Photoscreening for refractive errors in children and young adults with severe learning disabilities using the MTI photoscreener

PATRICK WATTS, KAREN WALKER, LYN BECK

Abstract

Purpose To test the potential ability of the MTI photoscreener to facilitate screening for significant refractive errors in children and young adults with severe learning disabilities. *Methods* Thirty-eight patients with severe learning disabilities from a special school were examined with the photoscreener, and underwent cycloplegic refraction, an ophthalmological and an orthoptic examination. The age at examination, the cause of learning disability, the pupil size, the number of photographs required for accurate interpretation, the co-operation of the subject and the presence or absence of strabismus were recorded. An educational psychologist had performed a psychological assessment on all the children. The results of the cycloplegic retinoscopy were compared with the photorefraction results.
Results A photorefraction was possible in 37 patients and cycloplegic refraction in all the patients. The patients had severe learning difficulties with an intelligence quotient of less than 50. All the patients had behavioural problems, 9 patients had associated cerebral palsy, 8 had chronic epilepsy, 1 patient was brain damaged from a non-accidental injury and 1 from a road traffic accident. The mean age of the patients was 10.0 ± 4.9 years (range 3–18 years), the average pupil diameter during photoscreening was 6.1 ± 0.9 mm (range 4–8 mm) and the average number of photographs required for each subject was 2.1 ± 0.9 (range 1–4). The photoscreener detected 10 patients with a manifest strabismus. There was one false positive and one false negative result giving a sensitivity of 92.8% and a specificity of 90%.
Conclusion The examination of children with severe learning disabilities for refractive errors can be extremely difficult. The MTI photoscreener is an effective means of screening such children and young adults for refractive errors and strabismus so that the children with these abnormalities may be targeted for a more detailed evaluation.

Key words Photoscreener, Refractive errors, Severe learning disabilities

The incidence of refractive errors and strabismus is high in children with learning disabilities.[1] Visual acuity is difficult to test; often the pupillary responses and the fixation behaviour are the only means of assessing these severely handicapped children. The clinical examination and evaluation with a cycloplegic refraction involves a considerable amount of time and patience to be accurate and is often inadequate. An additional problem is the altered behaviour of these children in an unfamiliar hospital environment. This places further constraints on the limited time available for each individual patient. However, it is this group of disadvantaged children who need help most, as their rehabilitation and care is helped by optimising their visual input. An accurate screening method whereby the children with significant visual problems are referred for further evaluation would allow more time for clinical evaluation of a targeted group with better utilisation of limited resources.

Photoscreening devices are effective tools for detecting refractive errors in children at risk of developing amblyopia;[2] however, their role in evaluating refractive errors in children with severe learning disabilities (SLD) has not been assessed. We document our experience with the MTI photoscreener in a group of such children.

Subjects and methods

The parents or legal guardians of 40 children attending a school for those with special needs gave written informed consent for their

P. Watts
K. Walker
L. Beck
Cardiff Eye Unit
University Hospital of Wales
Cardiff CF4 4XW, UK

Patrick Watts, FRCOphth ✉
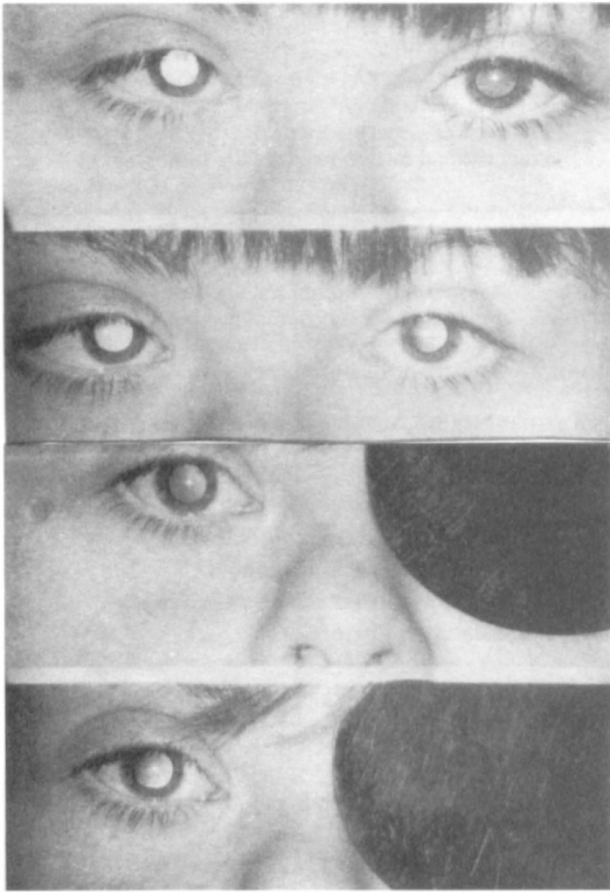58 Crystal Wood Road
Heath
Cardiff CF4 4HW, UK

