did not develop squints but in these children, in contrast to the former group, the hypermetropia had decreased by 4 years of age. The study also documents the changes in refraction that occurred in this group of children over this period. Most babies were more hypermetropic at 6 months than they were at 3 months and, at this age, the modal refractive index was $+3.0$ – 3.75 D. Hypermetropia reduced in all children except those who developed a squint and, at 4 years of age, the modal refractive index was $+1$ – 1.75 D. The study was small and the statistical significance of the results was not tested.

In a study of 186 1-year-old children,³⁴ bilateral hypermetropia of $+2.00$ D or more and/or anisometropia or astigmatism was significantly associated with a child eventually developing a squint and/or amblyopia. This finding also applied to a group of 215 preschool siblings of children presenting with squint and/or amblyopia, in whom the presence of $+2.00$ D or more of bilateral hypermetropia, or $+1.00$ D or more of anisometropia was significantly associated with the child being found to have a squint and/or amblyopia 2 or more years later.³⁵

These results lend support to the hypothesis that hypermetropia in early infancy which does not reduce with age results in cosmetically obvious squint. However, treatment following

early detection will result in the correction of hypermetropia in many children in whom it would regress naturally.

One small study was found that provides some circumstantial evidence of the natural history of amblyopia in people with squints. This reported the prevalence of amblyopia in 20 immigrants to the USA from south-east Asia (average age, 20 years) with a history of untreated early-onset esotropia, who were seeking an improvement in their cosmetic appearance.³⁶ These were compared with 20 people with the same condition who had received orthoptic and surgical treatment, and for whom the follow-up period varied from 1 year to 8 years. In the treated group, 20% had amblyopia prior to surgery and 80% afterwards. In the untreated group, only 15% had amblyopia. Although the two groups were not at all comparable, the findings in the untreated immigrant population

are important as they suggest that, in this group at least, amblyopia was by no means an inevitable consequence of uncorrected cosmetically obvious squint.

Summary

The few studies which provide information on what would be expected to happen to the vision of children with any of the target conditions at 3–4 years of age in the absence of intervention do not support the need to treat these children, but there are many important gaps in the data. Lack of documentation of the natural history of the three target conditions means that it is impossible to estimate the effect of treatment from studies which have no control group. Any improvement observed during the course of treatment might be occurring in spite of, rather than because of, the treatment.

Chapter 7

Results – disability

A total of 21 studies were found in which the aim was to investigate whether a variety of disabilities were associated with any of the three target conditions. The literature on the relationship between visual defects and reading difficulties is particularly extensive and diverse. The reviews identified on this subject^{37–39} include studies dating back to 1932 conducted by a range of professionals (psychologists, optometrists, ophthalmologists, educationalists, and neurologists). No attempt has been made to appraise all of the studies in these reviews as they predate the rest of our search.

Types of study design

Five different types of study design were identified in the review.

- Studies of representative cohorts of children in which the performance of the small number of children with a visual problem is compared with that of the remainder of the population.
- Studies in which a group of children or adults with a problem is compared with a similar group without the problem. Most of these studies were comparative rather than true case-control studies. This study design has been applied to groups of children with reading difficulties, groups of clumsy children and groups of children with learning difficulties; in these studies the outcomes were visual defects. The same study design was applied to a group of students with amblyopia; in this study the outcome was performance of everyday activities.
- Studies in which the level of vision is correlated with the level of potential disability using both attributes as continuously distributed variables rather than categorical variables, as in the designs above.
- Experimental studies in which the vision of normal subjects is artificially impaired in the manner in which the vision of people with the target conditions might be impaired and performance of everyday activities is measured.
- Studies of the epidemiology of partial sight aiming to identify the proportion of the study population in which amblyopia is a contributory factor.

The first two of these types of study are methodologically sufficient only to establish the first of the epidemiological criteria necessary to conclude that the target conditions cause disability. They should be able to identify a strong and consistent association if one exists. To fulfil these criteria, such studies need to have tested whether potential confounding factors associated with both the problem and the outcome (for example, social class) have been taken into account. The mathematics are complex and time-consuming. Computer software which can ‘adjust’ for confounding factors was only developed in the 1980s and these calculations were not commonly undertaken before then. Two of the later cohort studies^{40,41} and one of the studies comparing matched groups⁴² did make these calculations.

The third type of study (correlating levels of defect with levels of disability) can go some way towards demonstrating that the disability gets worse as the target condition gets worse – a dose–response relationship. The problem with this design of study is that some measures of visual performance, such as visual acuity, are rank ordered rather than continuously distributed variables.

The fourth type of study is valuable for showing that a reduction in visual function could result in impaired performance, that is, that the vision defect precedes the disability. The findings from this type of study, however, need to be substantiated in people who have had the target conditions since childhood in order to demonstrate that the developing brain was not able to develop compensatory mechanisms.

The fifth and last type of study is important in defining the size of this particular and important outcome in later life.

None of these study designs is sufficient to demonstrate the last, and most important, criteria in establishing a causal relationship – that by reversing or treating the visual defect, it is possible to prevent the development of disability.

The studies identified and appraised are presented in *Table 1*, organised by study design and topic.

TABLE 1 Disability studies

Study	Study type	Sample	Visual defect or function and tests	Disability or affected activity and methods of assessment	Results	Comments
Alberman <i>et al</i> ⁴² (UK, 1971)	Cross-sectional; 7-year-old children born in 1 week in 1958, comparing social function and educational performance in those with squints and those without.	478 children examined by school doctor and found to have squint compared with 12,904 children not found to have squint and in whom squint not reported by parents. Children reported as having squint but one not found on medical examination were excluded as were educationally subnormal children and those with cerebral palsy.	Squint.	Clumsiness, speech intelligibility and reading ability assessed by teachers: Southgate group reading test, copying design test, arithmetic test, draw-a-man test. Social maladjustment (Bristol social adjustment guide). Education and vision tests carried out independently. All outcomes analysed categorically. Cut-off points for abnormality not stated to be set prior to analysis.	Children with squints poorer at reading and copying design tests; rated by teachers as being poorer readers, having less intelligible speech, and being more clumsy and fidgety. No significant differences in arithmetic performance. Significantly higher incidence of social maladjustment in children with squints. Authors investigated hypothesis that results were attributable to children with 'minimal cerebral dysfunction' (clumsiness and mild learning difficulty). After excluding clumsy children, the only significant remaining differences were reading and copying design tests.	Squints diagnosed by school doctor. Type not classified – might include latent as well as manifest squints. Other visual defects not reported (e.g. refractive errors and amblyopia). Differences small and those for reading in the analysis without clumsy children only just significant in this large sample. No justification presented for cut-off points chosen to define abnormality.
Bax & Whitmore ⁴⁴ (UK, 1973)	Cohort; representative sample of children to investigate their neuro-developmental status.	All 5-year-olds entering ordinary schools on Isle of Wight in 1 academic year. All children followed-up aged 7 years (reading test and behavioural questionnaire), and referrals to psychologist by age 9 years noted.	Squint.	Neuro-developmental screen performed including tests for hearing, speech, facial symmetry, motor impersistence (tongue protrusion), tongue tremor, fine motor control (hand-patting), drawing shapes, hopping.	The presence of a squint was significantly correlated with poor performance overall in the neuro-developmental tests.	Not clear if tests used had been validated on population samples. They are in standard clinical use. Medical officers assessed both squint and neuro-developmental status, so not blinded. Total number of children examined not stated. Full data available on 602 children.
McGee <i>et al</i> ⁴⁰ (New Zealand, 1987)	Cohort; representative sample of children examining correlation between stereopsis and motor ability.	858 children Motor abilities at 5 years examined, and level of stereopsis at 7 years.	Stereopsis (TNO plates).	Motor ability (Arnheim & Sinclair basic motor ability tests).	Children with poor stereoscopic vision also had poorer motor ability at age 5. Results suggest a significant relationship between stereoscopic vision and motor ability.	Potentially confounding factors considered: poor visual acuity, socio-economic status, physical development, IQ; however, nature of relationship unclear. Assessment blinded.

continued

TABLE 1 contd Disability studies

Study	Study type	Sample	Visual defect or function or tests	Disability or affected activity and methods of assessment	Results	Comments
Stewart-Brown <i>et al</i> ¹ (UK, 1985)	Cross-sectional; children aged 10 years and all born in 1 week in 1970.	9500 of 14,906 children for whom information on visual acuity and educational tests complete. None of severely educationally subnormal and only 60% of mildly educationally subnormal children in sample completed educational tests.	Eligible children classified into 10 different groups on basis of near and distant visual acuity tests without spectacles. Educational performance of these groups compared with that of children with perfect visual acuity.	Educational performance assessed by British Ability Scales (BAS) (intelligence), Edinburgh Reading test and a specially designed maths test; parental assessment of sporting ability. All scores adjusted for sex and social class.	Distant visual defects (presumptive myopia) associated with increased intelligence. Mixed distant and near defects (variety of types of defect including amblyopia) with slightly reduced intelligence. After adjusting for BAS score, near vision defects (presumptive hypermetropia) associated with below average reading scores and severe distant defects (myopia) with above reading scores. Mothers perceived children in 8/10 defect categories to be less able at sport. Performance of children prescribed spectacles no better than those not.	Impossible to relate visual acuity test results to types of visual defect with precision. Differences in mean scores were small. Children not prescribed spectacles cannot be regarded as true controls for those who had. Visual status would not have been known to those conducting educational tests.
Simons & Gassler ³⁹ (USA, 1988)	Systematic search 1930-87; review of studies comparing prevalence of visual anomalies in poor readers and control groups of average or above average readers.	34 studies with quantitative outcome data permitting calculation of effect size. No quality criteria applied in process of study selection.	Visual anomalies including refractive errors, strabismus, reduced stereopsis and reduced visual acuity.	Reading performance.	Hyperopia, exophoria at near, vertical phoria, anisometropia and anisokonia associated with below average reading performance. Myopia, esophoria, and esophoria at far negatively associated with poor reading. Reduced visual acuity, astigmatism, esophoria at near, fusional convergence and divergence, strabismus, near-point of convergence and stereopsis not associated with reading performance.	Lack of critical appraisal is a problem in assessing validity of the findings. In the meta-analysis of results for reduced visual acuity the acuity of each eye was averaged so the prevalence of amblyopia cannot be assessed.
Grisham & Simons ³⁷ (USA, 1986)	Literature review of controlled studies. Search strategy not specified.		Refractive errors.	Reading performance (measures varied between studies).	Hyperopia and anisometropia appear to be related to poor reading; their correction seems to result in improved performance. Reduced distance visual acuity and myopia not associated. Studies on astigmatism too poor to draw conclusions.	Few recent studies. Studies on hyperopia, 1932-69. Most studies on visual acuity pre-1970. Two studies, showing performance of children with refractive errors improved after spectacle correction, not true control studies.
Grosvenor ³⁸ (USA, 1977)	Review: results of studies demonstrating relationship between visual defects and reading.	19 studies known to author.	Visual anomalies, including refractive errors, strabismus, colour vision defects.	Reading performance (measures varied between studies).	Myopia consistently associated with good reading performance. Hypermetropia, astigmatism, lateral phorias, poor fusional vergence, strabismus and colour vision anomalies tend to be associated with below average reading performance.	Study selection biased. Authors call for well-designed, well-controlled studies to be carried out.

continued

TABLE 1 contd *Disability studies*

Study	Study type	Sample	Visual defect or function and tests	Disability or affected activity and methods of assessment	Results	Comments
Ygge <i>et al</i> ^{29,45} (Sweden, 1993)	Comparative: visual defects and function in children with and without dyslexia. Groups matched for age, sex, class in school and IQ.	86 dyslexic children and 86 controls aged 9 years. Groups selected from whole school year tested. 'Dyslexic' group had mean reading level at least 2 years below chronological age.	Strabismus, refractive errors, visual acuity, contrast sensitivity (Vistech's test), accommodation, binocularity (Bagolini test) stereopsis (TNO test), vergence function, ocular dominance (Dunlop test), eye movement.	Reading performance (OS-400 test of decoding ability and 'word-chain test').	No significant difference in visual function between dyslexic and control groups.	Vision testing conducted blind.
Latvala <i>et al</i> ⁴⁶ (Finland, 1993)	Comparative: visual defects in dyslexic and non-dyslexic children matched for age, sex and social class.	50 dyslexic children and 50 matched controls aged 12–13 years. Exclusions incl. IQ < 80, neurological disease.	Visual acuity, refraction, fusion, stereopsis, strabismus, contrast sensitivity, accommodation, convergence.	Reading difficulties grouped: general deficiency; general language; visuo-motor; naming; mixed; normal.	No significant difference found in visual acuity, refraction, amount of phorias and tropias, stereopsis, fusion, accommodation. Convergence nearpoint 8 cm or more – more frequent in dyslexic group. Findings also suggest low accommodative convergence/accommodation ratio in dyslexic children.	Subgroups small. Assessment not blind.
Buzzelli ⁴⁷ (USA, 1991)	Visual function in dyslexic boys compared with normal readers matched for sex and age.	26 male pupils: 13 dyslexics and 13 controls, all with visual acuity 6/6 (normal or corrected). Average age 13 years. Exclusions incl. amblyopia, strabismus and nystagmus.	Stereopsis (random dot stereograms), accommodation and vergence facility tested.	Reading performance: reading age assessed by Woodcock word recognition test.	Dyslexic boys did not have poor stereopsis or poor visual acuity, but took longer to make accurate shifts between successive vergence eye movements. Less efficient dynamic vergence facility may contribute to reading impairment – further investigation warranted.	Small sample. Assessment not blind.
Evans <i>et al</i> ^{48,49} (UK, 1994; 1996)	Visual function in dyslexic compared with non-dyslexic children of similar age, sex, socio-economic status and intelligence. Control group from two primary school populations of similar socio-economic status to dyslexic group.	39 dyslexic and 43 control children aged 7–12 years.	Deficits of visual function including reduced visual acuity with spectacles if usually worn (Bailey-Lovie), reduced contrast sensitivity (Vistech VCTS Near Vision Test), saccadic eye movements, vergence amplitude and stability, amplitude of accommodation.	Reading performance (simulated reading visual search task).	Dyslexic children had worse near and slightly worse distance binocular visual acuity and impaired contrast sensitivity. No difference between groups in refractive errors. Vergence amplitude and stability and amplitude of accommodation all poorer in dyslexic group. Scores on vision tests not correlated with WISC-R coding test except for saccadic eye movements. Authors concluded that visual deficit in dyslexic children unlikely to be cause of their specific reading difficulty.	Not stated whether assessment was blind.

