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REVIEW

To prescribe or not to prescribe? Guidelines for spectacle prescribing in infants and children

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This paper discusses the considerations for prescribing a refractive correction in infants and children up to and including school age, with reference to the current literature. The focus is on children who do not have other disorders, for example, binocular vision anomalies, such as strabismus, significant heterophoria or convergence excess. However, refractive amblyogenic factors are discussed, as is prescribing for refractive amblyopia. Based on this discussion, guidelines are proposed, which indicate when to prescribe spectacles and what amount of refractive error should be corrected. It may be argued that these are premature because there are many questions that remain unanswered and we do not have the quality of evidence that we would like; the clinician, however, must make decisions on whether and what to prescribe when examining a child. These guidelines are to aid clinicians in their current clinical decision making.

Key words: amblyopia, anisometropia, astigmatism, children's vision, hyperopia, myopia, refractive error

There are numerous guidelines that have been published to help optometrists and ophthalmologists when prescribing for refractive errors in infants and children. The American Academy of Ophthalmology has published guidelines based on consensus of opinion among an expert panel,[1] while Miller and Harvey[2] suggested recommendations based on consensus among members of the American Association for Pediatric Ophthalmology and Strabismus (AAPOS). The American Optometric Association provides guidelines for correction of hyperopia and myopia based on consensus among expert optometrists,[3,4] and Blum, Peters and Bettman[5] suggested guidelines for referral from vision screening, based on consensus among optometrists and ophthalmologists. The Royal College of Ophthalmologist guidelines[6] were developed by a group of different eye-care professionals, including paediatric ophthalmologists, orthoptists, an ophthalmic epidemiologist and an optometrist. Several of these guidelines are only for a single age (see Directorate of Continuing Education and Training [DOCET] recommendations in Farbrother[7]), an unspecified age[6] or a wide range of ages or refractive errors.[3]

Some authors have also developed recommendations. Leat, Shute and Westall[8] and Leat[9] previously published guidelines on prescribing for infants and children, which were based on the best available evidence at that time. Bobier[10] provided evidence-based guidelines for infants and young children up to the age of three years, which are similar in many respects to those given by Leat, Shute and Westall.[8] Marsh-Tootle[11] and Ciner[12] published quite comprehensive recommendations in their textbook chapters.

The purpose of this paper is to review the current evidence, to update these guidelines and to provide more detail, so that the clinician can see how each guideline relates to the current evidence. Although there are many research questions that still need to be answered, the clinician has to make a management decision regarding the child who sits in the chair today. The proposed guidelines are to assist such decisions, based on our

current level of knowledge. Of necessity, these must be reviewed frequently, as knowledge in this area is rapidly expanding.

The proposed guidelines concentrate on the management of refractive error. Prescribing as part of the management of ocular misalignment (heterotropia, significant heterophoria) or convergence excess is not covered in detail; refractive amblyogenic factors, however, are discussed, as is prescribing for refractive amblyopia.

The format of the paper is as follows. First, the main considerations for prescribing from birth to six years of age, followed by school-age children, are discussed, together with the best research evidence that exists to guide a decision to prescribe. When evidence from research is scarce or poor, clinical opinion is added. The guidelines, which result from this discussion, are provided in tabular format (Table 2) and this is followed by notes that relate to this table.

INFANTS AND CHILDREN FROM BIRTH TO SIX YEARS

When considering prescribing glasses for a young child (birth to six years), the following questions must be considered:

1. Is the refractive error within the normal range for the child's age?
2. Will this particular child's refractive error emmetropise?
3. Will this level of refractive error disrupt normal visual development or functional vision?
4. Will prescribing spectacles improve visual function or functional vision?
5. Will prescribing glasses interfere with the normal process of emmetropisation?

The evidence which helps the clinician to answer each of these questions is reviewed below.

Is the refractive error within the normal range for the child's age?

To answer this question we need to know the natural history of the refractive error and the normal range at each age.