Fig. 1. *Case 16. The upper two photographs demonstrate esotropia; hence only the left eye was used for interpretation (hypermetropic astigmatism). In the lower two photographs the esotropic right eye is now fixing with an occluder over the left eye, and hence can be used for interpretation.*

mean age of the patients was 10.0 ± 4.9 years (range 3–18 years). All patients had been psychologically assessed and found to have severe learning disabilities and behavioural problems, and had an intelligence quotient (IQ) below 50. Nine patients had associated cerebral palsy, 8 patients had chronic epilepsy, 1 had sustained non-accidental injury and 1 had been in a road traffic accident, both in infancy. Communication skills were limited in all patients.

An orthoptist and an ophthalmologist examined all patients. The orthoptic assessment and the photoscreening results were masked to the examining ophthalmologist. The records of 30 of these children who had undergone previous eye examinations at the time of entry to the special school were available but masked to the examiners. The parents or guardians of the remaining 8 children did not recall a previous eye assessment apart from testing by the school nurse or a health visitor. The examinations took place at the special school in a darkened room in an area familiar to the patients. Soft background music was played which had a soothing effect on particularly disruptive children.[3]

The MTI photoscreener (Medical Technology & Innovations, Inc.) uses a camera with off axis or eccentric photorefraction and fixed flash eccentricity, with respect to the camera lens. A fixed testing distance achieves consistent result.

Photoscreening was carried out initially with both eyes open. If a deviation of the visual axis was detected by the position of the corneal reflexes, each eye was photographed separately to determine the refractive status with accurate fixation (Fig. 1). A twinkling red light, slightly eccentric to the camera flash, was the fixation target. The examiner was at a standard fixed distance as judged by the position of two illuminated red arrows, which were projected onto the patient's forehead and aligned to touch at their points (Fig. 2). Photographs

children's eyes to be examined, which included refraction and photography. Two children's parents refused eye drops for the cycloplegic refraction and these patients were hence excluded from the analysis. Of the remaining 38 children, 22 were female and 16 male. The

Fig. 2. *Demonstration of the use of the photoscreener (in a volunteer), which achieves a constant distance from the examiner to the patient when the illuminated arrowheads meet on the forehead. A twinkling red light and a musical tune, which emanate from the instrument, hold the patient's fixation.*
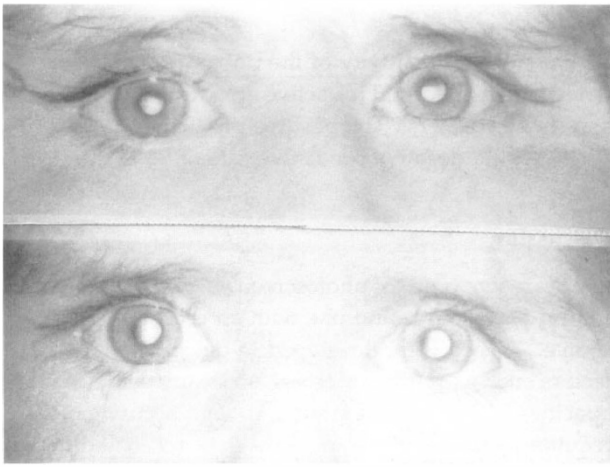
Fig. 3. *Case 19. Hypermetropia with astigmatism: the bright cresents are placed inferiorly in the pupillary area in the upper photograph and to the right of the pupillary area in the lower photograph.*
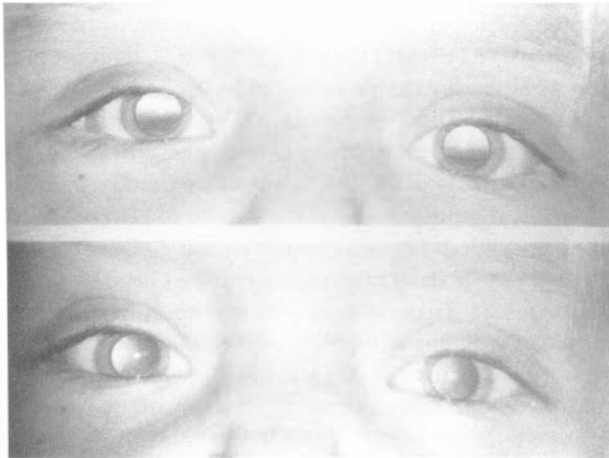