continued

TABLE 1 contd Disability studies

Study	Study type	Sample	Visual defect or function and tests	Disability or affected activity and methods of assessment	Results	Comments
Henderson <i>et al</i> ⁴² (UK, 1994)	Visual defects in clumsy children compared with children who were not clumsy. Groups matched for age, sex and verbal IQ.	Two groups of 16 children aged 7–12 years.	Visuo-spatial difficulties. Discriminative ability assessed by Lord & Hulmes' triangular stimuli and graphic reproduction tasks. Also draw-a-man test.	Clumsiness. Motor competence assessed by Test of Motor Impairment	Clumsy children performed less well on test of visuo-spatial discrimination but no relationship found between magnitudes of perceptual and motor impairment, and no trend towards increase in correlation between visuo-spatial and motor ability seen when focused on less able children.	Small sample. Drawings assessed by experienced raters, blind to group allocation.
Sucher & Stewart ⁵⁰ (USA, 1993)	Visual defects in all children with learning difficulties in one school compared with those in all children in same grade in a normal school.	5th and 6th grade children, 72 with learning difficulties and 64 controls. No information available on IQ.	Vertical fixation disparity (Turville Infinity Balance test), horizontal pursuits, accommodative infacility, refractive error, depth perception (Wirt stereo rings), phoria (cover test). Testing undertaken by two masked examiners.	Children classified learning-disabled based on academic tests indicating that child's grade equivalent more than 2 years behind age group. These children in special class at school.	Three times as many instances of vertical fixation disparities occurred in learning-disabled group. Inaccurate pursuits, accommodative infacility and uncorrected refractive error also showed association with learning difficulties at or above 90% confidence level.	Children with uncorrected refractive errors excluded from vertical fixation disparity, depth perception, pursuits and accommodative facility tests. This removed 21% learning difficulties group and 9.5% control group. 18 false-positives found and removed on retesting (equal number in each group).
Kani ⁵¹ (UK, 1980)	Undergraduates with amblyopia and controls matched for monocular acuities in good eye.	Undergraduates with amblyopia paired with those without amblyopia but with monocular acuity deficits due to uncorrected refractive errors. Sample sizes varied (up to 53) for different tests.	Amblyopia.	Perceptual skills (judgment of spatial relationships, ability to detect depth in stereopsis tests, contrast sensitivity).	Results suggest that everyday life of person with amblyopia unlikely to be affected as a consequence of perceptual losses. Monocular amblyopia seems to have little impact on perception of space and contrast. Reduced stereopsis likely to hamper perception only in very restricted visual situations.	Levels of amblyopia not specified. Small samples. Control group also had monocular acuity deficits; this might explain similar performance of two groups.
Fielder & Moseley ⁵² (UK, 1996)	Review of studies of aspects of binocular function including normal stereopsis, how it may be disrupted and its functional significance.	Conclusions of range of studies presented.			Experimental studies suggest that binocularity is an advantage in certain tasks, e.g. those requiring complex hand-eye coordination. Anecdotal evidence suggests binocular-dependent motor skills improve in children following surgical correction of squint. In study of attrition rate from USAir Force pilot training, absent stereopsis not significant. In survey of dentists, 26% had poor stereopsis; consequences not explored.	Non-systematic review. Critical appraisal of studies not described.

continued

TABLE 1 contd Disability studies

Study	Study type	Sample	Visual defect or function or tests	Disability or affected activity and methods of assessment	Results	Comments
Helveston et al ⁵³ (USA, 1985)	Representative sample of schoolchildren investigating the relationship between visual functions and reading performance.	1910 schoolchildren, grades 1–3.	Visual function incl. visual acuity, muscle balance, preferred eye and hand, colour vision, refraction, convergence, accommodation, stereopsis. Each attribute defined as continuous variable.	Academic performance: measured by reading. Tests included Metropolitan Readiness Test, Cognitive Abilities Test, Iowa Test of Basic Skills, and teacher's assessment of reading level.	No significant relationship found between reading performance and ocular abnormalities.	Large representative sample. Different testers for vision and reading. Not clear whether other educational tests were assessed blind.
Bishop et al ⁵⁴ (UK, 1979)	All children of a given age registered at one GP practice for whom reading ability and IQ were known	147 children aged 8 years.	Convergence, stereopsis (TNO test), visual acuity, squint, reference eye (Dunlop test). Tests conducted by orthoptist. Each attribute defined as continuous variable.	IQ (Wechsler Intelligence Scale for Children); reading (Neale Analysis of Reading Ability). Tests conducted by psychologist.	No significant correlation between visual acuity, squint (all treated or well-controlled), stereopsis (five children with manifest squint excluded), or crossed-dominance (i.e. lack of correspondence between sighting eye and preferred hand) and reading ability. Only two cases of mild convergence insufficiency found; number too small for statistical analysis.	Orthoptist and psychologist conducted independent assessments.
Hall ⁵⁵ (USA, 1991)	All children in small primary school, exploring relationship between 11 visual functions and reading performance.	111 children, grades 1–6. 14 children with manifest squint, significant uncorrected refractive errors or low IQ excluded.	'Normal vision' with most small refractive errors and 'minimal heterophorias' (not defined). Also tested accommodation, stereopsis (Titmus & Randot measures), convergence and vertical fixation disparity.	Reading performance: King-Devick Test (simulates movements demanded by efficient reading) and composite reading score from Stanford Achievement Test.	Multivariate correlation used to analyse data. No relationship found between ocular functions and reading performance.	Assessment was blind.

continued

TABLE 1 contd Disability studies

Study	Study type	Sample	Visual defect or function and tests	Disability or affected activity and methods of assessment	Results	Comments
Jones & Lee ⁵⁶ (UK, 1981)	Experimental study; cross-over design in normal volunteers. Subjects did tests in bright and dim light, with one eye and two eyes with dominant eye first and last. Order of tests randomised.	10 adults, all university department staff or students, with normal or corrected-to-normal vision.	Subjects required to detect black letters on white card and a camouflaged octopus in colour photograph, complete the Farnsworth-Munsell 100-hue test of colour discrimination, thread beads on string with hands only visible on TV monitor, stand with one foot in front of other without swaying, track, moving target thread needle, pour water into narrow-necked beaker and reach for object with hand visible and occluded.	Advantage of binocular vision for exteroception (pick-up of information about the environment) and exteroception (detection of information about position, orientation and movement of body relative to environment) in conditions where influence of stereopsis could be estimated.	Subjects scored higher on all five tasks with two eyes than with one. They also scored higher in bright light than dim and in 5/9 tests there was a significant interaction between intensity of lighting and binocular vision. Binocular stereopsis did not facilitate performance significantly in the four tasks requiring visual control of movements and distance estimations.	Well-conducted tightly controlled experiment. Results are at variance with earlier studies. Authors suggest this is because subjects were free to move their heads in these experiments whereas in earlier experiments their heads were held stationary. They suggest head movement may be an important part of the orientating mechanism involved in use of binocular concordance.
Sonksen & Macrae ⁵⁷ (UK, 1987)	Controlled; performance of visual tasks in children with artificially superimposed refractive errors.	60 normal-sighted children with refractive error artificially superimposed and 10 controls, ages 6–10 years.	Refractive errors.	Recognition of letters and life-sized pictures of objects.	Compared with acuity measures based on Snellen letters, pictures had to be brought closer than expected before children with induced minor refractive errors could recognise them. Highlights importance of correcting refractive errors in young children who learn from this type of material.	Small control group.
Tommila & Tarkkanen ⁵⁸ (Finland, 1981)	Retrospective; people with amblyopia treated for loss of vision in healthy eye or for impending blindness.	35 people with amblyopia (details available for 23) in 1958–78, aged 8–72 years (mean 30.5 years) at time of treatment for loss of vision in healthy eye.	Amblyopia.	Incidence of loss of vision in healthy eye.	Loss of vision in healthy eye caused by trauma in 60.9% and disease in 39.1%. Incidence of loss of vision in healthy eye: 1.75 ± 0.30 per 1000. Same period, overall blindness rate 0.11 per 1000 children, 0.66 per 1000 adults aged 15–64 years. Risk of blindness for those with amblyopia is higher than for general population.	Data for all amblyopic patients who received pleoptic treatment at Helsinki University Eye Hospital (main centre for this treatment in Finland). If birth rate or incidence of amblyopia changed over period, calculations likely to be inaccurate. Reason for cut-off at age 64 years not stated.

Studies comparing the performance of children with a visual problem with that of the remainder of the population

The strength of these studies is that the groups of children with whom the ‘abnormal’ children were compared are truly representative of the general population. An additional advantage is that, in all but one study,⁴⁴ vision and educational tests were carried out independently of each other. The disadvantage of such studies rests in the level of diagnostic accuracy; this is limited because many different people (school medical officers and nurses) carried out the testing and standardisation of testing and diagnosis is difficult.

Four studies of this kind were identified.^{40,41,43,44} The earliest,⁴³ in children aged 7 years, showed an association between squint and educational performance. Children with squints scored less well on tests of reading and copying, and were rated by teachers as fidgety and clumsy, with less intelligible speech. This association appeared to be due to a clustering of problems in some children who were labelled as having ‘minimal cerebral dysfunction’. After excluding clumsy children, significant differences remained in the performance of children with squints in the reading and copying design tests. The results of the second study⁴⁴ in 5-year-old children were consistent with the first. They showed an association between squint and poor performance in neuro-developmental tests. In the third study,⁴⁰ the motor abilities of children with reduced stereoscopic function likely to be due to amblyopia or squint were examined and compared with those of other children. Children with poor stereoscopic vision at 7 years of age had poorer motor ability at 5 years of age. In this study, potentially confounding factors like socio-economic status, physical development and IQ were taken into account. The fourth study⁴¹ was a large UK study using more complex analysis on children aged 10 years. The results of school visual acuity testing were used to group children with less-than-perfect vision according to the likely cause. The performance of these children was compared with those with perfect vision. The most dramatic finding of this study was the superior intelligence test performance of children who were likely to have myopia. This association has also been found in other studies.^{59–61} The differences between the other groups were small. The only group who appeared to be reading at a level that was inconsistent with their intelligence were children who failed near but not far vision tests. These children

were likely to have been hypermetropic and to have had poor accommodative powers. This study also adjusted for confounding factors. Because of the very large size (15,000 children), the statistically significant differences are small in absolute terms.

Studies comparing a group of children or adults with a problem to a similar group without the problem

Reading

The literature suggests that the relationship between reading and vision has intrigued researchers for almost a century. We identified three reviews looking at the prevalence of visual defects in children with reading difficulties compared with children who had no reading difficulties.^{37–39} These covered studies dating back to the 1930s. The most recent of these studies,³⁹ was based on a systematic search for studies with quantitative outcome data and included 34 studies. The authors applied statistical tests of heterogeneity to the data and provided results for analyses with and without the outliers. It does not appear that the studies were critically appraised and that any were excluded on the grounds of methodological inadequacy. The results of this review are consistent with the studies showing that myopia is negatively associated with poor reading. The authors found a positive association with hypermetropia and anisometropia. Some types of squint (exotropia at near and vertical phorias) were positively associated with poor reading, and others (esophorias at both near and far) were negatively associated.

The authors of the second recent review³⁷ did not specify their search strategy. They aimed to identify studies with a control group, which looked at the prevalence of refractive error in children with reading difficulties. They did not specify methodological quality criteria and do not appear to have excluded studies on the grounds of methodological inadequacy. They presented a qualitative synthesis of the results of the studies and concluded that myopia was not associated with reading difficulty but that hypermetropia and anisometropia were. None of these three conditions was defined in terms of the level of refraction, and the ages of the children in the different studies were not specified. It is impossible to tell whether the visual assessment was carried out by an independent reviewer.

The third review³⁸ was another non-systematic review of studies of children with reading diffi-

culties. It included “only studies which adhere to the rudiments of scientific investigation” but did not specify what these were. The findings are consistent with the above reviews with regard to refractive errors. Squints were found to be positively associated with poor reading.

Lack of information on the methodological quality of the studies included in these three reviews makes it impossible to place much weight on the findings. The one finding which would appear to be consistent in all these studies, and is born out in the studies quoted above, is that children with myopia perform better than their peers at reading. In contrast, hypermetropia and anisometropia may be associated with poor reading. The studies on oculomotor function and squint have produced inconsistent findings.

The four primary studies we have included were undertaken more recently than those included in the reviews and two are methodologically superior. These studies have concentrated on the relationship of oculomotor abnormalities to reading difficulty. The largest study^{29,45} was a case-control study of 86 dyslexic children in a cohort of children from one Swedish county, each of whom were matched to a non-dyslexic child of the same age, sex, social class and intelligence. Visual assessments were undertaken by an ophthalmologist and orthoptist blinded to the child's reading ability. This study concluded that dyslexic children did not differ significantly from control children in terms of oculomotor function. A study of similar design and size in Finland,⁴⁶ but in which visual assessment was not blinded, concluded that the only oculomotor difficulty was reduced convergence at near. The two remaining studies^{47,48} had small sample sizes and matching was restricted to age, sex and, in the latter study, intelligence. Visual assessment was not blinded. These studies suggested that dyslexic children had an abnormal vergence response. It is likely to be important that the largest study, which was also the only one in which the possibility of bias in visual assessment was excluded by blinding, found no difference in oculomotor function between children with dyslexia and those without. In three studies by one team,⁶²⁻⁶⁴ reading and spelling performance in children with unstable binocular vision were compared with control group without this defect. Both groups had been drawn from a population of children referred for orthoptic assessment because of suspected reading difficulties. These studies showed only that there were differences between the groups in the types of errors made. They have not been included in the table as they investigated a link between binocular

control and the ways in which children read and spell in a group who all had suspected reading difficulties and were of comparable reading ages. Although potentially valuable as background knowledge for further research, these studies do not tell us the extent of disability associated with any of the target conditions.

