A new approach to vision screening in schools

W. David Thomson¹ and Bruce Evans²

¹Department of Optometry and Visual Science, City University, Dame Alice Owen Bldg, 311–321 Goswell Rd, London EC1V 7DD, UK,
²Institute of Optometry, Newington Causeway, London, UK,

Summary

Purpose: To determine the prevalence of visual “defects” among a sample of young schoolchildren and evaluate a new system for vision screening in schools.

Methods: A new system for vision screening in schools has been developed. The system is based on a computer program which may be run on a low specification personal computer. Information about the child’s symptoms, history and family history is acquired by means of a parental questionnaire and entered into the program prior to the vision screening. Distance visual acuity and stereopsis are measured directly on the computer screen and colour vision is assessed using a reduced Ishihara test. The program carries out an “expert” analysis of the questionnaire data and the vision test results and determines the most likely diagnosis. Reports for parents, teachers, optometrists, doctors can be generated automatically and statistics relating to the overall screening program are available. An evaluation of a prototype version of the system was carried out on 245 schoolchildren aged between 5 and 8 years.

Results: Overall, 48 children failed the screening (excluding colour vision deficiencies), 32 of whom were unaware of any problem with their eyes. Comparison of the result of the vision screening with the outcome of a full eye examination gave a sensitivity of 93.8% and a specificity of 96.1%.

Conclusion: A significant number of young school children have unsuspected remediable visual defects. The computer-based vision screener provides an efficient, sensitive and specific method for screening in schools. © 1999 The College of Optometrists. Published by Elsevier Science Ltd. All rights reserved

Introduction

The purpose of vision screening in schools is to “identify children with unsuspected remediable conditions, so that treatment can be offered before educational and social progress is affected” (Stewart-Brown and Haslum, 1988). Routine assessment of vision in schools was first implemented in Britain almost 90 years ago. However, it is only in recent years that the effectiveness of school vision screening has been scientifically appraised.

Vision screening in schools is usually the responsibility of school nurses and represents a continuation of primary vision care provided during the pre-school years by General Medical Practitioners, health visitors and orthoptists.

The value of vision screening in schools has been the subject of much debate. Wilson and Junger list general guidelines for an effective screening programme (Wilson and Junger, 1968). These include: (a) the condition being screened for is common; (b) it is a significant health problem; (c) it is amenable to treatment;
(d) the cost of case-finding (including diagnosis and treatment) should be economically balanced in relation to medical expenditure as a whole; (e) a cheap and reliable screening test exits.

The condition being screened for is common?

There can be little doubt that vision screening in schools meets the first criterion. Relative to other “health” conditions, visual defects (refractive errors, oculomotor problems, amblyopia, colour vision deficiencies, etc.) are common.

The condition is a significant health problem?

There is more debate about whether vision screening in schools meets the second criterion. Severe congenital disorders are likely to be identified before school entry. Serious acquired eye disease is extremely rare among school-age children and most of the conditions which affect this age group are untreatable anyway. While it is difficult to place a value on the rare cases of undiagnosed eye disease detected by vision screening, the principal justification for vision screening has to rest on the value of detecting and “treating” refractive errors, oculomotor problems and amblyopia in school-children (Stewart-Brown and Haslum, 1988; Laatikainen and Erkkila, 1980). None of these conditions can be described as significant health problems. However, within the context of vision screening in schools, it may be more appropriate to ask whether the conditions are likely to affect “educational and social progress”.

Of the three main types of refractive error, only myopia commonly develops during school age (Blum et al., 1968; Goss and Winkler, 1983). In a study involving secondary school children, it was found that few cases of undiagnosed myopia were detected by vision screening (Jewell et al., 1994). This is presumably because an eye test is often sought when a child reports problems seeing the blackboard etc. However, there is little information about the prevalence of undiagnosed myopia among younger school children who are less able to self-refer.

Children with hypermetropia require increased accommodative effort in order to see clearly and may experience transient blurring, fatigue and decreased span of attention particularly for close work. There is some evidence that mild hypermetropia can affect the development of reading skills, but the case is far from proved (Stewart-Brown et al., 1985). High degrees of hypermetropia are likely to cause problems particularly for close work and may lead to accommodative strabismus or even bilateral amblyopia.

Amblyopia affects approximately 2–4% of the population (Grounds, 1996). The main effect of amblyopia on binocular visual function is to reduce stereopsis which in turn may make some tasks involving the judgment of depth more difficult to perform. Furthermore, having only one good eye means that the child would be visually impaired (to some extent) if the good eye was damaged by trauma or disease. For these reasons a number of occupations insist on a minimum acuity standard in each eye.

Colour vision deficiencies are relatively common, affecting approximately 8% of males and 0.5% of females (Birch, 1993). The condition is non-progressive and untreatable and therefore the only justification for colour vision screening is to enable affected individuals to be made aware of their problem and steered away from occupations requiring normal colour vision. While it is conceivable that a colour deficient child could have some difficulties with certain classroom tasks which in turn might affect educational development, the case is not proven (Hill, 1984). Most agree that a colour vision test should be carried out at some stage during a child’s time at school but there is some debate as to the preferred age for testing. Assuming the child is able to perform the test adequately, there is no justification for administering the test on more than one occasion.