Fig. 4. *Case 28. Myopia: the bright cresents are placed superiorly in the pupillary area in the upper photograph and to the left in the pupillary area in the lower photograph.*

Fig. 5. *Case 27. Intermittent right esotropia; photorefraction demonstrates hypermetropia in the right eye and emmetropia in the left (anisometropia). Cycloplegic refraction uncovered hypermetropia in the left eye as well.*

were repeated if the fixation pattern was inadequate for interpretation. The darkened examination area allowed photoscreening with an ideal pupillary size range of 4 mm to 8 mm (mean 6.1 ± 0.9 mm).

The interpretation of the photographs was assessed independently by two examiners (P.W. and K.W.) whose results were masked from each other. The position and the size of the bright crescent provide an estimate of the refractive error. In the upper photograph the flash is oriented horizontally; hence the bright crescents are located either at the top or bottom of the photograph. In the lower photograph the flash is oriented vertically and the bright crescents are formed either to the left or right. The type of refractive error detected for each eye can be interpreted by considering the following:

- An equal-sized bright crescent, 3 mm or more, located at the bottom in the upper photograph and to the examiner's right in the lower photograph signifies a positive screen for hypermetropia (Fig. 3).
- An equal-sized bright crescent, 2 mm or more, located at the top in the upper photograph and to the examiner's left in the lower photograph signifies a positive screen for myopia (Fig. 4).
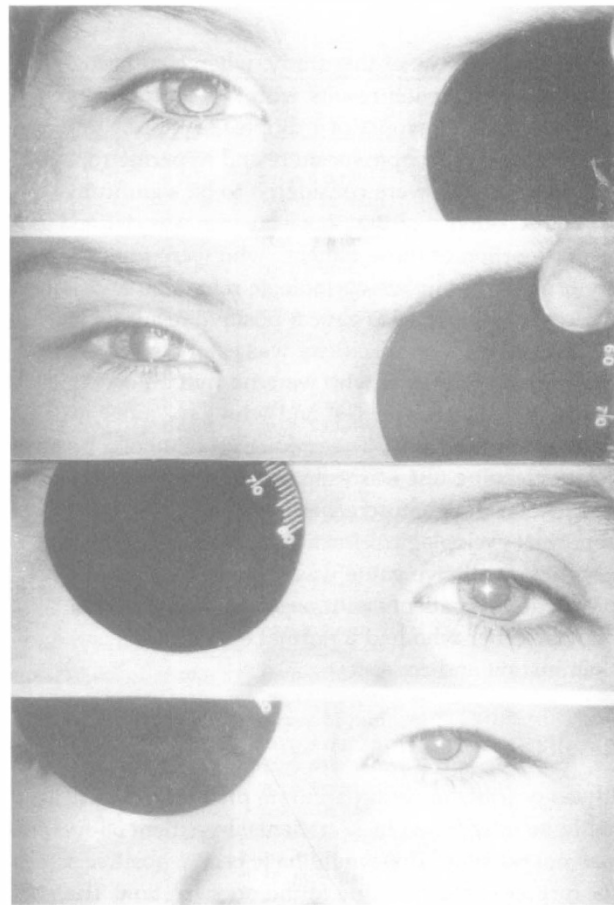
- Bright crescents located in the same positions in both eyes, with the same size for the upper and lower photographs but a larger crescent in one eye (difference of 2 mm or more), signifies anisometropia (Fig. 5).
- A difference of 2 mm or greater in the size of the bright crescent between the upper and lower photographs of the same eye indicates astigmatism (Fig. 1).

The above interpretations are based on those recommended in the manufacturer's instruction manual for system model MTI-PS100.

In addition to an estimate of the refraction and the presence or absence of strabismus, an evaluation of the lid position and the clarity of the fundal reflex (which is grey) was also possible.

Ophthalmic assessment included a visual acuity assessment if possible with one of the following: Snellen acuity, Sheridan Gardiner test, Kay pictures or Cardiff visual acuity cards. Assessment of the patient's ocular motility and cycloplegic refraction (half an hour after 1% cyclopentolate was instilled) was then carried out. The media and fundi were examined with a direct and indirect ophthalmoscope.