NATURAL HISTORY OF REFRACTIVE ERROR FROM BIRTH TO THREE YEARS

There is now general agreement that the range of refractive errors is wider at birth and in the first year of life than in later childhood, that most infants are hyperopic and that the average cycloplegic refractive error is approximately +2.00 D[13,14] with a standard deviation of approximately 2.00 D. There is some uncertainty regarding the changes in the first three months, with some studies showing that the average refractive error increases during this time and others suggesting that it remains static or decreases.[14,15] From three months to 12 months, there is a period of fast emmetropisation as shown by longitudinal[15–17] and clinical cross-sectional studies.[14] In a predominantly white sample, Mutti and colleagues[16] showed that the average cycloplegic spherical equivalent decreases from 2.16 D at three months to 1.36 D at nine months. This is followed by a period of slower change until two years for hyperopes and four to five years for myopes.[13,14,18,19] A more recent, population-based, cross-sectional, Multi-Ethnic Pediatric Eye Disease (MEPED) study[18] has shown differences between ethnic groups. There was a higher prevalence and mean hyperopia in Hispanic children compared with African Americans. Table 1 shows a summary of the means and lower and upper 95% limits of cycloplegic spherical refractive error according to age calculated from 1.96× the standard deviation from studies which provide this information.[14,16,18,19]

A few infants are myopic at birth and most of those who are either myopic or hyperopic will emmetropise.[13,20,21] The rate of emmetropisation is generally proportional to the initial error. Thus, those who start off close to emmetropia or with a low amount of hyperopia show little change, while those who have higher ametropia generally show greater and faster changes.[16,22]

There is also a higher prevalence of astigmatism at birth, with as many as 69 per cent of full-term newborns having astigmatism 1.00 D or more.[23] In most populations there is a decrease in both the prevalence and degree of astigmatism in the first few years. Of the studies with larger samples, eight to 30 per cent have 1.00 D or more of astigmatism at one to two years, four to 24 per cent at three to four years and two to 17 per cent at six to seven years[24] (see Harvey and colleagues[24] for more detail). The longitudinal study of Abrahamsson and colleagues[25] found that 90 per cent of Swedish children with astigmatism 1.00 D or more over the age of one year experienced a decrease in their astigmatism.[25] Harvey and colleagues[24] found a sustained and higher prevalence of astigmatism in a Native American population. Those studies that show a decrease in prevalence are not in agreement about when this process ends, that is, at what age does the prevalence of astigmatism stabilise and become adult-like? Cross-sectional studies by Mayer and colleagues[14] and Atkinson, Braddick and French[26] showed that the prevalence stabilises by 1.5 years. Cross sectional data from Gwiazda and colleagues[27] show a decreasing prevalence until approximately three years, while their longitudinal data show that it does not stabilise until four to five years.[13,28]

As with spherical error, the rate of decease of astigmatism is generally associated with the initial level,[22,29] with those with higher amounts usually decreasing more rapidly. With regard to the type of astigmatism, there is a higher prevalence of all types in infancy. Significant with-the-rule (WTR), against-the-rule (ATR) and oblique astigmatism are all more common in young children than adults.[14,22,27] Of these types, oblique astigmatism is the least common.[14, 22] There is general agreement that all types of astigmatism decrease, with infants losing approximately two-thirds of their astigmatism between nine and 21 months,[22] and that most of this loss occurs in the first 1.5 to two years of life.[13,14,26–28] Some studies show that WTR decreases more rapidly,[22] while others show that ATR is lost more rapidly, even switching to WTR in some cases.[27]

Most studies have shown that anisometropia is more common in infants than adults. Varghese and colleagues[23] and Zonis and Miller[30] reported that 30 and 17 per cent of newborns, respectively,