Advocates of vision screening in schools would argue that any visual defect will have some effect on a child’s visual capabilities which in turn may have some detrimental effect (large or small) on their educational and social development. Others would argue that children with significant visual defects will self-refer anyway and those with minor visual defects are unlikely to be significantly disadvantaged at school. Clearly there is a need for a controlled study to investigate the link between minor visual defects and social and educational development but it is difficult to conceive how such a study could receive ethical approval. Without firm evidence to support the view that vision screening could be abolished without disadvantaging a significant number of children, there must be a strong case for maintaining some form of vision screening in schools.

The condition is amenable to treatment

All forms of refractive error are readily corrected with spectacles or contact lenses and many oculomotor problems can be treated using lenses or prisms or by some form of orthoptic exercises (Evans, 1997). By comparison, the treatment of amblyopia is time-consuming, expensive and results are variable. While some studies report high rates of improvement, results from other studies are less encouraging (Bremner, 1984).
Even if some improvement in visual acuity in the amblyopic eye is possible, the value of this in terms of overall visual performance is debatable. Many are starting to question if the improvement in the quality of life brought about by a small improvement in the vision of the non-dominant eye justifies the expense of detecting and treating these children, particularly when weighed against the cost–benefit ratio of other medical treatments. If amblyopia is to be treated, most agree that treatment should begin as early as is practicable (Von Noorden, 1985; Awaya et al., 1987; Dunlop and Dunlop, 1981). The importance of early detection of amblyopia has been the principal justification for preschool vision screening. However it is often difficult to obtain reliable results with young children and the sensitivity and specificity of such screening programs is low (Egan and Brown, 1984; Ingram, 1977). Furthermore, the attendance rates at clinics are low. School screening programs have the advantage of having a “captive” population and are therefore much cheaper to organise. While there may be some disadvantage in delaying the detection of amblyopia until school entry, the reliability of the screening is higher and the cost significantly less. The detection of amblyopia in children of secondary school age may only be justified in terms of making the child aware of the problem and providing them with advice on eye protection and the choice of career.

The cost of case-finding (including diagnosis and treatment) should be economically balanced in relation to medical expenditure as a whole

Concurrence with this criterion is dependent on the perceived benefits of vision screening in schools and the relative cost of providing the service. While the debate as to the benefits of school vision screening awaits firm evidence, progress could be made in improving the cost/benefit ratio if the cost of vision screening could be reduced and the sensitivity/specificity increased.

A cheap and reliable screening test exists

Screening methods, frequency of testing and referral criteria vary significantly from area to area (Bishop, 1991). In a survey of 165 districts in 1984, Stewart-Brown and Haslum (1988) found that all districts screened for reduction in distance visual acuity, 96% screened for colour vision defects, 73% for strabismus and 67% for reduction in near visual acuity. The frequency of testing varied from yearly, to once on school entry.

The main problems identified with the existing methods for screening in schools can be summarised as follows:

1. The facilities available for vision screening in schools are often inadequate. Lighting and general ambient conditions are often difficult to control and the viewing distance for test charts is often constrained by the dimensions of the room allocated by the school.

2. The personnel responsible for administering vision tests often have very limited knowledge of the eyes or vision and yet are required to interpret test results and exercise some discretion about the need to refer.

3. The battery of tests employed for vision screening is usually predetermined and fixed. This takes no account of a child’s symptoms and history and excludes the use of other tests which may provide valuable information about the visual status of the child.

4. The time taken to perform a vision screening is dependent on the protocol employed. In most cases the process is entirely manual requiring a school nurse to administer the tests and prepare referral reports. This can be tedious and time consuming.

In this paper, a radical new system for vision screening in schools is described which overcomes many of the criticisms of current screening methods. The system is based on a computer program designed to run on any PC running under Microsoft Windows 3.1 or Windows 95.

The eventual aim is for the program to be used by school nurses or other suitable personnel. The program interface has been carefully designed to allow vision screening to be carried out by those with minimal computer skills.

The program provides a self-contained vision screening system capable of generating questionnaires, presenting test stimuli on a standard computer monitor, performing an expert analysis of results, managing a database of each child’s visual history, generating reports for parents, optometrists, doctors and teachers and providing summary statistics relating to the overall screening program.

A prototype system has been used to screen 245 children aged between 5 and 8 years. On the basis of this evaluation, the program has been modified and a brief description of the new system is included in the discussion.

Screening using the program involves three phases: (a) questionnaire phase; (b) vision testing; (c) analysis and report generation.
(a) Questionnaire phase

A printed questionnaire and consent form is sent home with each child to be completed by the child’s parents or carer. The questionnaire includes a series of questions relating to symptoms, signs, history and family history (Figure 1). This data is entered into the program’s database prior to the vision screening via a simple graphical interface (Figure 2).