365

For the purpose of this study, when comparing cycloplegic refraction results with the photoscreening positive results, myopia of 1 dioptre or more, astigmatism of 1 dioptre or more and hypermetropia of 2 dioptres or more were considered to be significant.

The sensitivity of the photoscreener was defined as the proportion of those patients who were found to be abnormal on complete cycloplegic refraction and with the cover test who also gave a positive result with the photoscreener. The specificity was estimated as the proportion of patients who were normal on cycloplegic examination and cover test and who gave a negative photoscreening result. The predictive value of a positive photoscreening test was estimated by the proportion positive on the photoscreener and those with an abnormal cycloplegic refraction or cover test. The negative predictive value was estimated as the proportion of patients with negative results on the photoscreener who had a normal cycloplegic examination and cover test.

Results

It was possible to obtain accurate photographs which could be interpreted in 37 patients. In patient 38 fixation was not possible. This would have been a positive screen for further evaluation due to the poor fixation. The details of patients are included in Table 1.

Although the camera was developed only to estimate the type of refractive error, some quantification of the magnitude of the refractive error based on the size of the bright crescent was possible.

There were 6 patients with manifest esotropia and 4 patients with a manifest exotropia. These patients had additional photographs performed with each eye fixing to evaluate the refractive error of each eye independently with accurate fixation. Agreement was found between the two observers in the interpretation of the photoscreener results in 100% of cases.

There was a 73.5% positive screening result with the photorefraction (65.7% manifesting refractive errors and 7.8% with strabismus alone), with 1 false positive refractive error screen and 1 false negative refractive error screen. Of those who screened positive with the MTI photoscreener, 31.5% (12 patients) had astigmatism, 21.1% had myopia (8 patients), 13.2% had hypermetropia (5 patients), 7.8% had strabismus alone (3 patients) and fixation was poor in 1 patient (2.5%). The other 7 patients with strabismus screened positive for strabismus and refractive errors.

Cycloplegic refraction revealed that 68.4% had significant refractive errors with more astigmatism being uncovered, 20 patients had astigmatism, 2 were myopic and 4 were hypermetropic.

The one false positive result was where the photoscreener incorrectly identified myopia. However, the patient had no significant refractive error with cycloplegic refraction. The false negative result was due to the photoscreener failing to identify a significant degree of astigmatism.

The overall sensitivity of the photoscreener in detecting an abnormal refractive error was 92.8% and the specificity was 90%. The positive predictive rate was 96.4% with a negative predictive rate of 90%.

Discussion

There are two types of photoscreeners: one with a coaxial central flash source and one with an eccentric flash source.[4–7] They were developed to detect amblyogenic factors such as refractive errors, strabismus and media opacities.[8,9] The coaxial system, though accurate, requires a number of photographs to be taken at different distances and is more complex in its interpretation than the eccentric system.[10] The MTI photoscreener utilises an eccentric flash source to measure refraction in the vertical and horizontal meridians. The sensitivity of the MTI photorefractor in young children (6–59 months) has been reported as 81.8% and the specificity 90.6%, with positive and negative predictive values of 68.9% and 95.2%, respectively.[2] The Visiscreener 100, with an eccentric flash source, has been shown to have a sensitivity of 91% and a specificity of 74%, with a positive predictive value of 84% and a negative predictive value of 85%, when used in children between 3 months and 8 years.[11] Two other eccentric flash photoscreeners, the Otago photoscreener (sensitivity of 70% and specificity of 82%) and the Dortmans videophotorefractor (sensitivity of 70% and specificity of 90%), are also useful screening devices for refractive errors.[12,13] The sensitivity and specificity in our study of children with severe learning disabilities were 92.8% and 90%, respectively.

In a study by Tong et al.[14] when preverbal children (aged 3 years or younger) were tested with the MTI photoscreener and the photographs graded by 18 different graders, ranging from paediatric ophthalmologists to Lion's club volunteers, the sensitivities ranged between 37% and 88% and specificities between 40% and 88%. This difference between the results in our study and the one above may be due to the different group of children tested, the graders used (which in our study were an orthoptist and an ophthalmologist) and the number of photograhs taken before an ideal one was chosen for interpretation.