Clumsiness

One small study⁴² compared the visual performance of children who were defined as clumsy on a test of motor competence with that of a group of children who were similar in terms of age, sex and IQ. Blind assessment was undertaken. The study found that clumsy children performed less well on tests of visuo-spatial discrimination but there was no dose-response relationship.

Learning difficulty

In another small study,⁵⁰ the visual performance of children from classes classified as learning disabled was compared with a group of children from a conventional class in the same school grade. The assessment was not carried out blind, no academic testing was carried out and no information on IQ was available. Vertical fixation disparity was said to be more common in the learning disabled children.

Amblyopia and perceptual skills

One non-systematic review was found⁵² in which the authors brought together a number of studies that contribute to the debate on the importance of stereopsis in humans. They noted the lack of studies exploring the functional consequences of reduced stereopsis. Evidence relating to the importance of binocular vision seems to be conflicting. The authors concluded that even people who require a high level of visual skills, such as pilots, function well without stereopsis but that it appears to be an advantage in certain tasks, such as those requiring complex hand-eye coordination.

One unpublished study was identified⁵¹ that investigated the impact of amblyopia on contrast sensitivity, the ability to detect depth in stereopsis tests, and the judgment of spatial relationships. The performance of students with amblyopia in exercises designed to test these skills were compared with those of students who had the same level of visual acuity in their better eye and no amblyopia, but who had monocular acuity deficits due to under-corrected or uncorrected refractive errors. This study suggested that monocular amblyopia had little impact on perceptual skills and was unlikely to affect the performance of everyday tasks in “most normal environments where spatial cues

are abundant”. The author suggested that people with amblyopia might find it difficult to construct topographical maps from aerial photographs or to detect counterfeit money but did not investigate further the possible functional consequences of amblyopia in terms of ‘real life’ activities. The severity of amblyopia in these students was not specified and the sample sizes were small. The fact that those in the control group also had reduced vision in one eye, albeit due to refractive errors, may offer some explanation for the similarities in the test performances of the two groups.

Another study with several methodological weaknesses⁶⁵ attempted to assess the stereoscopic ability of office workers. The study used an outcome measure which was not validated and collected this data in a questionnaire. The results suggest that the majority of office workers do not make use of the stereoscopic function they do have. One hour of instruction produced a subjective improvement.

Studies correlating the level of vision with the level of potential disability using both attributes as continuously distributed variables rather than categorical variables

Three studies of representative samples of children, one large⁵³ and two small,^{54,55} looked for a correlation between visual defects and reading ability, and found none. In these studies, children’s performance on various dimensions of visual function was graded, as were the outcomes (such as reading scores). The authors of these studies assessed the level of correlation between vision and outcomes.

Experimental studies on normal subjects with artificially-impaired vision similar to the vision of people with the target conditions

Two studies were found in which the vision of normal subjects was artificially impaired in order to assess the impact on specific tasks. The first⁵⁶ examined the performance of a small convenience sample of university staff in a tightly-controlled experimental situation. This sample performed less well at almost all tasks with one eye closed and there was a significant interaction with dim light. The reduced performance was not entirely accounted for by lack of stereopsis. In another

study,⁵⁷ primary school children were rendered myopic with spectacles. The children performed less well than would have been expected from their visual acuity in discriminating complex pictures.

Studies of epidemiology of partial sight which aim to identify the proportion in which amblyopia is a contributory factor

Finally, the results of one much-quoted study,⁵⁸ in which an attempt was made to calculate the contribution which amblyopia makes to blindness, suggested that the rate of 1.75 per 1000 amblyopes was higher than the risk of blindness in the general population. During the same period in Finland, the overall blindness rate in children was 0.11 per 1000 and in adults aged 15–64 years 0.66 per 1000. These calculations did not take account of changes in the birth rate or in the incidence of amblyopia over time, and were dependent upon the quality of the ascertainment and registration of blindness in Finland. Knowledge of the size of this problem is very important in assessing the potential impact of screening and treatment, and it is surprising that the Finnish study has not been repeated elsewhere. There are reports of improvement in vision in amblyopic eyes after functional loss in the good eye. One study⁶⁶ found that in 47.5% of 59 cases of unilateral amblyopia with the loss of the good eye taken from literature and 28.5% of 144 cases obtained from a questionnaire sent to ophthalmologists, there was a reported improvement in the acuity of the amblyopic eye. The authors took the latter group to constitute a more random selection and noted that 17.4% of that group improved without any treatment.

Summary

Although experimental studies suggest that people with good vision in only one eye might be expected to be disabled in a number of ways, this finding has not been born out in the one study of the performance of people with amblyopia. This may be because most people with amblyopia have some vision in their poor eye or because those with only one good eye since childhood develop compensatory visual mechanisms. This study did not carry out tests on all the areas demonstrated to be affected in the experimental study and the participants were not tested in the dark. Furthermore, detailed studies of the performance of adults with amblyopia are urgently needed. One

strong and consistent relationship emerges from studies of visual defects and reading. Children with myopia perform better in tests of reading than their peers. Whether this is due to superior intelligence or to reading ability alone is not so clear. The relationship, although of academic interest, is of little consequence to the debate about the importance of preschool vision screening, partly because myopia is rare in this age group and partly because there are no clear therapeutic implications. The possibility that hypermetropia

might interfere with learning to read warrants testing in a well-designed RCT of spectacle correction but the evidence is not sufficient to warrant screening at this stage.

The quality of the literature on visual defects and disability is insufficient to offer any advice to parents about what might be expected to happen to children who have amblyopia, non-cosmetically obvious squint or refractive errors if they were left untreated.

Chapter 8

Results – treatment

RCTs and CCTs of treatment

Five prospective RCTs and six prospective CCTs of treatment for the target conditions were identified. None were found which were specifically relevant to the age group for the three target conditions. As our electronic search was complemented by the extensive hand-searching of relevant journals undertaken by the Cochrane Collaboration, it is unlikely that any studies meeting our inclusion criteria were missed.

Study findings

Three RCTs compared the effect of the CAM vision stimulator with conventional orthoptic treatment in children aged 5–15 years.^{67–69} The studies found no significant benefit from CAM treatment, which may explain why it is no longer used in this country.

Only one study was found in which any treatment for any of the target conditions was compared with placebo.⁷⁰ Given the uncertainty about the natural history of these conditions, this is a serious omission. Even the one study that was found had no no-treatment control arm. This study was an RCT, in which all patients received orthoptic treatment, and was an investigation into whether there was any benefit from additional treatment with the drug levodopa/carbidopa (which had been found in single-dose studies to temporarily improve contrast sensitivity and visual acuity). Placebo capsules were given to the control group. Improvements were seen in both groups, although the intervention group showed greater improvement both in visual acuity and contrast sensitivity than the control group. After 1 month, the levodopa/carbidopa group had regressed slightly and the control group had not maintained any improvement.

The final RCT looked at the beneficial effect of prism adaptation on surgery for acquired esotropia.⁷¹ Many of the participants had squints that would have been cosmetically obvious. Success rates were highest in those patients in whom surgery was based on the prism-determined angle. The characteristics of those who did and did not respond to prisms were analysed in a subsequent study.⁷² No controlled studies, with or without randomisation, of treatment for latent squints were found.

One prospective CCT of the efficacy of pre-operative prism correction for acquired esotropia was found,⁷³ in which the findings were similar to the RCT for this intervention.⁷¹ The other five prospective CCTs that were found compared different approaches to amblyopia treatment.^{74–78} The studies that compared treatment with CAM gratings and either blank discs (instead of gratings)⁷⁶ or occlusion⁷⁴ found no significant difference in visual acuity between the groups after treatment. Small improvements in visual acuity were seen but the small number of participants in each study limits the value of the findings. Confidence intervals are wide owing to small sample sizes. Furthermore, in the study comparing treatment with blank discs or gratings, people in both groups received both types of treatment at each session and, although visual acuity was measured before, between and after each treatment, there remains a possibility that the two interventions might have interacted. In the study comparing three different occlusion regimes,⁷⁵ ‘improvement’ in visual acuity and fixation is reported but not defined, and it lacks information on baseline measurements, the method of allocation to treatment groups, the personnel involved, and any explanation of the variety in the length of treatment. The study in which minimal occlusion and full-time occlusion are compared in addition to CAM treatment⁷⁷ shares several of these flaws. It reports a greater improvement in visual acuity in the group prescribed full-time occlusion, and notes that 33% of those with improved acuity after treatment showed some deterioration 3 months later. The study in which occlusion was compared with pleoptics⁷⁸ found that pleoptics offered no advantage over treatment with occlusion.

The validity of the findings

Some of the limitations of the studies have been outlined above and further details are given in *Table 2*. Appraising the quality of these studies is made difficult by the lack of information on one or more aspects of the study design. Information on the means by which people were allocated to each treatment group is essential when assessing study validity. If they were allocated according to the clinician’s judgment, it is likely that the groups were not comparable at baseline. To reduce the potential for investigator bias, it is important for the personnel examining participants for the

TABLE 2 Treatment studies

Study	Study type	Sample	Intervention	Visual or other outcome	Comments
Keith et al. ⁶⁷ (Australia, 1980)	RCT: treatment for amblyopia.	60 people with amblyopia aged 5–15 years	Intervention group: CAM treatment. Control group: same visuo-motor tasks but gratings replaced by a grey background.	Mean improvement in those with initial visual acuity < 6/60 same in both groups (0.48 log units). For those with visual acuity > 6/60, a small, non-significant difference in improvement between groups: gratings group 0.17 log units (confidence interval (CI): 0.12, 0.22); control group 0.14 log units (CI: 0.09, 0.19). No difference in rate of or tendency for improvement to be sustained. No difference according to type of amblyopia or whether previously treated. Some subsequently deteriorated in each group.	Not stated how the participants were found. Blind assessment undertaken.
Leguire et al. ^{70,79} (USA, 1993)	RCT: treatment for amblyopia.	10 people with amblyopia aged 6–14 years.	Intervention group: Levodopa/carbidopa capsules plus part-time occlusion. Control group: placebo capsules plus part-time occlusion. Treatment period: 3 weeks; follow-up 4 weeks after completion of treatment.	Levodopa/carbidopa group improved visual acuity by 2.7 lines and contrast sensitivity by 72% in amblyopic eye. Placebo group improved visual acuity by 1.6 lines, little change in contrast sensitivity. Tolerance and occlusion compliance similar in both groups, but capsule ingestion significantly lower in levodopa/carbidopa group. 1 month after treatment, levodopa/carbidopa group maintained significant improvement of 1.2 lines; placebo group did not maintain improvement.	Children had previously participated in 8-hour long single dose study of effects of levodopa/carbidopa. No significant side-effects found. Blind assessment undertaken.
Nyman et al. ⁶⁸ (Sweden, 1983)	RCT: treatment for amblyopia.	50 people with amblyopia aged 4–6.5 years.	Intervention: CAM treatment (25 cases). Control: occlusion therapy – patching over eye or occlusion with Emschleich filter on spectacle lens over best eye (25 cases).	Visual acuity improved by 2 Snellen lines or more in 80% of both groups. CAM group: mean improvement 3.11 lines (CI: 2.7, 3.5). Occlusion group: mean 3.3 lines (CI: 2.8, 3.8). No significant differences. Groups comparable before treatment for visual acuity, fixation, refractive errors and strabismus.	Lack of information on, personnel, compliance and duration of treatment. Those testing visual acuity after treatment not blinded to allocation.
Prism Adaptation Study Group ⁷¹ (USA, 1990)	RCT: effectiveness of prism adaptation in improving outcomes of surgery for acquired esotropia.	333 people with esotropic deviations of 12–40 Δ, aged 3 years and over. 322 included in analysis.	Randomisation at 2 levels. 199 underwent prism adaptation and 134 did not. Those responding to prisms (131) were randomised to undergo conventional surgery (67) or surgery based on prism-adapted angle of deviation (64).	Success rates (0–8 Δ, 6 months after surgery) highest in prism adaptation responders who had prism angle based surgery (89%); lowest in the non-prism adaptation group (72%). Non-responders had a success rate of 73%. Significant beneficial effect of prism adaptation in people with acquired esotropia: success rates 83% versus 72%.	Post-surgical deviations were measured by a masked examiner.
Tytla & Labow Daily ⁶⁹ (Canada, 1981)	RCT: treatment for amblyopia.	15 people with amblyopia aged 5–12 years.	Intervention: CAM therapy (9 cases). Control: CAM with grey discs instead of gratings (6 cases). One 7-minute session weekly for 4 weeks. Visual acuity and contrast sensitivity measured before, during and after CAM sessions. Complete optical correction worn during tests and treatment.	No difference between groups. Distance linear visual acuity: 6 unchanged; 4 (incl. 3 controls) improved 2 lines; 3 improved 1 line or more; 2 regressed 1 line. Mean, 2 lines improvement in single letter acuity. At 1 month follow-up, both positive and negative changes seen. Some improvement in contrast sensitivity in 6 (incl. 4 controls).	Small study and groups uneven in size. Lack of information on how sample selected. During testing, children urged to read beyond what appeared to be their limit. Different personnel used to administer treatment and assess vision but not clear whether assessment was blind.