(b) Vision testing

When the program is first loaded onto a computer, a simple calibration procedure is carried out. This requires the user to measure the width and height of a square displayed in the centre of the screen and to enter the screen viewing distance for the visual acuity tests (3–6 m). This calibration data is used to scale the test stimuli and calculate test results in terms of angular subtense (e.g. visual acuity).
At the time of the screening, the child's name is selected from the database and a series of vision tests are conducted. Throughout the screening the examiner is given instructions in a small help window at the bottom of the screen (Figure 3). Results for each test are recorded by simply “clicking” on the appropriate option and all data is stored in the database automatically.

The prototype system included tests of colour vision, monocular distance visual acuity for each eye and stereopsis.

Due to the problems of generating precise colours on a VDU screen, colour vision is assessed using selected plates taken from the Ishihara test. The result for each plate is entered into the program so that the diagnosis can be included in the analysis and reports.

Visual acuity is measured by presenting a single line of letters on the computer screen (Figure 3). The letters are surrounded by crowding bars and the size of the letters is scaled according to the viewing distance (3–6 m) and the size of the screen (available from the calibration routine). The initial letter size is set at LogMAR = 0.1 (6/7.5) (Bailey and Lovie, 1976). If all five letters are read correctly, the program moves on to the next test. If the child fails to identify one or more of the letters, letter size is increased by 0.1 LogMAR units. This is repeated until all letters are read correctly (or a predetermined ceiling is reached). The letter order is randomized to avoid learning effects. Laboratory studies have shown that visual acuities measured using the system correlate very well with those obtained using a standard LogMAR chart. Furthermore, results do not change significantly over a typical range of screen luminances (50–120 cd/m²).

The prototype program used a series of red/green stereo pairs to assess stereopsis. The child viewed the computer screen through red/green goggles from a distance of 50 cm. Four pairs of red and green circles were displayed, with one pair having a greater separation (disparity) than the other three. The task for the
Figure 3. Screen layout for the visual acuity test. The examiner simply “clicks” on the option buttons at the bottom of the screen to record the number of letters correctly read.

Table 1. The Risk Index is enumerated by first calculating a separate Risk Index for symptoms, family history and vision. For each type of eye defect ($ED_i$), the Symptoms Risk Index is determined by summing the weighted products of $S_n$ and $W_{ED,Sn}$, where the weighting ($W_{ED,Sn}$) reflects the probability of symptom $S_n$ occurring in condition $ED_i$. The Family History Risk Index and Vision Risk Index are calculated in a similar manner. The overall Risk Index is the sum of the Symptoms Risk Index, the Family History Risk Index and the Vision Risk Index.

<table>
<thead>
<tr>
<th></th>
<th>Eye Defect 1 ($ED_1$)</th>
<th>Eye Defect x ($ED_x$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Symptom 1 ($S_1$)</td>
<td>$S_1 \cdot W_{ED}, S_1$</td>
<td>$S_1 \cdot W_{ED}, S_1$</td>
</tr>
<tr>
<td>Symptom 2 ($S_2$)</td>
<td>$S_2 \cdot W_{ED}, S_2$</td>
<td>$S_2 \cdot W_{ED}, S_2$</td>
</tr>
<tr>
<td>Symptom n ($S_n$)</td>
<td>$S_n \cdot W_{ED}, S_n$</td>
<td>$S_n \cdot W_{ED}, S_n$</td>
</tr>
<tr>
<td>Symptoms Risk Index (SRI)</td>
<td>$\sum_n S_n \cdot W_{ED}, S_n$ ($SR_{E,D}$)</td>
<td>$\sum_n S_n \cdot W_{ED}, S_n$ ($SR_{E,D}$)</td>
</tr>
<tr>
<td>Family History 1 ($F_1$)</td>
<td>$F_1 \cdot W_{ED}, F_1$</td>
<td>$F_1 \cdot W_{ED}, F_1$</td>
</tr>
<tr>
<td>Family History 2 ($F_2$)</td>
<td>$F_2 \cdot W_{ED}, F_2$</td>
<td>$F_2 \cdot W_{ED}, F_2$</td>
</tr>
<tr>
<td>Family History n ($F_n$)</td>
<td>$F_n \cdot W_{ED}, F_n$</td>
<td>$F_n \cdot W_{ED}, F_n$</td>
</tr>
<tr>
<td>Family History Risk Index (FHRI)</td>
<td>$\sum_n F_n \cdot W_{ED}, F_n$ ($FHR_{E,D}$)</td>
<td>$\sum_n F_n \cdot W_{ED}, F_n$ ($FHR_{E,D}$)</td>
</tr>
<tr>
<td>Acuity (RE) ($V_1$)</td>
<td>$V_1 \cdot W_{ED}, V_1$</td>
<td>$V_1 \cdot W_{ED}, V_1$</td>
</tr>
<tr>
<td>Acuity (LE) ($V_2$)</td>
<td>$V_2 \cdot W_{ED}, V_2$</td>
<td>$V_2 \cdot W_{ED}, V_2$</td>
</tr>
<tr>
<td>Stereopsis ($V_3$)</td>
<td>$V_3 \cdot W_{ED}, V_3$</td>
<td>$V_3 \cdot W_{ED}, V_3$</td>
</tr>
<tr>
<td>Colour Vision ($V_4$)</td>
<td>$V_4 \cdot W_{ED}, V_4$</td>
<td>$V_4 \cdot W_{ED}, V_4$</td>
</tr>
<tr>
<td>Vision Risk Index (VRI)</td>
<td>$\sum_n V_n \cdot W_{ED}, V_n$ ($VRI_{E,D}$)</td>
<td>$\sum_n V_n \cdot W_{ED}, V_n$ ($VRI_{E,D}$)</td>
</tr>
<tr>
<td>Overall Risk Index</td>
<td>$SR_{E,D} + FHR_{E,D} + VRI_{E,D}$</td>
<td>$SR_{E,D} + FHR_{E,D} + VRI_{E,D}$</td>
</tr>
</tbody>
</table>
child was to identify which of the four circles "stood out more" than the others. If the child was able to identify the circle correctly, the procedure was repeated with a reduced disparity. The three levels of disparity used by the prototype program were 110, 220 and 330 s of arc.