Mayer and colleagues[14] (clinical, cross-sectional, predominantly white population)				MEPED study[18] (cross-sectional, population based, based on right eye data)								Mutti and colleagues[16] (population sample, longitudinal, predominantly white)			
				African American				Hispanic							
Age (months)	Mean SE (D)	Lower 95% range (D)	Upper 95% range (D)	Age (months)	Mean SE (D)	Lower 95% range (D)	Upper 95% range (D)	Age (months)	Mean SE (D)	Lower 95% range (D)	Upper 95% range (D)	Age (months)	Mean SE (D)	Lower 95% range (D)	Upper 95% range (D)
1	2.2	-1.1	5.5												
1.5	2.1	-0.2	4.4												
2.5	2.4	-0.3	5.1												
4	2.0	-1.2	5.2												
6	1.8	-0.8	4.4									6	2.2	-0.4	4.7
9	1.3	-1.0	3.6	6–11	0.6	-2.2	3.4	6–11	1.3	-1.5	4.1	9	1.4	-0.7	3.4
												Ingram and Barr[19] (population sample, longitudinal, predominantly white)			
12	1.6	0.0	3.2									12	0.95	-1.2	3.1
18	1.2	-0.6	3.1	12–23	0.7	-1.2	3.3	12–23	1.0	-1.18	3.9				
24	1.2	-0.5	2.9												
30	1.3	-0.6	3.1	24–35	0.9	-1.7	3.5	24–35	1.1	-1.7	3.8				
36	1.0	-0.6	2.6	36–47	1.1	-1.7	3.9	36–47	1.3	-1.4	4.0	42	1.1	-1.0	3.2
48	1.1	-0.6	2.9	48–59	1.1	-1.7	4.0	48–59	1.4	-1.2	4.0				

Table 1. Means and upper and lower 95% ranges of cycloplegic spherical refractive error according to age. The various data are placed to compare equivalent or nearly equivalent ages across studies. MEPED = Multi-Ethnic Pediatric Eye Disease, SE = spherical equivalent

have anisometropia greater than 1.00 D. Ingram, Traynar and Walker[31] and Abrahamsson, Fabian and Sjöstrand[32] found that spherical anisometropia remains more common in children compared with adults up to at least four years of life, while the more recent, population-based MEPED study[33] found differences between ethnic groups, the prevalence of anisometropia decreasing from the first year to the second year of life in children of Hispanic origin, but not for African-American children. The studies of Abrahamsson, Fabian and Sjöstrand[32] and Ingram, Traynar and Walker[31] were longitudinal and reported that while approximately seven to 11 per cent of one to four year old children have spherical anisometropia of 1.00 D or more (compared with zero to five per cent of school children[34–36]), it is not the same children who make up this percentage. Some children gain anisometropia during this period, while others lose it.[31,32] This led Abrahamsson, Fabian and Sjöstrand[32] to postulate that there are different rates of emmetropisation between the two eyes, resulting in 'transient' anisometropia. It is thought that these transient anisometropias are of relatively lower level, for example, 2.00 or 2.50 D or less and may not lead to amblyopia. Higher levels of anisometropia (3.00 D or more) are more likely to remain.[37]

NATURAL HISTORY OF REFRACTIVE ERROR IN THREE- TO SIX-YEAR-OLDS

There is less change occurring during this period of life. Gwiazda and colleagues[13] showed that there is still a slow movement of the refractive error towards emmetropia during this period. This was evidenced by the finding that the smallest standard deviation of the population's spherical equivalent refraction occurred at six years,[13] at which age the mean is 0.70 to 1.00 D.[38,39] There is also less change occurring in astigmatism in this age group compared with younger children, although the longitudinal studies of Gwiazda and colleagues[13,28] showed that there is still some decrease in astigmatism until approximately four to five years.