continued

TABLE 2 cont'd Treatment studies

Study	Study type	Sample	Intervention	Visual or other outcome	Comments
Lennerstrand & Samuelsson ⁷⁴ (Sweden, 1983)	Partly randomised, controlled; treatment for amblyopia.	38 previously untreated children with amblyopia aged 4 years. All those meeting amblyopia criteria and accepted for treatment for 6 months entered study.	Intervention group: CAM treatment Control group: full-time occlusion.	Measured visual acuity (adjusted for time-dependent changes in best eye), stereopsis and fixation. Visual acuity improved with both CAM and occlusion ($p < 0.01$). Mean visual acuity (95% CI) in amblyopic eye at start and finish of treatment and at 3 month follow-up (decimal values given; 0.5 is approx. 6/12 Snellen, 0.66 6/9): CAM (anisometropic amblyopia): 0.46 (0.54, 0.38), 0.78 (0.93, 0.63), 0.76 (0.86, 0.66). Occlusion: 0.44 (0.53, 0.33), 0.61 (0.70, 0.51), 0.71 (0.83, 0.58). CAM (strabismic amblyopia): 0.29 (0.41, 0.17), 0.48 (0.70, 0.27), 0.56 (0.70, 0.42). No significant difference in outcome between treatments, although grating stimulation was slightly better than occlusion in improving visual acuity of those with anisometropic amblyopia with central fixation ($p = 0.05$). (Groups initially comparable for visual acuity and binocular function).	Grouped according to amblyopia type and some randomly assigned to treatment groups, but distance from hospital precluded allocation to CAM in some cases. Interventions not standardised, e.g. some had occlusion after CAM and CAM group had more hospital visits. Lack of information on compliance, attrition and whether assessment was blind. Wide confidence intervals.
Malik et al ⁷⁵ (India, 1970)	Prospective, controlled; treatment for amblyopia.	70 people with amblyopia with eccentric fixation, aged 3–6, 7–9, 10–12, & 12+ years.	Group 1: full-time occlusion of unaffected eye (18 cases). Group 2: full-time occlusion of the affected eye (24 cases). Group 3: red-filter occlusion of the affected eye (28 cases).	Assessed visual acuity and fixation. Group 1: 83.3% (15) improved. Initial visual acuity and fixation more important than age. Group 2: 33.3% (8) improved. Results poor in all subgroups. Group 3: 57.1% (16) improved. Better results in children under 12 years. Response to all treatments better in those with better initial visual acuity and eccentric fixation close to the fovea.	'Improvement' is not defined. Lack of information on baseline measurements, method of allocation, personnel used. Treatment period ranged from 6–30 weeks, no details given.
Ohtsuki et al ⁷³ (Japan, 1993)	Prospective, controlled; preoperative prism correction for acquired esotropia.	77 people with esodeviations of 18–50 Δ, aged 5 years and over (one patient was under 4 years, 53% aged 5–7 and 44% aged 8+ years).	All wore Fresnel prisms for 5–7 days. 63 responders randomly assigned to have surgery for original angle (PCR/OS group, n = 31) or prism-adapted angle (PCR/PS group, n = 32). 14 non-responders had surgery for angle before prism correction (PCNR group). Follow-up at 1 week, 3 and 6 months, and 1 year after surgery, with no re-operation or prism correction.	Success rates with deviations of 0–10 Δ 1 year after surgery: PCR/PS group, 84%; PCR/OS group, 78%; PCR/NS group, 50%. No significant difference in success rates between PCR/PS and PCR/OS groups ($p = 0.41$), but both had significantly higher success rate than PCNR group ($p < 0.05$).	93% of non-responders were aged 5–7 years, had strabismus of earlier onset, and larger initial angles than other groups.

continued

TABLE 2 contd Treatment studies

Study	Study type	Sample	Intervention	Visual or other outcome	Comments
Sullivan & Fallowfield ⁷⁶ (UK, 1980)	Prospective, controlled: treatment for amblyopia.	20 children with amblyopia aged 3–8 years.	Two groups of 10 each received two treatments at each visit, one with normal CAM gratings and one CAM with blank discs instead of gratings.	Mean improvement at 1 Snellen line. No significant difference in improvement between control and CAM sessions.	Sample from pre-selected group (referred from one hospital to another for CAM); no details on selection criteria. Groups balanced for type of amblyopia and initial acuity. No pure control group – the two types of session could have interacted. Half the data was discarded (only used effects of first session in each pair), weakening statistical tests. Blind assessment of visual acuity before, between and after sessions.
Terrell Doba ⁷⁷ (Australia, 1981)	Prospective, controlled: treatment for amblyopia.	80 children with amblyopia (20 anisometropic and 60 strabismic) aged 4–16 years (mean 7.8 years). 49 had previously been occluded.	Group 1: CAM therapy + minimal occlusion (69 cases). Group 2: CAM + full-time occlusion (11 cases).	Group 1: 47% achieved visual acuity 6/12 or better; mean improvement 0.3–1.0 lines. Group 2: 91% achieved visual acuity 6/12 or better; mean improvement 0.4–2.3 lines. Of those improved and followed-up at 3 months (number not stated), visual acuity in 33% had deteriorated.	Number in Group 1 given as 60 and 69 in different places. Groups uneven – 11 in one and 60 (or 69) in other. Children with anisometropia not previously occluded had been prescribed spectacles 2–4 weeks before treatment. Lack of information on allocation to groups, personnel conducting testing and treatment, compliance and follow-up.
Veronneau-Troutman et al ⁷⁸ (USA, 1974)	Prospective, controlled: treatment for amblyopia.	90 children with amblyopia aged 5+ years, average age 7.4 years.	Group 1: 'direct occlusion', constant or intermittent. Group 2: occlusion of amblyopic eye, then pleoptics followed by direct occlusion.	Direct occlusion: initial visual acuity < 20/100, 45%; 20/60–20/100, 55%; final visual acuity 20/100, 9%; 20/60–20/100, 32%; 20/40–20/50, 31%; 20/30 or better, 28%. Pleoptics then direct occlusion: initial visual acuity < 20/100, 68%; 20/60–20/100, 32%; final visual acuity after pleoptics (and both treatments) < 20/100, 27% (16%); 20/60–20/100, 57% (38%); 20/40–20/50, 11% (35%); 20/30 or better, 5% (11%). Significantly better: results after occlusion alone than pleoptics alone ($p > 0.001$) but not after occlusion applied to the pleoptics group ($p > 0.30$). Groups comparable at baseline in visual acuity and refractive state.	Blind assessment not carried out.

outcome measure of interest, such as visual acuity, to remain 'blind' to their status in terms of exposure to a particular treatment. This was done in some of the studies but in one of the RCTs it was not;⁶⁸ in other studies, blind assessment was not mentioned and presumably, therefore, was not part of the study design. Knowledge of the comparability of control and treatment groups at the start of the study is essential when interpreting treatment outcomes, but this information was missing from several studies. A lack of information about compliance with treatment also weakened the findings of these studies. Most importantly, in none of them was there a comparison of a treated group with an untreated group so they cannot provide an answer to the question, "Does treatment for the target conditions work?"

Other studies of treatment

Because of the paucity of evidence from prospective RCTs and CCTs we reconsidered including retrospective controlled trials in the review. Such studies suffer from all the problems outlined above as well as loss of data through missing case notes and inadequate recording of outcomes. It was decided that such studies are methodologically weak and would be unable to answer the research questions. However, some retrospective studies provided data on two important areas of treatment – compliance and outcomes at different ages. These studies have been included in the text but their methodological limitations need to be remembered when evaluating the 'evidence' they provide.

Outcomes of treatment at different ages

One UK study was found in which the outcome of treatment for amblyopia was compared in children of different ages.⁸⁰ This was a retrospective uncontrolled study of a large unselected population of children at seven orthoptic centres in the UK. The paper did not discuss the sources of referral for these children. Final visual acuity was not significantly different in children treated at ages 3–5 years compared with those who started treatment at 5–8 years. The initial visual acuity was a more important determinant of outcome than the child's age.

Non-attendance and compliance

A study of a preschool vision screening programme in an inner city area in Scotland looked at factors affecting the attendance rate for treatment of amblyopia detected on screening.²⁴ Stepwise

regression analysis showed that socio-economic status was the only variable to significantly affect the attendance rate, which declined as socio-economic status fell. The probability of non-attendance obtained from the model was 20.5% for classes one and two, and 37.1% for class three. In a prospective controlled study comparing visual outcomes in children from three different screening programmes in Newcastle-upon-Tyne and Northumberland,³¹ 26.8% of 97 children, across all three groups, identified as having defective vision defaulted from further investigation or treatment.

Two studies were found which looked at attendance at follow-up appointments and parental reports of compliance with patching in different age groups. A retrospective review of the records of 496 children with amblyopia in one study revealed that 11.7% of those aged 3–6 years were non-compliant compared with 14.5% of those aged 6–9 years.⁸¹ The other, a prospective study of 350 children with amblyopia, recorded non-compliance in 28% of children aged 2–5½ years, 36% in those aged 5½–8 years and 53% in those aged 8–11 years.⁸² The recent development of an occlusion dose monitor has made the objective monitoring of occlusion possible.⁸³

No studies were identified in which an attempt was made to assess any negative impact of orthoptic treatment on the child or the family. Preschool children are thought to be more compliant but enforcing patching on a reluctant child would be likely to have a negative impact on family life; some children are admitted to hospital to enforce patching. How common such difficulties are is not documented in the literature but the fact that non-compliance is a problem implies that patching is not easy.

Visual improvement following treatment for amblyopia

In seven of the screening programme studies discussed in the next chapter, attempts were made to measure the improvement in visual acuity that occurred in children who were screened positive, referred and treated.^{24,25,31,84–87} These results are equivalent methodologically to those that would be gained from uncontrolled observational studies of treatment. They substantiate clinical beliefs that children's vision does improve during treatment but, without a comparison group of untreated children, they cannot show that treatment works. They provide an indication of the extent of improvement that can be expected from an unselected sample of children while undergoing treatment. In these studies, visual acuity improved

by two or more lines in 50–85% of children and 60–80% of children achieved 6/6 vision.

Few studies examined the extent to which these observed improvements in visual acuity following treatment are maintained. In three studies of CAM therapy,^{67,69,77} it was reported that some of those who had initially responded to treatment subsequently deteriorated and, in the RCT of levodopa/carbidopa treatment,⁷⁰ neither group maintained their initial improvement in visual acuity, although deterioration was greater in the control group. However, in these studies only short-term outcomes were evaluated, giving results of follow-up between 1 and 3 months after completion of treatment.

Treatment of refractive errors

The immediate effect of spectacle correction of refractive errors on visual acuity is sufficiently well-established for an RCT of treatment to be superfluous. Questions remain, however, about the significance of reduced visual acuity in pre-school children. If these children do not suffer problems from isolated refractive errors before they get to school age, they could be identified and treated at school entry. Orthoptists treat children with minor refractive error to prevent the development of squint or amblyopia. The search did not reveal any studies of the impact of this intervention.

Summary

The search for evidence that treatment for any of the three target conditions is effective has been disappointing. Clinical beliefs that children with amblyopia do improve during treatment have been substantiated but, without sound evidence on the natural history of these conditions, this evidence falls very far short of showing that treatment works. Whether the documented improvement in visual acuity is accompanied by a reduction in disability is a question that does not seem to have been posed. All the studies of amblyopia treatment we have examined have taken as given that an improvement of visual acuity in one eye is important to children. Studies on compliance with treatment suggest that orthoptic treatment is not without problems for families but the potential negative effects of treatment have not been explored. The search did not pick up studies that followed the progress of children with non-cosmetically obvious squint through treatment. As the natural history of these conditions has not been documented, such evidence would not amount to proof that these treatments work. The case for identifying and treating refractive errors in this age group could only be made in studies which demonstrated that children with these problems were in some way disabled and that the disability could be corrected with spectacles. Such studies have not, apparently, been undertaken.

Chapter 9

Results – screening programmes

RCTs of screening

No RCTs of screening programmes for children aged 3–4 years were identified. An RCT that compared the effectiveness of two preschool vision screening programmes offered to children under 37 months of age in Avon has recently been completed.⁸⁸ In this trial, 2029 children were randomised into the intervention group and were offered vision screening at the ages of 4, 8, 12, 18, 25, and 31 months. A total of 1461 children were randomised into the control group and offered the current screening programme, which consisted of a check for squint at the age of 7 months by a health visitor and a secondary screen at an orthoptic clinic for those whom the health visitor or GP referred. The children in both groups received a ‘gold standard’ visual examination at 37 months of age; the results of these examinations were used to compare the effectiveness of the two programmes. The main outcomes of the trial were the sensitivities and specificities of the programmes, and also the sensitivities of the individual tests used at different ages. The data also provides some information on the natural history of refractive error up to the age of 3 years or until the development of squint and/or amblyopia, if sooner. Because the study is nested within an observational study of a population birth cohort, data is available on other aspects of the children’s development and the investigators will be looking at whether any disabilities are associated with squint, amblyopia or refractive errors.⁸⁹ Other questions relating to the screening of 3½-year-olds will not be answered by this study, such as when and how to treat the target conditions.

CCTs of screening

One highly relevant prospective CCT was found,³¹ in which visual outcomes at the age of 7 years, in children who were screened at age 3 years by orthoptists, GPs or health visitors, were compared. Following the introduction of a pilot community-based orthoptic screening programme in Newcastle-upon-Tyne in 1987, a cohort of 1026 3-year-old children who were offered screening by this method was compared with children from two local districts, matched for demographic factors, who were screened through existing programmes. In one

of these areas, screening by health visitors was offered to 1380 children and, in the other, 1151 children were invited for screening by health visitors, GPs or CMOs at clinics. The initial report on the programmes⁹⁰ suggested that orthoptic screening led to children receiving earlier treatment for ‘straight-eyed’ visual acuity deficits and squints. The uptake, referral and false-positive rates, together with the positive predictive value, for these programmes are presented later in *Tables 4 and 5*.

The cohorts of children examined at age 7 years were slightly larger, owing to the extension of the initial study.⁹¹ At this stage, children from all three cohorts with suspected visual defects were identified from six sources, including records from school entry visual screening (known to have more than 95% coverage). Children without a record of examination at the hospital were examined at school by an orthoptist. This study³¹ demonstrated a significant difference ($p < 0.0001$) in the age at which children presented with straight-eyed amblyopia in the orthoptic screening cohort (3.4 years) compared with the health visitor (5.6 years) or GP (4.5 years) cohorts. This was also true of refractive errors (age 3.8 years in the orthoptic screening cohort compared with age 5.4 and 5.1 years in the health visitor and GP cohorts, respectively) but there was no significant difference in the presentation of squint (ages 3.8, 3.9, and 4.1 years, respectively). Many more children with amblyopia were identified in the orthoptic screening cohort (*Table 3a*). However, the prevalence of amblyopia at age 7 years was very similar for all three cohorts (*Table 3b*). This study was adequately powered to detect a 40% difference in prevalence of the conditions at age 7 years but may have missed a smaller difference. The implication of the finding of this study is that orthoptic screening successfully identifies children with amblyopia, and that this improves following treatment but possibly to no greater extent than it would have done spontaneously without treatment. The study did not look at the outcome of screening in terms of the prevalence of non-cosmetically obvious squints not associated with amblyopia.