**Data analysis**

On completion of the screening, the data is analysed by a series of algorithms. Two forms of analysis are undertaken. The first is based on a simple set of criteria for each set of vision test results. The pass/fail criterion for each of the tests can be set to comply with the policy of the school or health authority. This basic analysis is similar to that performed in most screening programs.

The second analysis attempts to model the decision processes carried out by a clinician by taking account of symptoms, family history and test results. It has been assumed that the visual problems most likely to occur among school children are myopia, hypermetropia, astigmatism, strabismus, amblyopia and various binocular vision anomalies (decompensated phoria, convergence insufficiency, etc.) It is argued that all of these conditions can be detected by a combination of questionnaire data and vision test results. For example, myopia, astigmatism and amblyopia will all cause a reduction in visual acuity at distance. Strabismus will cause a reduction in stereoaucity and often a reduction in acuity in one eye. Binocular vision anomalies which are symptomatic will be detected from the questionnaire responses and perhaps by a loss of stereoaucity. Asymptomatic binocular vision anomalies usually do not require further investigation anyway.

The program determines the most likely diagnosis by means of a series of algorithms which determine a Risk Index for myopia, hypermetropia, astigmatism, amblyopia/anisometropia, strabismus, alternating strabismus and binocular vision anomalies respectively (see Table 1). The condition which produces the highest Risk Index is deemed to be the most likely diagnosis. If the Risk Index exceeds a predetermined threshold, the child is deemed to have failed the screening.

The Risk Index is enumerated by first calculating a separate Risk Index for symptoms, family history and vision (see Table 1). Symptoms ($S_n$) and Family History ($FH_n$) are binary values (yes/no) for questions 1 to n in the questionnaire. Vision ($V_a$) is a continuous variable derived for each of the vision tests. For each type of eye defect ($ED_a$), the Symptoms Risk Index is determined by summing the weighted products of $S_n$ and $W_{ED,S}$, where the weighting ($W_{ED,S}$) reflects the probability of symptom $S_n$ occurring in condition $ED_a$. The Family History Risk Index and Vision Risk Index are calculated in a similar manner. The overall Risk Index is the sum of the Symptoms Risk Index, the Family History Risk Index and the Vision Risk Index and provides an indication of the likelihood that the patient has condition $ED_a$. By performing the analysis for a range of conditions (myopia, hypermetropia, astigmatism, amblyopia and binocular vision problems) and comparing the Risk Indices for each condition, the program is capable of predicting the most likely diagnosis for a given set of symptoms, family history and vision test results.

For example, in binocular myopia the most likely symptom is "poor distance vision". This symptom would be given a high weighting, while symptoms "poor close vision", "frequent headaches", etc. are not common in binocular myopia and therefore receive a low weighting. The Symptoms Risk Index being the weighted sum of the symptoms thus gives a measure of the probability that the child has myopia based purely on the symptoms. As binocular myopia has a strong hereditary component, the risk of the child having myopia is increased if parents or siblings wear spectacles. This factor is taken account of by the Family History Risk Index which includes a high weighting for spectacles in the family and a low weighting for "squint" and "lazy eye". The effect of myopia on vision will be to reduce distance acuity; results for the stereopsis test may be normal. By giving a high weighting to distance acuity and a low weighting to the other test results, the Vision Risk Index for myopia indicates the probability that the child has myopia. In the same way that a clinician would take into account symptoms, history, family history and test results when making a diagnosis, the overall Risk Index takes account of the Symptoms Risk Index, the Family History Risk Index and the Vision Risk Index.