	When to consider prescribing	What to prescribe	Comments, rationale and references
Hyperopia			
1.	Outside the 95% range of refraction at any age according to any currently available data. This guideline could be applied to other refractive errors also, for example, astigmatism.	*Prescribe so as to leave the uncorrected hyperopia somewhat above the mean for the age (so as to give a slightly greater than average stimulus for emmetropisation—see text)*	See Table 1 and Figure 1 for currently available data, which give spherical equivalent and 95% confidence limits spanning the ages zero to 4 years
2.	3 to 6 months if outside the 95% range	In addition to the level of hyperopia determined by cycloplegic refraction, factors that would indicate correction are VA poorer than 6/100 plus non-cycloplegic (Mohindra) refraction that is high[15] and presence of against-the-rule astigmatism.[13] Give a partial prescription for both cylinder and sphere. Prescribe for sphere as in 1.	Mutti and colleagues[15] do not give a value of what exact level of Mohindra refraction would be considered as 'high', but from their data it appears that approximately ≥3.25 D of spherical equivalent is outside the normal range (they subtract a correction factor of 0.75 D from the gross retinoscopy)
3.	≥3.50 D in one or more meridian at 1 year of age upwards	Give a partial prescription. Atkinson's protocol, based on the refraction in plus cylinder format, at this age was: Sphere: prescribe 1.00 D less than the least hyperopic meridian Cylinder: prescribe half of the astigmatism, if >2.50 D Or use the approach in 1 above to determine the correction for hyperopia.	This is based on the randomised clinical trials of Atkinson and colleagues[46] and the natural history study of Ingram and colleagues[106]
4.	>2.50 D at 4 years upwards	*Still give a partial correction for hyperopia, undercorrecting by approximately 1.00 to 1.50 D, which is the mean hyperopia at this age. This undercorrection is not because of emmetropisation (which is almost completed at this age), but because the child does not require full correction of hyperopia for good function.*	This is based on studies of visual function and functional vision[25,64,65] and Mayer and co-worker's upper 95% range which was 2.6 at 3 years and 2.9 at 4 years.[14] For the African American and Hispanic populations, a slightly higher value of >3.50 D would be justifiable (see Table 1).
5.	≥1.50 D in the school years without symptoms Regarding lower amounts with signs or symptoms, see text.	A full or near full correction may be given at this age, as emmetropisation has essentially ended[9,11]	Studies on visual function show that hyperopia ranging from ≥1.00 D to ≥2.00 D may impact visual function and functional vision[83–86]
Astigmatism			
6.	>2.50 D at 15 months of age upwards	Give partial correction up to 3 to 4 years by which time emmetropisation is largely completed, *that is, decrease cylinder by 1.00 D or give 50%*[10,46]	Based on 15 months being the most critical period for the development of meridional amblyopia[55] and population studies, which show that approximately 5 to 10% of the population have this amount of astigmatism.[13,22,26–28] This is also the criterion used in the study by Atkinson and colleagues[46] for correction of astigmatism.
7.	≥2.00 D at 2 years of age upwards	Give partial cylinder up to 3 to 4 years, after which give full cylinder[46]	Based on findings of better VA in children whose astigmatism was corrected at this age[20] and at 2 years approximately 5 to 10% have astigmatism ≥2.00 D[13,22,27]
8.	≥1.50 D at 4 years upwards	Give full cylinder, *although in cases of previously uncorrected high astigmatism, a reduced prescription may be given initially, to allow the child to adapt*	Cowen and Bobier[107] found that the 95th percentile for astigmatism was 1.25 D in children of mean age 4 years. Five per cent or less have ≥2.00 D and 5 to 20% have between 1.00 and -2.00 D astigmatism at this age.[13,26–28] Roch-Levecq and colleagues[66] reported functional benefits of correcting ≥1.50 D astigmatism in 4- to 5-year-olds. Also see clinical recommendations.[11]
9.	Correct oblique astigmatism ≥1.00 D from 1 year onwards	*My clinical instinct would be to correct approximately ¾ to the age of 2 and then correct the full amount*	Oblique astigmatism is a risk factor for amblyopia.[25] Mayer and colleagues[14] show that oblique astigmatism of ≥1.00 D is rare after 12 months.
10	≥0.75 D at school age without symptoms. For lower amounts with signs and symptoms, see text.	Prescribed as in 8 above	Congdon and colleagues[96] found that correction of this level improved VA

Table 2. Guidelines for prescribing for refractive error in children. Guidelines in italics are those that are based on clinical opinion rather than a research evidence base. MEPED = Multi-Ethnic Pediatric Eye Disease, VA = visual acuity