Photoscreening in verbal children and older children of normal intelligence past the amblyogenic age is not necessary due to the relative ease of standard cycloplegic refraction. In non-verbal children with severe learning disabilities, refraction is an arduous task involving a considerable degree of time and patience. Howland and Sayles[15] found a 4-fold increase in the prevalence of refractive errors in disabled children compared with normal age-matched children. Neurologically or intellectually impaired children have a higher prevalence of refractive errors.[16] Mentally handicapped children have a high prevalence of ocular anomalies and 52% have high refractive errors.[17] In a Finnish study[1] of ophthalmic findings in children with severe learning difficulties, the prevalence of refractive errors was inversely related to the level of IQ. In children between 9

Table 1. *Patient details*

Case no.	Age (years)	Sex	Diagnosis	Eye	Cycloplegic refraction	Ocular examination	Pupil size	Photo-crescent	No. of photographs
1	6	M	cp/nystagmus	R	−9.00/−3.00×180	nystagmus	6 mm	myp 4 mm	2
				L	−9.00/−3.00×180		6 mm	myp 4 mm	
2	9	M	sld/bp	R	+7.50	–	7 mm	hyper 6.5 mm	1
				L	+7.50	–	7 mm	hyper 6.5 mm	
3	14	M	sld/bp	R	−0.50	–	5.5 mm	myp 1 mm	1
				L	−0.50	–	5.5 mm	myp 1 mm	
4	11	M	sld/nai	R	−1.50	–	7 mm	myp ast 3 mm/1 mm	1
				L	−1.50	–	7 mm	myp ast 3 mm/1 mm	
5	6	M	sld/aut	R	+0.75	–	5 mm	hyper < 1 mm	2
			bp	L	+0.75	–	5 mm	hyper < 1 mm	
6	17	M	RTA/brain	R	+0.50	pale disc	7 mm	myp 1 mm	3
			damage	L	+0.25	pale disc	8 mm	myp 1 mm	
7	14	F	sld/bp	R	emmetropic	–	6 mm	myp 1 mm	1
			epilepsy	L	−0.5 at 180	–	5 mm	myp 1 mm	
8	11	M	sld	R	+1.00	–	7 mm	hyper 1.5 mm	2
			labands	L	+1.00	–	7 mm	hyper 1 mm	
9	18	F	sld	R	−0.75/+2×90	–	7 mm	myp 2 mm/hyp 1 mm	2
			epilepsy	L	−0.75/+2.00×90	–	7 mm	myp 2 mm/hyp 1 mm	
10	12	F	sld/21	R	−0.75/+2.50×40	(L)ET−15	6 mm	myp 1 mm	2
			spina bifida	L	−4.00/+5.00×120		6 mm	myp 1 mm	
11	16	F	cp	R	+6.00	–	5 mm	hyper 3.5 mm	2
			epilepsy	L	+7.50/1.50×90	–	5 mm	hyper 4 mm	
12	17	F	sld	R	−16.00		6 mm	myp 5 mm	3
				L	−12.00/−4.00×60		6 mm	myp 5 mm	
13	12	F	sld/bp	R	+4.50		7 mm	hyper 4.5 mm	2
			epilepsy	L	+3.00/+1.00×110	ptosis	7 mm	hyper 4.5 mm	
14	15	M	sld	R	−1.25/−1.50×180	(R)XT−20	7 mm	myp 4 mm/myp 1 mm	4
				L	−1.25/−2.25×180		7 mm	myp 4 mm/myp 2 mm	