A similar analysis is performed for hypermetropia, astigmatism, amblyopia and binocular vision problems. The condition which produces the highest Risk Index is deemed to be the most likely diagnosis for the given set of symptoms, history and vision test results. In some cases the Risk Index for one condition is much greater than for all other conditions giving a clear diagnosis (Figure 4). In other cases the Risk Index for several conditions may be similar, thus making the differential diagnosis more difficult. The Risk Index for a given condition divided by the sum of the Risk Indices for all other conditions gives an indication of the confidence in the diagnosis.

The major challenge in this exercise was to establish suitable weightings for each of the symptoms, each aspect of the family history and each vision test result and the relative weightings for each condition. While some guidance is available in the literature, reports
relating symptoms and family history to specific eye defects are often anecdotal and are seldom quantitative. Therefore, in order to establish a set of initial weightings, five experienced optometrists were issued with a questionnaire and asked to estimate the weighting that they would give to each of the symptoms, each aspect of family history and each vision test result in relation to the diagnosis of each of the seven conditions. The mean of these results was used as the basis for the initial set of weightings. These initial weightings were then modified empirically by observing the results of the analysis algorithm for a series of model sets of data invented by the five optometrists. The weightings were then “fine tuned” with reference to vision screening and clinical data for 245 children (described below).

In order to generate appropriate recommendations, the program assigns a binary value to each of the following:

- Criterion Analysis
- Advanced Analysis
- Recent Eye Test
- Symptoms
- Family History

This gives a total of 32 \(2^5\) possible outcomes to the screening. An appropriate paragraph of text was prepared for each of these outcomes.

The exact wording and layout of reports can be customised to reflect the policy of each health authority. The layout of a typical report is shown in Figure 5. A summary report is also available for teachers and a technical breakdown of results can be produced for a referral letter to the optometrist or doctor.

The program also provides a breakdown of global statistics, e.g. prevalence of symptoms, distribution of acuity, overall pass rate, etc. Such statistics should be of value to those responsible for administering screening programs.

**Preliminary evaluation**

**Methods**

The prototype version of the program has been evaluated on a sample of children aged between 5–8 years in a school in Aylesbury, England. Questionnaires and a covering letter were distributed to 284 children who were asked to deliver them to their parents. Parents were requested to return the

![Figure 4](image-url)  
**Figure 4.** Graph showing the outcome of the advanced analysis for a 6 year old myope (−1.50DS R/L) who was reported to “screw up” his eyes and to have difficulties seeing objects in the distance. Both of his parents were myopic. Risk Indices for each potential eye defect are calculated from the sum of the Symptoms Risk Index, the Family History Risk Index and the Vision Risk Index.
completed questionnaire within 6 days. The question-
naire is shown in Figure 1. Questionnaire responses were
entered into the program’s database prior to the screening.

The program was installed on two PCs (486–50 MHz)
which were subsequently set up in two corridors in the
school. The screen “brightness” was adjusted so that the
background for the acuity test was 80 cd m⁻². The hori-
zontal illuminance at desktop level immediately in front
of the monitor was between 100 and 300 lx. Care was
taken to avoid reflections on the screen.

Dame Alice Owen School

VISION SCREENING REPORT (Parent’s copy) Date : 8-10-98

Dear parent / guardian,

RE: Andrew Myope  DoB: 12/02/1990  Class: 1

Andrew’s eyes were checked at school on 15 Sep 98. Results of the screening were as
follows:

History
Last Eye Test : Never.
Spectacles : Does not currently wear spectacles.

Symptoms
- Problems seeing in the distance.
- Screws up eyes.
- Blinks excessively.

Family history
- A member of the immediate family wears spectacles

Results of vision tests
Distance vision : Right Eye : Poor
Left Eye : Poor
Test for longsightedness : Good
Ability to use both eyes together : Good
Eye coordination : Good
Colour Vision : Some difficulty differentiating certain colours.

Summary
The results suggest that Andrew may be a little short-sighted. You are advised to get
Andrew’s eyes re-checked by an Optometrist (Ophthalmic Optician).

Andrew had some difficulty differentiating between certain colours. Colour vision
deficiencies are quite common and do not usually cause significant problems in everyday
life. However, it may affect Andrew’s ability to carry out certain classroom activities
(such as art). In addition, good colour vision is a requirement for a number of jobs/
occupations. If you were unaware of this problem, it might be worth getting your
optometrist (optician) to re-check Andrew’s colour vision and to discuss the implications
further.

If you require any further information, please contact the school nurse.

Figure 5. The program automatically generates customised reports for each child. The exact wording and lay-
out of each report can be modified by the operator.
At the time of the screening, the examiner selected the child’s name from the database and gave a brief explanation of each test as it was presented. The Ishihara plates were viewed under fluorescent light but if a child failed to read one or more plates, the test was repeated under daylight. Visual acuity was measured at 3 m while stereopsis was tested at 50 cm.

A child was deemed to have failed the vision screening if their visual acuity was less than LogMAR 0.2 (6/9.5 Snellen) in either eye or if the Risk Index calculated by the expert analysis exceeded a predetermined threshold. Details of how the Risk Index is calculated are given above.