The study design, although very much more appropriate to the research questions than any

TABLE 3a Prospective controlled trial of preschool vision screening – total number (%* and confidence interval*) of children with the target conditions identified in each area by final diagnosis

Study	Type	Cohort (n)	Squint	Straight-eyed amblyopia	Refractive errors
Bray et al ¹⁴ (UK, 1996)	Prospective, controlled trial comparing visual outcomes at 7 years in three cohorts of children screened at age 3 years by orthoptists, health visitors or GPs	Orthoptic screening (1582)	19 (1.2%) (0.7, 1.7)	43 (2.7%) (1.9, 3.5)	14 (0.9%) (0.4, 1.3)
		Health visitor screening (2081)	16 (0.8%) (0.4, 1.1)	12 (0.6%) (0.3, 0.9)	17 (0.8%) (0.4, 1.2)
		GP screening (1701)	22 (1.3%) (0.8, 1.8)	24 (1.4%) (0.9, 2.0)	16 (0.9%) (0.5, 1.4)
* Secondary calculation					

TABLE 3b Prospective controlled trial of preschool vision screening – total number of children aged 7 years with amblyopia in each cohort and prevalence of amblyopia

Study	Cohort	Number of 7-year-olds with amblyopia	Prevalence per 1000 of population (confidence interval)
Bray et al ¹⁴ (UK, 1996)	Orthoptic screening	18	11 (7, 18)
	Health visitor screening	21	10 (6, 15)
	GP screening	21	12 (8, 12)

of the other studies found, has a number of deficiencies. Firstly, the children did not undergo a 'gold standard' examination at age 7 years from which outcomes could be compared. Final outcomes were determined from a number of sources and by the results of tests conducted by different types of practitioner. Secondly, the children in the three cohorts came from areas that were matched for demographic factors and numbers of children but, as with all non-randomised trials, there remains a possibility that they differed in some other way. Family history of squint is an important risk factor for squint and consequently amblyopia in children.³³ A higher prevalence of squint in parents in the orthoptic screening cohort could account for these findings. The prevalence of squint was lower in the health visitor screening cohort but not to a statistically significant degree. Thirdly, children known to have visual abnormalities prior to 30 months of age were excluded from the analysis in all three cohorts. Fewer of these

exclusions in the orthoptic screening cohort could account for the findings. The study does not provide data on the comparability of the cohorts in these respects so it is impossible to be sure that such bias does not exist. Taken together these methodological problems limit the certainty that can be placed on the findings of the study.

Other studies of screening

One other study⁹² was found that compared the prevalence of visual defects in two groups of school entrants, only one of which had undergone preschool vision screening. There was a significant difference in the number of children with 'visual impairment' in the two groups: 10% in the screened and 15% in the unscreened group ($p < 0.01$). When divided into those with mild and moderate/severe visual impairment (visual acuity 20/40, equivalent to 6/12 Snellen, and 20/50+, respectively), the difference reached statistical significance only for those with moderate/severe impairment ($p < 0.01$).

A number of other studies of screening programmes were found which provided information on uptake rates, referral rates, positive predictive value and programme yield. The commonest type of screening researched in these studies is the primary orthoptic programme. Some of these studies^{25,26,93} compared this information from more than one type of programme (primary orthoptic screening and another type) but none of the latter type of study were set up as controlled experiments nor were the data collected prospectively. These studies allow a slightly more accurate comparison to be made between the outcome of different programmes than studies providing data on a

single type of programme because the data would have been collected in the same way and the same diagnostic tests are likely to have been used. However, the extent to which data from these studies compare with those collected in uncontrolled studies of the different programmes is also important. The results of these studies are presented in *Tables 4* and *5* according to programme type, with studies which compared more than one programme identified by bold type.

The largest group of studies provided information on uptake rates and referral rates (*Tables 4* and *5*). Of these, 15 provided data on primary orthoptic screening programmes, two on CMO screening, one on both health visitor and GP screening and one, from Sweden, on combined paediatrician and nurse screening. In 13 studies, referral rates were published or data were provided from which they could be derived by secondary calculation in primary orthoptic screening and, in four studies, referral rates on health visitor or doctor screening were provided. These studies are all observational studies or audits, with the advantage over studies carried out as part of a research programme of representing current practice; however, there may be bias in terms of which centres record and write-up their results.

Ten studies of primary orthoptic screening and four studies of other types of screening programme provided data on detection rates from which positive predictive values and programme yield could be calculated. Two studies produced values for false-negative cases (*Table 5*).

In eight studies, information is presented on visual outcomes following treatment of children identified in screening programmes, as discussed in chapter 8.

Uptake rates

Studies reporting uptake rates have been based on programmes using a variety of methods of invitation to parents of children in a range of socio-economic circumstances (*Tables 4a* and *4b*). In the majority of these programmes, children were invited to attend screening locally and some had a choice of sites.

Overall rates for primary orthoptic screening ranged from 43.9% to 80.3%, with a mean of 64.8%. This is excluding one study,¹⁰⁰ in which an uptake rate of 86% was reported for the first 3 months of a new screening programme in Ayrshire. This was exceptional and may reflect

the enthusiasm with which the programme was launched, with coverage in the local media as well as information being sent directly to parents of eligible children.

Studies which reported that a second invitation was sent to parents of children who failed to attend following the first invitation had a higher mean rate (77%) than studies which reported one invitation only (50.5%). In one area,⁸⁷ a second invitation resulted in the attendance of 40% of those who had previously failed to attend.

The rate of uptake following one invitation was higher in more affluent areas^{86,93} than in less affluent areas;^{91,95} it was also higher than the rate of uptake following two invitations in a less affluent area.⁹⁰ The rate of uptake in studies where the number of invitations was not specified was intermediate between those with two invitations and those with one.

Vision screening by health visitors, GPs and CMOs is undertaken as part of a routine surveillance contact in which parents are offered more than vision screening alone. These programmes would be expected to have a higher uptake rate. The range shown in *Table 4b* is from 53.5% to 84%, with a mean of 76.2%. The Swedish study should be considered separately.¹⁰² It evaluates a preschool vision screening programme provided in the context of the 4-year-old 'health control' in Sweden, for which the uptake rate was 95.1%.

A study comparing primary orthoptic screening with screening by health visitors in an area of Kent also requires separate consideration.²⁶ The 21 health visitors received training from orthoptists and were invited to screen children in their areas. Their cooperation was variable; eight screened no children at all, three screened 66% or more, and the remainder less than 66% of their caseload of eligible children. There is no information on the reasons why health visitors who did screen, screened some children and not others.

Some of a target population are not invited to attend screening because the children are not located. Few studies addressed this problem. Early screening programmes suffered from poor record-keeping and locating children could present a serious challenge.¹⁰⁴ In a study dating from the 1970s,¹⁰⁰ 39% of children were found to be untraceable if the information provided by the department of community health and child care was used alone. Enlisting the help of health visitors proved to be an effective means of reducing this

TABLE 4a Uptake rates – primary orthoptic population screening

Study	Type	Method of invitation and other relevant information	% (n) screened (95% CI)
<i>One invitation sent</i>			
Birmingham ⁹⁴ (UK, 1995–96)	Unpublished data for primary orthoptic screening programme.	Health visitors gave parents information leaflet about preschool vision screening with 'Bobby Bunny' motif. Same motif used on invitations.	43.9 (3164) (42.8, 45.1)
Dudley & Sandwell ⁹⁵ (UK, 1993–94)	Unpublished data for primary orthoptic screening programme.	One invitation sent.	51.0 (3967) (49.6, 51.8)
Ingram <i>et al</i> ⁸⁶ (UK, 1986)	Retrospective study of primary orthoptic/ ophthalmic screening programme.	One invitation sent.	66.4* (1507) (64.4, 68.3)
Wormald ⁹³ (UK, 1991)	Retrospective study of primary orthoptic screening programme.	One invitation sent.	67.2** (402) (63.5, 71.0)
Mean			50.5%
<i>Two invitations sent</i>			
Jarvis <i>et al</i> ⁹⁰ (UK, 1990)	Prospective study comparing pilot orthoptic and established health visitor and health visitor/GP/ CMO preschool vision screening programmes in three matched areas.	Two invitations sent.	59.6 (611) (56.5, 62.6)
Newman <i>et al</i> ⁸⁷ (UK, 1996)	Retrospective study of referrals from primary orthoptic screening programme.	Approximately 40% of those who failed to attend attended after second invitation.	79.3 (6794) (78.5, 80.2)
Gallaher ⁹⁶ (UK, 1994–95)	Unpublished audit of primary orthoptic screening programme.	Second invitation sent if child failed to attend.	76.3 (2823) (75.0, 77.7)
<i>Number of invitations sent not stated</i>			
Beardsell ⁸⁴ (UK, 1989)	Retrospective study of primary orthoptic screening programme.	Number of invitations sent not stated.	75.4 (2475) (73.9, 76.8)
Bolger <i>et al</i> ²⁵ (UK, 1991)	Retrospective cohort study using case notes of referrals, comparing primary orthoptic and CMO preschool vision screening programmes.	Number of invitations sent not stated.	72.8 (5176) (71.8, 73.9)
Edwards ²⁶ (UK, 1989)	Retrospective study comparing primary orthoptic and health visitor screening programmes.	Where possible, health visitors contacted parents to explain the nature and purpose of examination. Number of invitations sent not stated.	73.1 (3239) (72.0, 74.4)
* Secondary calculation. ** Estimated rate calculated from random sample.			
			<i>continued</i>

TABLE 4a contd Uptake rates – primary orthoptic population screening

Study	Type	Method of invitation and other relevant information	% (n) screened (95% CI)
<i>contd</i>		<i>Number of invitations sent not stated</i>	
Milne ⁹⁷ (UK, 1994)	Retrospective study of referrals from community orthoptic service; figure for primary screening given here.	Number of invitations sent not stated.	60.8 (1858) (59.0, 62.5)
Seng & Curson ⁹⁸ (UK, 1991)	Unpublished audit of primary orthoptic screening programme.	Number of invitations sent not stated.	56.8 (2179) (55.2, 58.4)
Swindon ⁹⁹ (UK, 1991)	Unpublished data for primary orthoptic screening programme.	Health visitors gave invitations for preschool vision screening at 3.5 year check. Number of invitations sent not stated.	80.3 (1317) (78.3, 82.2)
Williamson <i>et al</i> ²⁴ (UK, 1995)	Retrospective study of primary orthoptic vision screening programme.	Estimated 87–90% eligible population sent invitations. Number of invitations sent not stated.	57.0 (8142) (56.2, 57.8)
Mean			64.8%
<i>Other</i>			
Cameron & Cameron ¹⁰⁰ (UK, 1978)	Audit of first 3 months of primary orthoptic screening programme.	First 3 months of scheme, launched with publicity in local media. Parents informed about scheme and purpose of tests. In feasibility study, 23.6%* did not attend. Authors cited difficulties with obtaining addresses and 9.2% were not traced. This was improved in new programme by health visitors helping to identify eligible children.	86.0 (442) (83.0, 89.0)
* Secondary calculation. ** Estimated rate calculated from random sample.			

figure. It should now be possible to locate most children through GPs. In a recent study,²⁴ it was estimated that 87–90% of the target population were sent appointments.

Referral rates

Referral rates (*Tables 5a* and *5b*) determine the level of diagnostic resources required to support a screening programme and are predictive of an important component of the total costs. It should be possible to vary the rate by changing the referral criteria from the screening test. Referring all children with 6/9 vision or worse should result in a higher referral rate than referring only those with 6/12 or worse. Referrals should also depend on the type of test used. Some studies did not report which screening tests or referral criteria were used but most of those that did used a battery of tests (in orthoptic screening programmes) – the cover test, 20 D base-out prism, monocular visual acuity using Sheridan–Gardiner single optotypes.

Some programmes included a test of stereopsis but there was no consistency in the type of stereo test. With the exception of the Swedish programme,¹⁰² all those using a named visual acuity test used Sheridan–Gardiner optotypes, sometimes with the Kay picture test as an alternative if children were unable to cope with the Sheridan–Gardiner test.

In some programmes, a significant number of children were recalled for a second test before a decision was made to refer or not. The non-attendance rate for recall appointments was given in one study only and was 30.6%.⁹⁰ The same study noted that the referral rate from the recalled group was increased threefold. The re-examination of children should reduce the number of inappropriate referrals to eye hospitals and clinics but increase the workload in the community. In the two studies which gave figures, the proportions re-screened and found to be normal were 14.8% and 6.4%.^{26,98} Three studies gave rates of non-attendance at referral appointments of 4%, 4.3% and 5%.^{24,87,96} In an unpublished audit,¹⁰⁵

TABLE 4b Uptake rates – health visitor/GP/CMO population screening

Study	Type	Method of invitation and other relevant information	% (n) screened (95% CI)
Allen & Bose ¹⁰¹ (UK, 1992)	Audit of a CMO preschool vision screening programme using random sample of school health records.	No details of method of invitation. Estimated rate calculated from random sample.	53.5 (284) (49.2, 57.7)
Bolger et al²⁵ (UK, 1991)	Retrospective cohort study using case notes of referrals, comparing primary orthoptic and CMO preschool vision screening programmes.	Vision checked as part of developmental screening. No details.	85.0 (2530) (83.7, 86.3)
Jarvis et al ⁹⁰ (UK, 1990) <i>Health visitor programme data</i>	Prospective study comparing pilot orthoptic and established health visitor and health visitor/GP/CMO preschool vision screening programmes in three matched areas.	Home visit. Estimated rate as proportion of records seen (1259/1380 records seen).	59.0 (743) (56.3, 61.7)
Jarvis et al ⁹⁰ (as above) <i>Health visitor/GP/CMO programme data</i>	As above.	Local arrangement; no details of method of invitation. Estimated rate as proportion of records seen (967/1151 records seen).	84.0 (812) (81.7, 86.3)
Mean			76.2%
Kohler & Stigmar ¹⁰² (Sweden, 1973)	Cohort study of a primary preschool vision screening programme with testing by nurses and a paediatrician.	Parents sent invitation and questionnaire on family history of eye disorders, history of birth and neonatal period, and symptoms of eye disorders.	95.1 (2447) (94.3, 95.9)

which looked at whether children who failed visual screening at age 5 years had undergone orthoptic screening at age 3 years, it was reported that, of the 21 children who had previously been screened, nine had been unable to complete the vision test. Of these, six had refused to cooperate at the initial appointment and three of the six failed to attend the follow-up appointment. Of the remaining three, one was not followed-up and two again failed to complete the tests. They were not sent for again, as they were soon to start school.