	When to consider prescribing	What to prescribe	Comments, rationale and references
Anisometropia			
11.	Anisometropia with amblyopia	Correct the full anisometropia and astigmatism but correct the hyperopia or myopia according to age	
12.	≥3.00 D at 1 year upwards	Prescribe the full anisometropia if amblyopia is already present (see above). *If there is no amblyopia, a reduced anisometropic prescription could be considered (for example, prescribing 1.00 D less than the full difference between the eyes) and prescribing for astigmatism and spherical error according to age. According to Marsh-Tootle,[11] if amblyopia can be demonstrated to be absent, a prescription is not necessary.*	This is based on reports by Abrahamsson and colleagues[37] that ≥3.00 D of anisometropia is less likely to be transient
13.	≥1.00 D but <3.00 D after 1 year of age	Monitor first over 4 to 6 months. If it persists, prescribe as in 11 above.	This is based on reports of transient anisometropia[31,32,36]
14.	≥1.00 D of spherical hyperopic anisometropia, ≥2.00 D of spherical myopic anisometropia or ≥1.50 D of cylindrical anisometropia after 3.5 years of age	Prescribe as in 11 above. If amblyopia is absent, may monitor first.	These levels of anisometropia have been found to be amblyogenic at this age[32,60,61]
Myopia			
15.	*<-5.00 D, during the first year*	*Reduce by 2.00 D. Undercorrect because emmetropisation does occur for myopes.*[13,21]	*Clinical opinion and guidelines agree to prescribe when ≤-5.00 D*[1,12] *but not less than -3.00 D.*[4] *In the MEPED study,*[18] *less than 1% of children between 6 to 72 months had <4.00 D* of myopia.
16.	*<-2.00 D* myopia from one year or when child is walking	*Reduce by 0.50 D or 1.00 D until school age. Undercorrect because some emmetropisation is still occurring.*[13,21]	The MEPED[18] study showed that <-1.2 to -1.7 is the lower end of the 95% range in African Americans and Hispanics in the US. *Clinical opinion varies widely, between correcting -0.75 D to ≤-4.00 D, in infants and toddlers.*[1,2,4,7,11,101,108]
17.	4 years to early school years	<-1.00 D *or lower amounts if it improves VA and the child appreciates it, that is, correct for function. Can give full correction at this age.*	Congdon and colleagues[96] found that correction of ≤0.75 D improved VA. *Clinical opinion suggests correcting <1.00 D to ≤1.50 D in preschoolers*[2,11,101,108] *and <-0.50 D to <-2.00 D in school children.*[4,8,11,100–102]
18.	School age myopia	Prescribe full correction. Cases of myopia with near esophoria and larger lag of accommodation (>0.43 D) or with shorter habitual reading distances may be considered for a +2.00 D addition progressive lens.	Guideline for bifocal correction based on the Correction of Myopia Evaluation Trial study for 6- to 11-year-olds[81,82]
Aphakia or pseudophakia			
19.	In first few months	Overcorrect by 2.00 to 3.00 D, because the child's world is near, reducing to a single vision intermediate add of 1.00 to 1.50 D by 1 year.[8,9] Contact lenses are often the correction of choice.	Intraocular lenses may be implanted at surgery[109]
20.	2 to 3 years onwards	Distance correction with bifocals when the child can adapt to these	They will require bifocal/progressive addition lens correction for life[109]

Table 2. ***Continued***

Will this particular child's refractive error emmetropise?

Although the majority of children will emmetropise, this is not true for all. We would like to be able to predict those who will fully emmetropise, as there is likely to be no need to prescribe spectacles in these cases, at least in the early years of life. Alternatively, those who will not emmetropise and who have a high refractive error might benefit from spectacle correction. There is some evidence that children with very high refractive errors are less likely to emmetropise. This is suggested by animal studies[40] and by some human data.[15,22] Mutti and colleagues[15] showed how the probability of emmetropisation decreases as hyperopia increases (Figure 1). The probability is less than 50 per cent for three-month-olds, who had a cycloplegic spherical equivalent refraction greater