Following the screening, an eye examination was carried out on the following groups:

(a) all children who failed the vision screening (n = 48);
(b) all children who passed the vision screening but who had symptoms (n = 23);
(c) 55 children selected at random from the group who passed the screening and were asymptomatic.

The eye examination consisted of distance and near acuity, distance and near cover test, retinoscopy, ophthalmoscopy, Titmus stereotest and near fixation disparity.

Criteria for failure of the eye examination were based on those proposed by the American Association of Optometrists (1979) (see Table 2).

### Results

Of the 284 questionnaires issued, 253 (92%) were returned. However, 2 were completed but not named and 6 were incomplete (giving a total of 245 valid questionnaires).

The prevalence of each of the symptoms included in the questionnaire is shown in Table 3.

### Table 2. Criteria used to define a pass/fail result for the full eye examination

<table>
<thead>
<tr>
<th>Condition</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visual acuity</td>
<td>&lt;0.2 LogMAR (6/9.5 Snellen) in either eye or 1 or more lines difference in LogMAR scores between the two eyes</td>
</tr>
<tr>
<td>Hypermetropia</td>
<td>+3.00 DS or more</td>
</tr>
<tr>
<td>Myopia</td>
<td>−0.75 DS or more</td>
</tr>
<tr>
<td>Astigmatism</td>
<td>1.50 DC or more</td>
</tr>
<tr>
<td>Anisometropia</td>
<td>1.00 DS or more</td>
</tr>
<tr>
<td>Strabismus</td>
<td>Any</td>
</tr>
<tr>
<td>Exophoria (at dist)</td>
<td>5 prism dioptres or more</td>
</tr>
<tr>
<td>Esophoria (at dist)</td>
<td>5 prism dioptres or more</td>
</tr>
<tr>
<td>Exophoria (at near)</td>
<td>10 prism dioptres or more</td>
</tr>
<tr>
<td>Esophoria (at near)</td>
<td>6 prism dioptres or more</td>
</tr>
<tr>
<td>Hyperphoria</td>
<td>2 prism dioptres or more</td>
</tr>
<tr>
<td>Pathology</td>
<td>Any</td>
</tr>
</tbody>
</table>

### Table 3. Prevalence of symptoms reported in the questionnaire

<table>
<thead>
<tr>
<th>Symptom</th>
<th>Prevalence (n)</th>
<th>(%)</th>
<th>Percentage of those with symptom who failed the screening (excluding colour vision)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poor distance vision</td>
<td>19</td>
<td>7.8</td>
<td>63.2</td>
</tr>
<tr>
<td>Poor vision at near</td>
<td>14</td>
<td>5.7</td>
<td>64.3</td>
</tr>
<tr>
<td>Intermittent blurring</td>
<td>9</td>
<td>3.7</td>
<td>77.8</td>
</tr>
<tr>
<td>Double vision</td>
<td>14</td>
<td>5.7</td>
<td>78.6</td>
</tr>
<tr>
<td>Frequent headaches</td>
<td>14</td>
<td>5.7</td>
<td>57.1</td>
</tr>
<tr>
<td>Closes or covers one eye</td>
<td>4</td>
<td>1.6</td>
<td>50.0</td>
</tr>
<tr>
<td>Frequently rubs eye(s)</td>
<td>22</td>
<td>9.0</td>
<td>54.6</td>
</tr>
<tr>
<td>Blinks excessively</td>
<td>7</td>
<td>2.9</td>
<td>71.4</td>
</tr>
<tr>
<td>Head tilt</td>
<td>8</td>
<td>3.3</td>
<td>50.0</td>
</tr>
<tr>
<td>Holds books very close</td>
<td>5</td>
<td>2.0</td>
<td>40.0</td>
</tr>
<tr>
<td>Tends to skip, re-read or omit words or lines when reading</td>
<td>28</td>
<td>11.4</td>
<td>35.7</td>
</tr>
<tr>
<td>Tires easily/short attention span when reading</td>
<td>33</td>
<td>13.5</td>
<td>42.4</td>
</tr>
<tr>
<td>Has better vision in one eye compared to the other</td>
<td>10</td>
<td>4.1</td>
<td>80.0</td>
</tr>
<tr>
<td>Has difficulty differentiating between certain colours</td>
<td>5</td>
<td>2.0</td>
<td>***</td>
</tr>
</tbody>
</table>

Vision screener for schools: W. D. Thomson and B. Evans
Overall, 29% of children reported one or more symptoms. The predictive value of each symptom can be gauged from the percentage of children reporting the symptom who subsequently failed the screening (see Table 3). The most common symptoms were tired easily/short attention span when reading (13.5%) and tends to skip, re-read or omit words or lines when reading (11.4%). However, only 42.4 and 35.7% of children with these symptoms respectively, failed the vision screening suggesting that in most cases, this problem was related to the demands of this newly-acquired skill rather than eye defects. The symptoms with the highest predictive value were better vision in one eye compared to the other (80%) and double vision (78%).