Rates of referral from primary orthoptic screening programmes (Table 5a) ranged from 4.1% to 10.6% of the screened population. The programme with a referral rate of 10.6% included 'family history' amongst its referral criteria.²⁴ The lack of detail in some of the studies makes it difficult to comment on the impact of different types of test and referral criteria on referral rates; however, the relationship does not seem to be straightforward.

Referral rates from health visitor/GP/CMO screening programmes (Table 5b) were very low in the Newcastle-upon-Tyne study⁹⁰ but rates from the other two studies are comparable with those for primary orthoptic screening. One study from Sweden is exceptional, with a referral rate of 15.2%,¹⁰² but the referral criteria for this programme were both stringent and broad.

One study noted the problem of calculating referral rates from hospital records.²⁵ Although it was possible to ascertain which health professional made each referral, it was not possible to detect whether this was a result of primary screening. No other study discussed this problem but it may also have applied to other retrospective studies.

Detection rates

The two measures of the effectiveness of a screening programme which can be calculated

relatively simply using the number of true-positive cases are the yield – the proportion of cases of the target conditions in the screened population which are correctly identified – and the positive predictive value – the proportion of people with a positive test result who do have a target condition. These can be calculated either by obtaining and recording the results of the referral examination or by retrospective analysis of hospital case records. All of the studies identified did the latter (*Tables 5a and 5b*). Two other important indicators of screening test performance are sensitivity – the proportion of people with a target condition who were correctly identified on screening – and specificity – the proportion of individuals without a target condition who had a negative screening test result. The calculation of these measures, along with the identification of false-negative cases, requires the entire screened population to be re-examined at a later date.

Programme yield

The figures for programme yield have already been discussed under prevalence. Given the variety of different types of screening programme from which they are derived, they provide a consistent picture of prevalence of all target conditions of between 2.4% and 6.1%. Most studies gave a yield for broad categories of defect which included more than one of the target conditions. Studies in which figures for distinct conditions were given reported a range of yields: straight-eyed amblyopia, 0.3–1.0%;^{25,87} strabismic amblyopia, 0.2–0.6%;^{25,87} amblyopia (all types), 1.8%;¹⁰² strabismus without amblyopia, 0.1–0.8%;^{25,87} strabismus with or without amblyopia, 1.1–1.7%;^{24,26,84,102} refractive errors, 1.3–5.6%;^{24,26,84,87,102} One study gave a yield for micro-squint of 0.7%.²⁴

Positive predictive value

The positive predictive value depends on the definition of a positive case. Most studies have defined as positive all children who received treatment with patching, spectacles or surgery. This definition can only provide consistent data if there is complete agreement amongst orthoptists as to which children should be treated. The literature suggests that this is unlikely to be the case. In six studies of orthoptic screening programmes for which this figure could be calculated,^{24,25,87,90,93,94} the positive predictive value varied from 47.5% to 66.4%. Three studies gave much higher positive predictive values. One study⁸⁴ recorded only 4.1% false-positives, giving a positive predictive value of 95.9%. In this study, children with hypermetropia of 2 D or more

were classified as true-positive. In the other studies tabulated, most of these children would have been counted as false-positives. In another study,²² a similarly high positive predictive value was recorded but, in this study, a large number of children were reviewed twice before referral. In the third study, in which a positive predictive value of over 90% was recorded,⁹³ children were reviewed before referral where there was doubt and positive cases were broadly defined as those with 'reduced vision in one or both eyes and/or squint'.

In health visitor and CMO programmes, the positive predictive value was much more variable, ranging from 14.4% to 61.5%, and the yields lower. If a study which excluded refractive errors and gave a yield of 0.6% is considered separately,²⁵ the yield from these programmes ranges from 0.9% to 2.6%.

In another study,¹⁰⁶ not included in the tables because it covers school-age as well as preschool children, some light is thrown on the predictive value of health visitor screening. This was a study of all referrals of children aged under 11 years attending a first outpatient appointment at Suffolk eye clinics. Among those attending hospital eye clinics, the proportion assessed as normal by health visitors or school nurses who were found to have visual defects (68%, 71% and 80% in the three districts) was similar to those whom they had referred as being abnormal. The positive predictive value of health visitor or school nurse screening was estimated to be 62%, 64% and 80%, but with a similar false-positive rate. Those whom the health visitors regarded as normal may have been referred because of parental concern or because the child had a family history of a visual defect such as squint. Health visitors undertaking formal visual acuity testing did no better than those carrying out a general check with no formal visual acuity test in terms of the yield of children with amblyopia. This study is discussed further below.

Negative predictive value

In two studies,^{86,103} researchers have attempted to identify the false-negatives of preschool vision screening and have based their results on the findings at school entry vision screening. These studies give negative predictive values of 98.1% and 99.3%, respectively. The problem with this study design is that it is impossible to be sure that the visual defect identified at age 5–6 years was present when the child was examined at age 3 years. Screening at school entry is easier than at age 3 years because children find it easier to complete the tests. The accuracy, however, depends on the tester, usually school nurses whose training and skills may vary.

A minimum estimate of the number of false-negatives can be made by examining all eye hospital records and identifying children who were screened as normal but presented to the eye hospital with a problem at a later date. Eye hospital records rarely record sufficient detail about screening to allow this to be undertaken.

Studies of other types of screening programme

Three studies were found in which an attempt was made to evaluate secondary community orthoptic screening clinics. The aim of the first of these studies¹⁰⁷ was to assess only whether such a service reduced unnecessary referrals to eye hospitals. This was an audit evaluating a mobile orthoptic service, to which health visitors made referrals, 18 months after its introduction. A 25% reduction in inappropriate referrals of children aged under 5 years was reported. The second study¹⁰⁶ was of the referrals of all children under 11 years attending a first outpatient appointment at Suffolk eye clinics in 1 year. It sought to assess the impact of different community-based vision assessment services on referral patterns for assessment of visual acuity or ocular motility. Three districts were compared, in which health visitors checked children's eyes at age 3½ years. In district one, health visitors referred to GPs or opticians. In both the others, a secondary orthoptic screening service was in place which took referrals from health visitors. The secondary orthoptic service appeared to offer little advantage over direct referral to the eye hospital in district two but, in district three, there were fewer false-positive referrals to the eye clinics. There was no significant difference in the age at presentation of amblyopia between districts, despite the operation of a secondary orthoptic service to which health visitors could refer in two districts. No relationship was found between community vision screening and the referral of new cases of manifest squint.

In a third study,¹⁰⁸ data on all referrals to eye hospitals over a long period was also examined. Two cohorts of amblyopic children from before and after the introduction of a secondary orthoptic screening service and the transfer of responsibility for child health surveillance to GPs were compared. The initial screening at 3½ years continued to be carried out by health visitors throughout this period. For children with large angle strabismus no change was detected in the mean age of presentation, and regression analysis showed no significant effect of ethnic origin or social deprivation

(estimated using the Townsend deprivation score) in either cohort. For children with amblyopia without large angle strabismus, the average age of presentation was reduced by 19 months following the changes from 6.6 years to 5.0 years, and a link between social deprivation and age at presentation was no longer seen.

One study in progress is attempting to evaluate a secondary screening programme based on family history of visual defects or parental concern. In this district all parents are sent a questionnaire and those with a positive family history or parental concern invited for a screening test.¹⁰⁹

Factors influencing presentation

Some evidence was found relating to the spontaneous presentation of children with visual defects. A Swedish study of children found to be strabismic and/or amblyopic over a period of 9 years noted that micro-squints and straight-eyed amblyopia were mostly detected at preschool vision screening and manifest large-angle squints by parents.⁵ A survey of 525 children (mean age 3.7 years) referred from any source to an ophthalmology department in Leicester⁶ found that parents and other relatives made up the largest group of those first noticing the defect and that they had an overall accuracy of 76%. They were the first to pick up 47% of suspected, and 54% of confirmed, squints, 62% of cases of strabismic or mixed strabismic/anisometropic amblyopia and 17% of amblyopia with anisometropia only. No distinction was made in this study between cosmetically obvious squints and those that cannot be detected without screening. Parents who noticed a defect did not always take action, a referral being made only after the child had been seen by a health visitor. An unpublished audit of an orthoptic screening programme⁹⁸ looked at parental concern in those for whom a record was available (74% of those referred). Of 31 children referred with an initial visual acuity of 6/24 or worse, 17 had no history of parental concern and, of 24 strabismic children (no details of the type of squint given), 18 had no history of parental concern.

Four studies examined variables which it was thought might influence presentation.^{108,110,111,112} One study¹¹⁰ looked at 1531 new cases of amblyopia and found that the median age of presentation for strabismic amblyopia (3.64 years) was significantly lower than for strabismic/anisometropic amblyopia (4.68 years) and anisometropic amblyopia (6.27). Only 15% of children with anisometropic

amblyopia presented before the age of 5 years. Boys presented later than girls and Asians later than Caucasians. At the time of this study, vision screening at 3½ years of age was undertaken by health visitors. There was no significant association with ethnic origin. Another study,¹¹¹ which used data from a historical cohort of 897 children in seven orthoptic centres in the UK, found no significant association between sex or ethnicity and age at presentation for any type of amblyopia. A relationship between social deprivation and age at presentation was found only in children with anisometropic amblyopia, with those from the most deprived areas presenting 22 months later than those from the least deprived. In a slightly larger cohort of children from the same centres, variations were found in the age and proportion of patients presenting with anisometropic amblyopia at the different centres.¹¹² The third study¹⁰⁸ is discussed above. A limitation of these studies is the lack of information on the source of referral for each child.

In a case-control study in the USA,¹¹³ a comparison was made of several characteristics in 75 children with late diagnoses of amblyopia (median age, 5.5 years) and 86 with early diagnoses (median age, 3 years). This was a selective population of predominantly white, upper-middle class children with good access to primary care during the preschool years. Children with early diagnoses more often had a positive family history of strabismus, larger angles of strabismus, higher maternal educational level, greater parental suspicion that a defect was present and an increased chance that the parents requested the examination that led to diagnosis.

Summary

Taken together these studies provide reasonable evidence that primary orthoptic screening programmes can be provided in the UK with acceptable uptake and referral rates. In the one prospective controlled study that has been undertaken primary orthoptic screening was shown to be more effective at identifying children with straight-eyed amblyopia and refractive errors (but not necessarily squint) than health visitor, GP or CMO programmes. Primary orthoptic screening has not been compared with open access secondary orthoptic screening or with spontaneous presentation. The former has been shown to reduce unnecessary referral to eye hospitals and possibly to reduce the age at presentation of amblyopia. In order for spontaneous presentation to be more effective than health visitor or GP screening it would need to be postulated that the latter actually inhibit parents from seeking specialist advice for children about whom they are concerned. Children with straight-eyed amblyopia rarely present spontaneously.

The one prospective controlled study identified does not, however, support the belief that identifying children with amblyopia in the preschool period reduces the prevalence of this condition in children aged 7 years. No studies were identified that enable comment to be made on the benefit of identifying and treating refractive errors in this age group. None of the studies provide evidence for or against screening for non-cosmetically obvious squint.

TABLE 5a Referral and detection rates – primary orthoptic screening

Study	Screening tests and referral criteria	% (n) of screened (95% CI)	Target condition	Yield, % (n)	Positive predictive value, % (n)	False-positive rate	Comments
Beardsell ⁶⁴	Screening tests: cover test, ocular movements, convergence, 20 D base out prism, Frisby stereotest, monocular visual acuity Sheridan–Gardiner (single optotype) at 6 m. Referred criteria: visual acuity 6/9 or less either eye and/or manifest strabismus.	4.1 (102) (3.3, 4.9)	Anisometropic amblyopia Strabismus Bilateral refractive errors Total	0.7* (18) 1.7* (41) 1.3* (31) 3.6*		Maximum 4.1* (see comments).	False-positive rate is from primary and secondary screening combined.
Birmingham ⁹⁴	No details.	9.4 (297) (8.4, 10.4)					
Bolger et al ²⁵	No details.	5.1* (263) (4.5, 5.7)	Amblyopia without strabismus Strabismic amblyopia Strabismus without amblyopia Total	1.0* 0.6* 0.8* 2.4*	19.0 (50) 11.8 (31) 16.7 (44) 47.5	46.4* (122)	Some referrals may have come from CMOs or orthoptists outside routine screening. True-positive cases defined as those with amblyopia and/or strabismus. Refractive errors excluded. Four children unaccounted for.
Cameron & Cameron ¹⁰⁰	No details.	8.4 (37) (5.8, 11.0)					32 others had defects already detected through child health surveillance programme.
Dudley & Sandwell ⁹⁵	No details.	5.9 (236) (5.2, 6.7)					
Edwards ²⁶	Screening tests: appearance of eyes, cover test, ocular movements, monocular visual acuity Sheridan–Gardiner optotypes, 20 D base out prism, Lang stereotest. Referral criteria (one or more): visual acuity < 6/9 either eye, > 1 line difference between eyes, eso/exophoria > 10 D base out/in near/distance, heterotropia, abnormality of muscle balance, convergence insufficiency 8 cm or worse, abnormal response to prism, abnormal appearance of eyes. Re-examined, if any doubt, before referral.	6.1 (198); incl. 40 reviewed. (5.3, 6.9)	Strabismus Refractive errors (incl. anisometropia) 'Reduced vision' aetiology unknown Total	1.4* 4.3* 0.1* 5.9*	23.2 (4) 70.7 (140) 2.0 (4) 96.0	1.0 (2)	14.8% reviewed & found normal. Additional 112 referred from child health surveillance programme (83 GP, 29 health visitor referrals). No definition of refractive error and amblyopia not identified as a separate entity. Other defects were also included in the definition of true-positives; when these included, positive predictive value is 97.5%*. 5 (2.5%) lost to follow-up and excluded.
* Secondary calculation.							