15	13	F	sld	R	−2.00/−5×180	(L)XT−10	6.5 mm	myp 4 mm/myp 3 mm	2
				L	−3.00/−4×180		6.5 mm	not possible	
16	15	F	sld/Down's	R	−1.00/+2.75×90	(R)ET−18	6 mm	ast-nil/hyper 4 mm	3
			syndrome	L	+0.5/+2.00×90		6 mm	ast hyper 1 mm/hyper 3 mm	
17	15	F	sld/bp	R	−1.00/−6.50×160	(R)XT−20	8 mm	ast myp 6 mm/myp 3 m	4
				L	−1.25/−4.25×180		8 mm	ast myp 6 mm/7 mm	
18	6	M	cp/sld	R	−1.75/+2.25×90	nystagmus	4 mm	emm	2
			deaf	L	−1.75/+2.75×90		4 mm	ast-nil/hyper 2 mm	
19	9	M	sld	R	+5.00/+5.00×90	onh	4 mm	ast hyper 2.5 mm/3.5 mm	2
				L	+6.00/+2.00×90	–	4 mm	ast hyper 2.5 mm/3.5 mm	
20	15	F	22 deletion	R	−6.00	–	7 mm	myp 6 mm	1
			sld, epilepsy/cp	L	−5.50/−1.00×180	–	7 mm	myp 6 mm	
21	15	F	sld	R	+0.50	(L)XT−10	6 mm	myp 1.5 mm	4
			epilepsy	L	+0.50/+0.50		6 mm	emm	
22	9	M	cp/epilepsy	R	emmetropic	–	6 mm	emm	2
			diplegia	L	emmetropic		6 mm	emm	
23	6	F	cp/quad riparesis	R	−0.5	disc col	5 mm	myp 3 mm	2
			sld/premature	L	emmetropic	(R)ET−20	5 mm	emm	
24	4	M	sld	R	+0.5	–	6 mm	myp 2 mm	2
			cp-athetoid	L	+0.5		6 mm	myp 2 mm	
25	3	F	cp	R	+1.25/0.75×90	–	7 mm	hyper 6 mm	2
			n. convulsions	L	+1.75/+1.25×90		7 mm	hyper 6 mm	
26	6	F	sld/aut	R	0/+1.25×90	–	6 mm	ast-nil/2 mm hyper	2
			bp	L	0/−1.25×180		6 mm	emm	
27	4	F	sld/dd	R	+3.50	(R)ET−14	6 mm	hyper 3 mm	4
				L	+3.75		6 mm	hyper 1 mm	
28	4	F	sld/dd	R	−1.75/−1.25×180	–	7 mm	myp 4 mm	1
				L	−2.00/−1.50×180		7 mm	myp 4 mm	
29	7	F	sld	R	+1.00	(R)ET−12	6 mm	ast-hyper 3 mm/1 mm	2
				L	+0.75/+1.00×140	(L)HT	6 mm	hyper 3 mm	
30	6	F	add/sld	R	+1.00		6 mm	myp 1 mm	2
				L	+1.00		6 mm	myp 1 mm	
31	8	F	gdd/sld	R	+1.75	(R)ET	5.5 mm	emm	2
			bp	L	+2.75		5.5 mm	emm	
32	7	M	sld	R	+1.00/+3.00×90		6 mm	ast-hyper < 1 mm/3 mm	1
			deaf-sn	L	+1.00/+3.00×90	–	6 mm	ast-hyper 1 mm/3 mm	
33	4	M	deaf/sld	R	+2.00	–	6 mm	ast-hyper < 1 mm/2 mm	1
				L	+2.00	–	6 mm	ast-hyper < 1 mm/2 mm	
34	6	M	gdd/cp	R	+0.75	–	6 mm	hyper 1 mm	2
			dyspraxia	L	+0.75		6 mm	hyper 1 mm	
35	4	M	sld/	R	−0/+1.25×90		6 mm	ast-hyper nil/1 mm	1
				L	−0/1+1.00×90		6 mm	ast hyper nil/1 mm	
36	4	M	sld/dd	R	0/+0.50×90	–	6 mm	emm	2
					0/+0.50×90		6 mm	emm	
37	18	F	cp	R	−2.75		6 mm	myp 3 mm	3
			hypertension	L	−2.25	(L) RD	6 mm	myp 2 mm	
38	15	F	cri du chat syndrome	R	+1.50/2.50×145		6 mm	no fixation	4
			sld	L	+1.00/+1.00×90		6 mm	no fixation	