The prevalence of eye conditions in the family are shown in Table 4. 68% of those who failed the screening had a family history of eye problems (“lazy eye”, “squint”, “spectacles”) as compared to 42% of those who passed.

Data relating to the last eye examination is shown in Table 5. It can be seen that nearly half of the children screened had never had an eye examination by an optometrist.

Vision screening was carried out on 245 children. The average duration of a screening was just over 3 min.

Ten children (4.1%) failed the reduced Ishihara test while a further 5 had some difficulty with one or more of the plates. Only five of these were aware of their colour vision deficiency.

A frequency distribution of LogMAR scores is shown in Figure 6. 36 children (14.7%) had visual acuities of less than 0.2 LogMAR (6/9.5) in one or both eyes and of these, 7 had reduced acuity in both eyes. 26 of those with reduced acuity had not had an eye test in the past two years, two had spectacles but did not wear them for the test and 8 were wearing spectacles. Of the 8 spectacle wearers who failed the screening, four had an amblyopic eye, one had high astigmatism and 3 required a change in their spectacle prescriptions.

A further 12 children failed the screening on the basis of the advanced analysis. This occurred when visual acuity was borderline but the child had reported symptoms or when the child failed the stereopsis test and reported symptoms. This gave a total failure rate of 19.6%. However, 16 of those who failed had undergone an eye examination within the last 2 years and were simply advised to continue having regular eye examinations. Thus, the overall referral rate was 13.1%.

68% of those who failed the test reported one or more symptoms on the questionnaire, compared with 34% of those who passed the screening.

A total of 126 children were given a full eye examination following the screening. This included the 48 children who failed the screening, 23 children who passed the screening but had reported symptoms and 55 children who passed the screening and were asymptomatic.

### Table 4. Prevalence of a family history of eye defects

<table>
<thead>
<tr>
<th>Family member</th>
<th>Strabismus</th>
<th>“Lazy” eye</th>
<th>Spectacles (other than for reading only)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(n)</td>
<td>(%)</td>
<td>(n)</td>
</tr>
<tr>
<td>Father</td>
<td>5</td>
<td>2.0</td>
<td>13</td>
</tr>
<tr>
<td>Mother</td>
<td>9</td>
<td>3.7</td>
<td>12</td>
</tr>
<tr>
<td>Brother</td>
<td>3</td>
<td>1.2</td>
<td>1</td>
</tr>
<tr>
<td>Sister</td>
<td>5</td>
<td>2.4</td>
<td>2</td>
</tr>
</tbody>
</table>

### Table 5. Date of last eye examination by an optometrist as reported in the questionnaire

<table>
<thead>
<tr>
<th>Last eye examination by an optometrist</th>
<th>Number</th>
<th>%</th>
<th>Number who failed the screening</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than 1 year ago</td>
<td>64</td>
<td>26.1</td>
<td>8</td>
<td>12.5</td>
</tr>
<tr>
<td>1–2 years ago</td>
<td>40</td>
<td>16.3</td>
<td>8</td>
<td>20.0</td>
</tr>
<tr>
<td>More than 2 years ago</td>
<td>25</td>
<td>10.2</td>
<td>4</td>
<td>16.0</td>
</tr>
<tr>
<td>Never</td>
<td>116</td>
<td>47.3</td>
<td>30</td>
<td>25.9</td>
</tr>
</tbody>
</table>
Using the criteria given in Table 2, results of the screening were classified as true positive/negative or false positive/negative (Table 6).

This gives an overall sensitivity of 93.8% (95% confidence limits = ±6.85%) and a specificity of 96.1% (95% confidence limits = ±4.27%). Of the three false negatives, one was a +3.50DS hypermetrope who was asymptomatic and had good stereopsis, one was a −0.75DS myope whose visual acuity was just within the 0.2 LogMAR criterion and the other had an alternating esotropia with good visual acuities in each eye and surprisingly good stereopsis on both the screener and the Titmus test.

Of the three children who met the visual acuity criterion but failed on the basis of the advanced analysis, only one was found subsequently to be a false positive. Without the advanced analysis, there would have been 12 more false negatives reducing the sensitivity to 69%.

The three false positive results can only be explained by a lack of understanding on behalf of the children of what was required of them during the screening, in particular confusion over the stereopsis test.

A degree of caution is required in the interpretation of these results as the weightings used in the analysis were modified to some extent using the results themselves. This may have given a false impression of the effectiveness of the analysis algorithm. A true picture will only emerge when the same algorithm is used on a new set of data.

**Discussion**

The *City University Vision Screener for Schools* was well-received by the school nurse, teachers, parents and the children. Teachers particularly valued the detailed report about each child generated for them by the program. The high return rate of questionnaires indicated strong support by parents for vision screening and informal feedback indicated that the reports sent home with every child were well-received. The children themselves viewed the tests as a form of “computer game” and responded extremely well.