continued

TABLE 5a contd Referral and detection rates – primary orthoptic screening

Study	Screening tests and referral criteria	% (n) of screened referred (95% CI)	Target condition	Yield, % (n)	Positive predictive value, % (n)	False-positive rate	Comments
Ingram et al ⁸⁶ [36]	Screening tests: cover test, visual acuity linear Sheridan-Gardiner or Snellen. All children also underwent cycloplegic refraction by ophthalmologist. Vision deemed abnormal if there was a squint and/or visual acuity 6/12 or less in either eye and/or > 1 line difference between eyes.		Defective acuity without optical correction and/or strabismus	4.9			False-negatives: 1.9 (26), defined as those who screened positive at school entry and passed preschool vision screening.
Jarvis et al ⁹⁰	Screening tests: cover tests, ocular movements, 20 D base out prism, visual acuity Sheridan-Gardiner letter matching or Kaye pictures. Referral criteria: unknown.	7.9* (48) (5.7, 10.0)	Squints and/or visual acuity loss (due to refractive errors or amblyopia), newly confirmed and/or treatment prescribed.	4.4*	56.2 (27)	25.0* (12)	19.8%* called for review. 30.6%* of these failed to attend. Referral rate for reviewed group was three times higher: Different values given for referral rate in Figures 1 & 2. Children with non-target conditions given repeat appointments for observation included in the false-positives.
Milne ⁹⁷	Screening tests: cover test, ocular movements, convergence, 20 D base out prism, visual acuity Sheridan-Gardiner single optotype or Kaye pictures. Referral criteria: visual acuity < 6/6 either eye, significant eso/exophoria, manifest strabismus, nystagmus, abnormal head posture, ptosis, facial asymmetry, ocular muscle imbalance, poor fusion or binocular vision. Recalled once before referral if cooperation poor.	4.5 (83) (3.5, 5.4)	Children requiring immediate treatment with spectacles, patching or surgery.	4.4*	58.6 (82)	41.4* (58)	19.3% recalled (outcome unknown). Of 349 recalled from previous visit, 16.3% referred. False-positive rate of 10.4% given based on 14 children discharged as normal within 9 months of initial visit. Secondary calculation based on all those not treated.
Newman et al ⁸⁷	Screening tests: cover tests, ocular movements, convergence, 20 D base out prism, TNO stereotest, monocular visual acuity Sheridan-Gardiner single optotypes at 6 m. Referral criteria: visual acuity (6/6 either eye, manifest strabismus, decompensating heterophoria, abnormal ocular movements, abnormal response to prism test, negative response to stereotest, any other ocular abnormality. Recalled, if in doubt, before referral.	5.1 (348) (4.6, 5.6)	Amblyopia without strabismus Strabismic amblyopia Strabismus Refractive errors Total	0.7* 0.6* 0.6* 1.5* 3.4	15.8 (48) 14.1 (43) 13.2 (40) 32.8 (100) 66.4 (231)	20.1 (61)	No child referred solely on failing prism test or stereotest. 4.3% failed to attend referral appointment.
* Secondary calculation.							
							continued

TABLE 5a contd Referral and detection rates – primary orthoptic screening

Study	Screening tests and referral criteria	% (n) of screened referred (95% CI)	Target condition	Yield, % (n)	Positive predictive value, % (n)	False-positive rate	Comments
Seng & Curson ⁹⁸	No details.	6.4 (140) (5.4, 7.5)					6.4% reviewed and found normal.
Gallaher ⁹⁶	Screening tests: cover test, ocular movements, convergence, 20 D base out prism, stereotest (usually Lang), visual acuity (usually Sheridan-Gardiner single optotypes). Referral criteria: visual acuity (< 6/9 one or both eyes, manifest of significant latent squint, any other test not completed to orthoptist's satisfaction).	6.3 (178) (5.4, 7.2)					5% opted for a private consultation. 5% failed to attend referral appointment.
Williamson et al ⁷⁴	Screening tests: cover test (33 cm and 6m), ocular movements, 20 D base out prism, stereotest (randot circles or TNO), visual acuity Sheridan-Gardiner single optotypes. Referral criteria: visual acuity 6/9 or less either eye, squint, abnormal ocular movements, family history , lack of response to prism or stereotests.	10.6 (863) (9.9, 11.3)	Strabismus, excluding microtropia Microtropia Refractive errors incl. anisometropia (These groups include people with amblyopia) Total	1.1* 0.7* 4.3* 6.1	74 (528)		4% failed to attend referral appointment. Based on 712 referrals for whom records available and who had not been diagnosed before screening. Of confirmed cases of amblyopia (visual acuity < 6/9), 82.7% correctly identified as positive at screening by test result. Of children who failed the test at < 6/9, 46.9% found to be false-positives. Similar details given for other screening tests used.
Wormald ⁹³	Screening tests: cover tests, convergence, ocular movements, 20 D base out prism, stereotest (Wirt Fly and pictures of animals), head posture, visual acuity Snellen 6 m with card (Sheridan-Gardiner chart at 6 m or Kaye pictures when cooperation poor). Referral criteria (any): visual acuity < 6/9 (Snellen) either eye, inward/outward deviation on cover test (> 8 prism D), obvious squint or other clinical abnormality. May be reviewed if any doubt.	6.7* (27) (4.3, 9.2)	Reduced vision in one or both eyes and/or squint	4.0	94.6 (317)	5.4* (18)	Referral rate estimated from sample.

* Secondary calculation.

TABLE 5b Referral and detection rates – health visitor/GP/CMO screening

Study	Screening tests and referral criteria	% (n) of screened referred (95% CI)	Target condition	Yield, % (n)	Positive predictive value, % (n)	False-positive rate	Comments
Bolger et al²⁵ (CMO, with referral to secondary orthoptic centres)	Screening tests: visual acuity each eye, ocular movements. No further details. Referral criteria: unknown.	4.4 (111) (3.6, 5.2)	Amblyopia without strabismus Strabismic amblyopia Strabismus Total	0.3* 0.2* 0.1* 0.6	7.2 (8) 5.4 (6) 1.8 (2) 14.4	82.0	True-positive cases defined as those with amblyopia and/or strabismus. Refractive errors excluded. Four children unaccounted for.
Jarvis et al⁹⁰ (health visitor; no secondary orthoptic programme)	Screening tests: (at 30 months) standard check, 'pick-up-a-thread'. Referral criteria: unknown.	1.7* (13) (0.8, 2.7)	Squints and/or visual acuity loss (due to refractive error or amblyopia), newly confirmed or treatment prescribed.	0.9*	53.8 (7)	38.5* (5)	Screening coverage estimated from records seen.
Jarvis et al⁹⁰ (health visitor/GP/CMO; no secondary orthoptic programme)	Screening tests: (at 30–36 months) squint check – parents asked if squint noticed, then checked for obvious squint and for symmetry of corneal reflections for far and near vision. Referral criteria: unknown.	1.6* (13) (0.7, 2.5)	Squints and/or visual acuity loss (due to refractive error or amblyopia), newly confirmed or treatment prescribed.	1.0*	61.5 (8)	38.5* (5)	Screening coverage estimated from records seen.
Edwards²⁶ (health visitor; referral to hospital-based orthoptist)	Health visitors instructed in following screening methods and referral criteria. Screening criteria: appearance of eyes, cover test, ocular movements, monocular visual acuity Sheridan–Gardiner optotypes, 20 D base out prism, Lang stereotest. Referral criteria (one or more): visual acuity < 6/9 either eye, > 1 line difference between eyes, eso/exophoria > 10 D base out/in near/distance, heterotropia, abnormality of muscle balance, convergence insufficiency 8 cm or worse, abnormal response to prism, abnormal appearance of eyes.	7.4 (52) (5.5, 9.4)	Strabismus Refractive errors (incl. anisometropia) Total	1.0* 1.6* 2.6*	13.4 (7) 21.2 (11) 34.6		Rates are for primary health visitor screening. 61 GP referrals from same area: false-positive rate 27.9% (17), true-positive rate – squint 55.7%* (34); refractive errors 14.8%* (9). In orthoptic screening area, 83 referrals from GPs – false-positive rate 37.3%* (31); 29 from health visitors – false-positive rate 72.4%* (21).
Mean		3.9%					
* Secondary calculation.							

continued

TABLE 5b contd Referral and detection rates – health visitor/GP/CMO screening

Study	Screening tests and referral criteria	% (n) of screened referred (95% CI)	Target condition	Yield, % (n)	Positive predictive value, % (n)	False-positive rate	Comments
Kohler & Stigman ^{102,103} (nurse/paediatrician)	Screening tests: appearance, cover test, ocular movements, monocular visual acuity Marquetz-Boström's hooks at 5 m, Wirt Fly stereotest. Referral criteria: visual acuity 5/6 or less either eye, signs of strabismus or defective stereoscopic vision. After first year of programme, referrals made only if failed on re-testing.	15.2 (364) (13.7, 16.6)	Amblyopia Manifest strabismus 'Significant' refractive errors (hyperopia 2.5 D or more, myopia 1.0 D or more, astigmatism 2.5 D or more) Anisometropia (1 D or more) Significant disorders needing treatment immediately or after observation.	1.8 1.6 5.6	12.3 (44) 10.3 (37) 36.9 (132)	16.4 (59)	96% referred for failing visual acuity test. 1.6% (6) failed to attend referral appointment. Children with muscle imbalance without amblyopia and 'other types of strabismus' were treated. 1530 (62.5%) were re-screened at age 7. 11 had newly-detected defects and were either false-negatives from preschool screening or the defects had developed since age 4 years.

* Secondary calculation.

Chapter 10

Results – costs

The Standing Group on Health Technology has made the costs for childhood screening, including vision, a priority topic, and a review is being carried out by the York Health Economics Consortium. In this review, no studies were identified which were designed with the primary aim of evaluating the costs of screening.

Some of the observational studies and audits of screening programmes included some cost data. An audit of an orthoptic screening programme reported an estimated cost of £417 (1990 prices) per child with an initial visual acuity of 6/24 or less who improved by two lines or more after treatment.⁹⁸ In the same year, the cost of primary vision screening requiring 15 sessions a month in another area was calculated to be around £33 per session, with an additional cost to the NHS of providing salaries for

orthoptic screening of £6000.²⁵ The costs of a primary orthoptic screening programme from April 1995 to March 1996, for which the uptake rate was 44%, are given as £4.82 per child sent for and £10.99 per child seen.⁹⁴ These costs include the orthoptists' salaries, travel and stationery but exclude the costs for training, dressings and equipment. The costs of a secondary orthoptic screening programme in 1995 are given as £58 per session (almost £7000 per year), £4.49 per child sent for and £7.30 per child seen, where the uptake rate was 61%.¹¹⁴

These figures suggest that the cost of orthoptic screening is not great and means that a relatively small benefit to children's visual health from these programmes may be judged cost-effective when compared to the benefits to be gained from other more expensive programmes.

Chapter 11

Discussion

Although systematic reviews of other screening programmes have been undertaken, the methodology for this work is both less well developed and more complicated than for reviews of treatment RCTs. This review is unusual in that it concerns screening for a non-fatal disease, which has raised the issue of the appropriateness of the health outcome used to measure success or failure. This has been the most intellectually taxing part of this review and it is likely that it could be improved and developed with further work.

Search strategies

Search strategies were devised for each database with the aim of producing a high yield of potentially relevant studies. The Cochrane Collaboration's 'optimally sensitive strategy' for searching Medline was used for that database. Developed over a number of years and continually being revised, the aim of this search strategy is the identification of RCTs and CCTs. At the same time, the Cochrane Collaboration has been working with Medline to improve the coding of RCTs and CCTs, so that their search strategies are even more sensitive. This study has relied on searches of other databases, on which there has been much less developmental work. Inadequate indexing also adds to the difficulties of locating studies.¹¹⁵ Because we were only able to identify one RCT or CCT that aimed to answer the principle question, 'Is screening worthwhile?' we have searched for studies answering a number of different research questions relevant to the assessment of screening programmes.

Selection of studies

The searches initially yielded over 5000 references and all but those listed in this document were eliminated on the basis of titles and abstracts (where given) by one reviewer (SKS). Any reference that appeared remotely suitable for further scrutiny was downloaded and considered more carefully. A number of studies were found at this stage which did not strictly fulfil the search criteria and were not sufficiently robust from methodological point of view to answer our research questions, but whose results are nevertheless worthy of mention either

because they question currently held beliefs or because they throw some light on the research questions. It is possible that some studies of this nature were missed in the initial sift of 5000 references. Finding and critically appraising all of them was beyond the scope of this study.

Literature that had not been found in the electronic search or request for unpublished studies was also identified late in the course of the study, as a result of consultation on the draft report. Our advisory group was particularly helpful in this respect. Where possible and appropriate, these studies have been included in the review. This process improves the credibility of the review because it ensures that studies that clinicians believe are important and which underpin their professional practice are included. However, in a review like this, where the adequacy of electronic searching must be open to question, it is important to be aware that this process could lead to bias. Studies that support current clinical practice are more likely to be included than those that do not. None of the evidence identified late in the review provided definitive answers to our research questions. The problem of failing to identify all relevant literature is more likely to have affected the identification of studies relating to natural history and disability than the other topics.

Appropriateness of outcome measures

The most controversial component of this review is that pertaining to the extent of disability caused by these sight defects. This is also the area in which the review is least strong. Although we can be confident that studies which fulfil the criteria for causality have been identified, some studies may have been missed which might throw light on the subject and be useful for generating hypotheses. To many clinicians working in this field it appears self-evident that a reduction in visual acuity (which may range from one line on the Snellen chart to six) in one eye or a lack of stereopsis must be disabling. The risk of severe visual impairment for the person with amblyopia through loss of vision in the good eye is frequently cited as a key reason for identifying and treating amblyopia; however, the contribution of

amblyopia to blindness is virtually undocumented. There is also a need for further studies of the prognosis for vision in the amblyopic eye when vision in the better eye is lost. The belief that reduced binocular vision or minor refractive errors cause problems for children and adults is biologically plausible but does need supporting by methodologically sound studies, and these do not seem to have been performed. We have attempted to present a range of studies commonly quoted as demonstrating that visual defects must be disabling and to demonstrate why they do not prove this.