M, male; F, female; sld, severe learning disabilities; dd, developmental delay; bp, behaviour problems; cp, cerebral palsy; gdd, global developmental delay; sn, sensory neural; aut, autism; onh, optic nerve hypoplasia; disc col, disc coloboma, nai, non-accidental injury; RTA, road traffic accident; L, left; R, right; emm, emmetropia; hyper, hypermetropia; myp, myopia; ast, astigmatism; RD, retinal detachment; ET, esotropia; XT, exotropia.

and 10 years, with an IQ of less than 50, only 21–25% were emmetropic. In school children with cerebral palsy significant refractive errors were found in 50% and strabismus amblyopia in 15%.[18]

All children with severe learning disabilities hence need ocular assessment to rule out ocular defects and refractive errors. A method of screening these patients for significant refractive errors would allow targeting of limited resources and a better utilisation of time. The use of a photoscreener to detect refractive errors, in this specific group of patients, had not previously been described. This study shows that it is a useful accessory when evaluating the ocular status of such children.

The percentage of children in this group with abnormal screening results with the MTI photoscreener was 65.7% for refractive errors, with an additional 7.8% with strabismus alone, which is similar to other studies reporting refractive errors in similar children.

Though screening is best performed before the age where irreversible amblyopia sets in, the photoscreener may also be used to screen children on a regular follow-up basis to detect developmental myopia. The use of the new hand-held autorefractor might also prove to be a useful tool for evaluation of refractive errors in this group of children.[19]

Conclusions

It is possible to photorefract children with severe learning disabilities accurately. Photoscreening may be used as a method of detecting significant refractive errors and strabismus in this group of children and allows targeting of further evaluation of those screening positive. The portable MTI photoscreener could easily be used effectively by any trained health worker in special schools to detect significant refractive errors that may be referred for further specialist evaluation.

References

1. Tuppurainen K. Ocular findings among mentally retarded children in Finland. Acta Ophthalmol (Copenh) 1983;61:634–44.
2. Ottar WL, Scott WE, Holgado SI. Photoscreening for amblyogenic factors. J Pediatr Ophthalmol Strabismus 1995;32:289–95.
3. Oldfield A, Adams M. The effects of music therapy on a group of profoundly mentally handicapped adults. J Ment Defic Res 1990;34:107–25.
4. Howland HC, Braddick O, Atkinson J, Howland B. Optics of photorefraction: orthogonal and isotropic methods. J Opt Soc Am 1983;73:1701–8.
5. Hamer RD, Norcia AM, Day SH, Haegerstrom-Portnoy G, Lewis D, Hsu-Winges C. Comparison of on- and off-axis photorefraction with cycloplegic retinoscopy in infants. J Pediatr Ophthalmol Strabismus 1992;29:232–9.
6. Bobier WR, Braddick OJ. Eccentric photorefraction: optical analysis and empirical measures. Am J Optom Physiol Optics 1985;62:614–20.
7. Wesemann W, Norcia AM, Allen D. Theory of eccentric photorefraction (photoretinoscopy): astigmatic eyes. J Opt Soc AM 1991;8:2038–47.
8. Atkinson J, Braddick O, Bobier B, Anker S, Ehrlich D, King J, et al. Two infant vision screening programmes: prediction and prevention of strabismus and amblyopia from photo- and videorefractive screening. Eye 1996;10:189–98.
9. Morgan KS, Kennemer JC. Off-axis photorefractive eye screening in children. J Cataract Refract Surg 1997;23:423–8.
10. Atkinson J, Braddick OJ, Durden K, Watson PG, Atkinson S. Screening for refractive errors in 6–9 month old infants by photorefraction. Br J Ophthalmol 1984;68:105–12.
11. Morgan KS, Johnson WD. Clinical evaluation of a commercial photorefractor. Arch Ophthalmol 1987;105:1528–31.
12. Cooper CD, Bowling FG, Hall JE, Colville DJ, Dortmans RJ, Munch J, et al. Evaluation of photoscreener instruments in a childhood population. 1. Otago. Aust NZ J Ophthalmol 1996;24:347–55.
13. Kennedy RA, Sheps SB. A comparison of photoscreening techniques for amblyogenic factors in children. Can J Ophthalmol 1989;24:259–64.
14. Tong PY, Enke-Miyazaki E, Bassin RE, Tielsch JM, Stager DR, Beauchamp GR, et al. The National Children's Eye Care Foundation Vision Screening Study Group. Screening for amblyopia in preverbal children. Ophthalmology 1998;105:856–63.
15. Howland HC, Sayles N. Photorefractive studies of normal and handicapped infants and children. Behav Brain Res. 1983;10:81–5.
16. Mackie RT, McCulloch DL, Saunders KJ, Day RE, Phillips S, Dutton GN. Relation between neurological status, refractive error, and visual acuity in children: a clinical study. Dev Med Child Neurol 1998;40:31–7.
17. Kennerley Bankes JL. Eye defects in mentally handicapped children. BMJ 1974;II:533–5.
18. Black P. Visual disorders associated with cerebral palsy. Br J Ophthalmol 1982;66:46–52.
19. Harvey EM, Miller JM, Wagner LK, Dobson V. Reproducibility and accuracy of measurements with a hand held autorefractor in children. Br J Ophthalmol 1997;81:941–8.