There have been a number of large scale screening programs carried out on children of school age. However, results are difficult to compare in view of the different tests employed and failure criteria adopted. Hamilton (1974) showed a mean referral rate for school children aged 3–17 of 12.4%, with a further 7.9% not referred because they were already under professional care. Coleman (1970) examined 3623 school children (grades preparatory to 6) using the Modified Clinical Technique and found an overall referral rate of 20% for males and 26% for females. Robbins and Bailey (1975) examined 1243 children (aged 3–11) using the Modified Clinical Technique and reported that 29.2% had “significant or suspicious” defects of vision. However, some of these children were already under professional care and some did not warrant immediate referral. Their overall referral rate

### Table 6. Results of vision screening related to the outcome of a full eye examination

<table>
<thead>
<tr>
<th></th>
<th>False positive (Incorrect fail)</th>
</tr>
</thead>
<tbody>
<tr>
<td>True positive</td>
<td>3</td>
</tr>
<tr>
<td>(correct fail)</td>
<td></td>
</tr>
<tr>
<td>True negative</td>
<td>False negative (Incorrect pass)</td>
</tr>
<tr>
<td>(correct pass)</td>
<td>3</td>
</tr>
</tbody>
</table>

![Figure 6. Frequency distribution of LogMAR scores.](image)
was 10.1% for boys and 7.9% for girls. Jewell et al. (1994) measured the visual acuity of 1069 children of secondary school age and found that 8% had a visual acuity of 6/9 or less in one or both eyes. Hatch (1993) used a computerized screener known as the VTA/VERA to test 602 children aged between 6 and 13 years and found an overall referral rate of 15%. The overall failure rate of 19.6% and referral rate of 13.1% found in this evaluation was therefore similar to that found in previous studies.

Measures of the sensitivity and specificity of school vision screening programs are not often available and values for different programs are very difficult to compare because they depend on both the pass/fail criteria adopted for the screening test(s) and the methods and criteria used to define the “gold standard”. Hatch (1993) compared the results of the VTA/VERA screener with the outcome of a full eye examination and found the former to have a sensitivity of 75% and specificity of 93%. The sensitivity and specificity of the computer-based system evaluated in this study (96.1 and 93.8% respectively) compares favourably with this result. However, in this study the program was operated by experienced clinicians and it remains to be seen if similar results can be obtained when operated by school nurses. Furthermore, the analysis routines were fine-tuned using the same data and therefore the results must be interpreted with a degree of caution.

The value of including information about symptoms, history and family history in the analysis is demonstrated by the 12 children with vision problems who were detected by the advanced analysis but would have passed on the basis of a simple acuity and stereopsis criterion.

On the basis of experience using the prototype system, the screener has been developed further and is currently being evaluated on a larger sample of school children.

The main changes which have been made are as follows:

1. The questionnaire has been modified to reduce ambiguity. Questions found to have little diagnostic value have been removed and several new questions have been added.
2. A choice of test target is available during visual acuity testing including upper case letters, lower case letters and illiterate Es.
3. A red/green random dot stereotest is now used instead of the red and green circle pairs. The child views the screen through red/green goggles from a distance of 50 cm. Four separate random dot stereograms are displayed on the screen. Within each stereogram a shape is seen to stand out from the plane of the screen. The task for the child is to identify the shape in each stereogram. If the one or more of the shapes on the first screen are correctly identified, the procedure is repeated with a reduced disparity. The exact disparity is dependent on the size and resolution of the monitor which is known from the calibration data.
4. Additional tests are included when indicated by the symptoms or when the results of the core tests are ambiguous.

   Hypermetropia is screened for by measuring distance visual acuity with the child wearing +2.50DS lenses. If distance acuity is reduced by less than two lines by the +2.50DS lenses then hypermetropia is suspected.

   Binocular vision problems are detected using a fixation disparity test using red and green dissociation for the “nonius” markers.

5. The advanced analysis has been modified to include the new tests and now includes a logic structure in addition to the weighted analysis.

Conclusions

Overall, 19.6% of children screened were found to have some form of visual defect (excluding colour vision deficiencies). While some of these children were aware of their problem and were already under professional care, two thirds were not. It is clear therefore that many children with visual problems are not being detected by pre-school screening which reinforces the case for screening at least on school entry.

With the advent of computers, a vision screener does not need to be a passive device, applying a strict pass/fail result according to results of vision tests considered in isolation. The screener described in this paper uses a standard personal computer to provide a complete screening system for schools including the generation of questionnaires, presentation of appropriate test stimuli on the screen, analysis of results and the preparation of customised reports for parents, teachers, doctors, optometrists etc. A prototype system has been shown to be sensitive, specific and efficient.

On the basis of experiences with the prototype system, the screener has been developed further and the new system is currently being evaluated on a larger sample of school children. By using an “expert system” to analyse symptoms, history, family history and vision test results it is hoped that the program will enable semi-skilled personnel to provide a cost-effective screening service of unprecedented sensitivity and specificity.
References