Effectiveness of treatment

The second most controversial aspect of this review is the conclusion we have reached about the impact of treatment on the three target conditions. There is a strongly held clinical belief that treatment works and several clinicians have told us that the prevalence of dense amblyopia in childhood has reduced during their working lives. However, the evidence relating to the natural history of these conditions is inadequate and there do not appear to be any methodologically sound trials of the effect of treatment on any of the conditions on visual function. Current clinical practice appears to be based on theory and on observational studies of treatment. Although this may be considered

sufficient as a basis for clinical practice, it is not sufficient for the establishment of a screening programme. In the absence of knowledge of the disabilities attributable to the target conditions, it is difficult to see how clinicians can give parents a clear picture of how treatment will benefit their child and obtain informed consent for treatment.

Side-effects of screening and treatment

No studies were found that aimed to measure negative effects of screening. Potential visual side-effects of treatment (diplopia, deprivation amblyopia and failure of emmetropisation) are acknowledged^{11,32} but the potential psychological impact on the child or its family is seldom mentioned, still less explored. The evidence that the detrimental effects of screening programmes can outweigh the benefits is mounting.¹¹⁶ There is evidence that many older children prescribed glasses for refractive error do not wear them,⁴¹ which suggests that the perceived improvement in visual function achieved by wearing spectacles is not always sufficient to offset the perceived social disability attributed to wearing them. Patching is likely to be more socially and psychologically disabling than spectacle-wearing and could have deleterious effects on both the child and the family.

Chapter 12

Conclusions and recommendations

The conclusions and recommendations of this review differ from those of, for example, other recent reviews,^{15,16,117} which judge that preschool vision screening is worthwhile. The conclusions of these reviews are based on literature that has been appraised in this review. This review differs in that a more rigorous approach to the evidence relating to disability and treatment has been taken. We believe that this evidence is essential to support a screening programme for a non-fatal condition for which there have been no rigorously controlled trials. An invitation to preschool vision screening carries with it the implicit assumption that screening is going to benefit the child. In the absence of sound evidence that the target conditions sought in these programmes are disabling and that the interventions available to correct them do more good than harm, the ethical basis for such interventions is very insecure.

Recommendations

Clinical practice

Purchasers and providers should be appraised of the results of this review and advised not to implement new preschool vision screening programmes unless they have been rigorously evaluated.

The National Screening Committee should consider whether to recommend that existing vision screening programmes be discontinued. From an ethical point of view, it is appropriate to continue screening only in the context of a controlled trial of treatment, such as that described below.

Research

There is an urgent need for research in the following areas.

Disability

(a) The extent of disability that is attributable to amblyopia. A variety of different types of study are needed, including qualitative studies exploring with sufferers the ways in which they feel their condition has affected them. We are currently conducting a small qualitative study exploring this area. There is also a need for comparative experimental studies measuring the performance of people with amblyopia at

tests that might be expected to be affected by monocular function.

- (b) The disability attributable to refractive errors – particularly the possibility that hypermetropia might cause problems with reading that could be corrected with spectacles, or might contribute to the development of a squint. These possibilities could be studied in an RCT.
- (c) If there is any disability associated with non-cosmetically obvious squints.
- (d) The prevalence of blindness or partial sight attributable to amblyopia in the UK. A national survey of the incidence and causes of loss of vision in the better eye in children and adults with unilateral amblyopia, from data collected by the British Ophthalmic Surveillance Unit, is planned to start this year.¹¹⁸ Data will be collected for a period of not less than 18 months. Studies are also needed to assess the extent to which an amblyopic eye can regain function late in life if the good eye fails.

Until it is established that these conditions are disabling, and in what ways, it will remain impossible to demonstrate that preschool vision screening programmes offer any health gain. Once these studies have been completed, and it has been demonstrated that these conditions are disabling, appropriate health outcome measures can be devised.

Treatment

- (a) The impact of orthoptic treatment on family life and psychological well-being of the child. Initially, qualitative studies are needed to explore possibly unexpected consequences.
- (b) The effectiveness of orthoptic treatment on amblyopia and quality of life. This needs to be an RCT of treatment versus no treatment. The outcome of treatment needs to be measured in terms of health outcomes defined in studies of disability. Trials should be undertaken in children of both 3–4 years and 5–6 years of age to determine whether treatment at ages 3 years and 4 years confers any benefit over treatment at the age of school entry. This type of study would also provide data on the natural history of these conditions.

- (c) The effectiveness of treatment of non-cosmetically obvious squint and refractive errors in this age group. This also needs to be a no-treatment controlled RCT. However, if recommendation (d) above is under way, amblyopia could be used as an outcome.

Screening

No further studies of the efficiency of screening in identifying children with the target conditions should be undertaken until the research on disability and treatment has been undertaken.



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Appendix I

Search strategies

Medline

- 1 RANDOMIZED-CONTROLLED-TRIAL in PT
- 2 "RANDOMIZED-CONTROLLED-TRIALS"/
- 3 all subheadings
- 4 RANDOM-ALLOCATION
- 5 DOUBLE-BLIND-METHOD
- 6 SINGLE-BLIND-METHOD
- 7 #1 or #2 or #3 or #4 or #5
- 8 explode "REFRACTIVE-ERRORS"/
- 9 all subheadings
- 10 explode "OCULAR-MOTILITY-
- 11 DISORDERS"/ all subheadings
- 12 explode "VISION-DISORDERS"/
- 13 all subheadings
- 14 explode "VISION-TESTS"/ all subheadings
- 15 (VISION near SCREENING) in TI,AB,MESH
- 16 RETINOBLASTOMA in TI,AB,MESH
- 17 (VISION or SIGHT or EYE) near TEST*
- 18 DEFECT* near VISION
- 19 (EYE or SIGHT) near PROBLEM*
- 20 SPECTACLES or GLASSES
- 21 explode "CHILD"/ all subheadings
- 22 CHILD* or PRESCHOOL*
- 23 #18 or #19
- 24 #6 and #20 and (#7 or #8 or #9 or #10 or #11
- 25 or #12 or #13 or #14 or #15 or #16 or #17)
- 26 CLINICAL-TRIAL in PT
- 27 explode "CLINICAL-TRIALS"/
- 28 all subheadings
- 29 (CLIN* near TRIAL*) in TI,AB
- 30 "PLACEBOS"/ all subheadings
- 31 PLACEBO* in TI,AB
- 32 RANDOM* in TI,AB
- 33 RESEARCH-DESIGN"/ all subheadings
- 34 (SINGL* or DOUBL* or TREBL* or TRIPL*)
- 35 near (BLIND* or MASK*)
- 36 #22 or #23 or #24 or #25 or #26 or #27 or #28
- 37 or #29
- 38 #30 and #20 and (#7 or #8 or #9 or #10 or #11
- 39 or #12 or #13 or #14 or #15 or #16 or #17)
- 40 #31 not #21
- 41 TG=COMPARATIVE-STUDY
- 42 explode "EVALUATION-STUDIES"/
- 43 all subheadings
- 44 FOLLOW-UP-STUDIES
- 45 PROSPECTIVE-STUDIES
- 46 (CONTROL* or PROSPECTIV* or
- 47 VOLUNTEER*) in TI,AB
- 48 #33 or #34 or #35 or #36 or #37

- 38 #38 and #20 (#7 or #8 or #9 or #10 or #11 or
- 39 #12 or #13 or #14 or #15 or #16 or #17)
- 40 #39 not (#31 or #21)

Biological Abstracts

- 1 AMBLYOP*
- 2 REHABILITAT*
- 3 DISABILIT*
- 4 #1 and (2 or #3)
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Psychlit

- 1 explode VISION DISORDERS
- 2 explode EYE DISORDERS
- 3 explode OCULAR ACCOMMODATION
- 4 explode HYSTERICAL VISION DISTURBANCES
- 5 explode REFRACTION ERRORS
- 6 VISION near SCREENING
- 7 VISION SCREENING
- 8 6 or 7
- 9 AMBLYOP*
- 10 (VISION or SIGHT or EYE) near TEST*
- 11 SPECTACLES or GLASSES
- 12 DEFECT* near VISION
- 13 (VISION or SIGHT or EYE) near
- 14 (PROBLEM* or DISORDER*)

- 14 MICROTROPIA
- 15 SQUINT or STRABISMUS
- 16 MYOPI*
- 17 HYPERMETROP*
- 18 ANISOMETROP*
- 19 ASTIGMAT*
- 20 REFRACTIVE
- 21 PRESCHOOL* or CHILD*
- 22 21 and (1 or 2 or 3 or 4 or 5 or 8 or 9 or 10 or 11 or 12 or 13 or 14 or 15 or 16 or 17 or 18 or 19 or 20)

Science Citation Index (SciSearch)

- 1 RANDOMIZED CONTROLLED TRIAL*
- 2 RANDOM ALLOCATION
- 3 DOUBLE BLIND
- 4 SINGLE BLIND
- 5 1,2,3,4
- 6 CHILD*,PRESCHOOL*
- 7 AMBLYOPIA
- 8 REFRACTIVE ERROR*
- 9 STRABISMUS,SQUINT
- 10 VIS* SCREENING
- 11 VISION TEST*
- 12 SIGHT TEST*
- 13 EYE TEST*
- 14 SPECTACLES,GLASSES
- 15 OCULAR MOTILITY DISORDER*
- 16 5+6+(7,8,9,10,11,12,13,14)
- 17 CONTROL* TRIAL*
- 18 CONTROL* STUD*
- 19 CLINICAL TRIAL*
- 20 DOUBLE BLIND
- 21 SINGLE BLIND
- 22 TRIPLE BLIND
- 23 TREBLE BLIND
- 24 DOUBLE MASK*
- 25 SINGLE MASK*
- 26 TREBLE MASK*
- 27 TRIPLE MASK*
- 28 RANDOM*
- 29 PLACEBO*
- 30 RESEARCH DESIGN*
- 31 MULTICENT* STUD*
- 32 17,18,19,20,21,22,23,24,25,26,27,28,29,30,31
- 33 32+6+(7,8,9,10,11,12,13,14,15)
- 34 33-16
- 35 PROSPECTIV* STUD*
- 36 VOLUNTEER*
- 37 COMPARATIVE STUD*
- 38 EVALUATI* STUD*
- 39 FOLLOWUP STUD*
- 40 LONGITUDIN* STUD*
- 41 COHORT STUD*

- 42 35,36,37,38,39,40,41
- 43 42+6+(7,8,9,10,11,12,13,14,15)
- 44 43-(33,16)

Embase

Search strategy for RCTs and other controlled studies.

- 1 RANDOMIZED CONTROLLED TRIAL
- 2 RANDOMIZATION
- 3 randomi?ed control* trial*
- 4 DOUBLE BLIND PROCEDURE
- 5 SINGLE BLIND PROCEDURE
- 6 1,2,3,4,5
- 7 CHILD*, PRESCHOOL*
- 8 REFRACTI* ERROR*
- 9 AMBLYOPIA
- 10 explode EYE DISEASE
- 11 RETINOBLASTOMA
- 12 explode VISUAL DISORDER
- 13 explode VISUAL IMPAIRMENT
- 14 explode VISION TEST
- 15 explode VISUAL SYSTEM EXAMINATION
- 16 explode STRABISMUS
- 17 SPECTACLES,GLASSES
- 18 6+7+(8,9,10,11,12,13,14,15,16,17)
- 19 explode CLINICAL TRIAL
- 20 explode CONTROLLED STUDY
- 21 explode MAJOR CLINICAL STUDY
- 22 clinical trial*
- 23 control* stud*
- 24 control* trial*
- 25 double blind
- 26 single blind
- 27 treble blind
- 28 triple blind
- 29 double mask*
- 30 single mask*
- 31 triple mask*
- 32 treble mask*
- 33 explode PLACEBO
- 34 placebo*
- 35 random*
- 36 METHODOLOGY
- 37 INTERMETHOD COMPARISON
- 38 TECHNIQUE
- 39 19,20,21,22,23,24,25,26,2,28,29,30,31,32,33,34,35,36,37,38
- 40 7+39+(8,9,10,11,12,13,14,15,16,17)
- 41 40-18
- 42 COMPARISON
- 43 comparative stud*
- 44 evaluati* stud*
- 45 EVALUATION AND FOLLOW UP
- 46 FOLLOW UP
- 47 LONGITUDINAL STUDY

48	PROSPECTIVE STUDY	53	volunteer*
49	RETROSPECTIVE STUDY	54	PRACTICE GUIDELINE
50	COHORT ANALYSIS	55	42,43,44,45,46,47,48,49,50,51,52,53,54
51	control*	56	7+55+(8,9,10,11,12,13,14,15,16,17)
52	prospectiv*	57	56-(40,18)

Appendix 2

CROS search

This is conducted over all 60 biomedical sciences databases plus social sciences and general reference on DATASTAR and ranks the databases according to the number of 'hits'.

Vision and screening

Medline
Embase
IAC Health Periodicals
Biological Abstracts
Science Citation Index
Psychlit

Vision and disability

IAC Health Periodicals
Medline
Embase
Science Citation Index
Biological Abstracts
Psychlit

Vision and treatment

Medline
Embase
IAC Health Periodicals
Biological Abstracts
Science Citation Index
Psychlit

Vision and screening and preschool

Medline
Embase
Psychlit
IAC Health Periodicals
Biological Abstracts
CINAHL
Science Citation Index

Appendix 3

Advisory group

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The Western Eye Hospital

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Epidemiology, University of Leicester

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Mr Kevin Barton, Bromley Health Authority †	Professor Richard Hobbs, University of Birmingham †	Professor Martin Knapp, London School of Economics & Political Science †	Professor Gillian Parker, University of Leicester †	
Professor John Bond, University of Newcastle-upon-Tyne †	Professor Allen Hutchinson, University of Hull †	Professor Karen Luker, University of Liverpool	Dr Robert Peveler, University of Southampton †	* Previous Chair † Current members
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