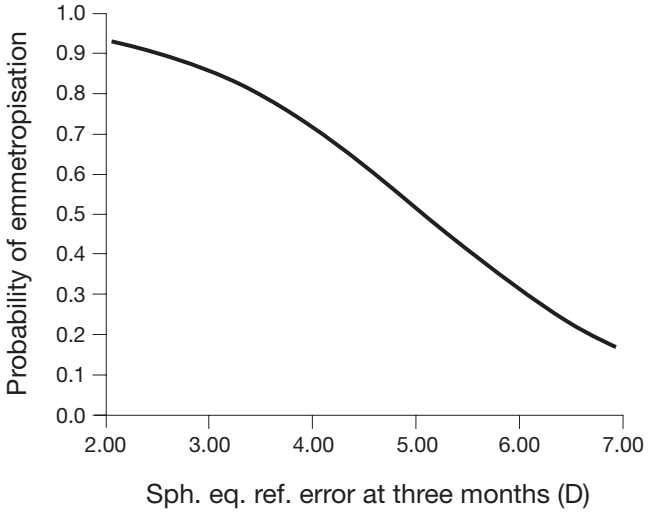

Figure 1. The probability of reaching 2.00 D by 18 months of age as a function of the level of cycloplegic spherical equivalent at three months of age. From Mutti DO, Mitchell GL, Jones LA, Friedman NE, Frane SL, Lin WK, Moeschberger ML, and Zadnik K. Accommodation, acuity, and their relationship to emmetropization in infants. *Optom Vis Sci* 2009; 86: 666–676. Reproduced with permission.

than 5.00 D. Apart from the cycloplegic refraction, visual acuity (VA) poorer than 6/100 and a higher non-cycloplegic Mohindra retinoscopic result also predicted which infants would emmetropise. Gwiazda and colleagues[13] found that hyperopic children with WTR astigmatism show different patterns of emmetropisation compared with those with ATR astigmatism. Although both groups lost their astigmatism, the hyperopic children with ATR astigmatism at six months maintained their hyperopia (approximately 2.00 D on average), while those with WTR astigmatism lost their hyperopia (ending up at approximately 0.75 D hyperopic at age six years). In contrast, Ehrlich and colleagues[22] did not find a similar relationship. Ingram and colleagues[41] showed that there is an association between lack of emmetropisation and the presence of strabismus. What is not clear is whether strabismus interferes with emmetropisation or whether those who do not emmetropise, and thus maintain their higher hyperopia, are more likely to develop strabismus.

Apart from the predictive factors described above, namely, level of ametropia, VA and type of astigmatism, which are still not as accurate as we would like, the other main tool that we have to predict emmetropisation is to monitor the refraction. Those that emmetropise lose approximately one-half of their spherical equivalent refractive error in the first year[42] and approximately one-third between nine and 21 months.[22] With regards to astigmatism, approximately two-thirds of the astigmatism is lost between nine and 21 months.[22]

Currently, there is no way to predict with certainty whether a particular child's anisometropia (measured at one point in time) is transient or will remain into adulthood (with the risk of amblyopia). There is no simple relationship between the anisometropia measured at one time, whether spectacles are prescribed and whether the anisometropia persists or amblyopia develops.[32] Nevertheless, if the anisometropia is 3.00 D or more at one year, there is a high risk of it remaining and resulting in amblyopia,[37] with 30 per cent of those with this level of anisometropia showing increasing anisometropia over the following nine years, 60 per cent developing amblyopia and 90 per cent retaining anisometropia of 1.00 D or more at the age of five years. Children with lower amounts of anisometropia, for example, up to 2.00 D, are more likely to lose it.[36,43] To summarise, currently the only methods we have to determine if a particular case of anisometropia is transient and therefore does not need intervention are:

1. monitor a child over a period of four to six months
2. consider the visual acuities—if amblyopia is already present it requires treatment and indicates that the anisometropia has been present for some time
3. be aware that higher levels of anisometropia (for example, 3.00 D or more and particularly 5.00 D or more[37]) are less likely to be transient.

Lastly, children with low vision are less likely to fully emmetropise.[44] Therefore, these children can be prescribed, with the main consideration being to optimise visual function.

Will this level of refractive error disrupt normal visual development or functional vision?

There is evidence that uncorrected high refractive error (hyperopia, astigmatism and anisometropia) during the first few years of life is a risk factor for amblyopia. The studies of Abrahamsson and colleagues[25] and Ingram and colleagues[45] indicate that there is an increased chance of monocular or binocular amblyopia in one-year-olds with 3.50 D or more in one meridian, in four-year-olds if the most hypermetropic meridian is 2.00 D or more and if there is increasing or unchanged refractive error between one and four years. Atkinson and colleagues[20,46] showed that partial correction of hyperopia greater than 3.50 D at nine to 11 months resulted in improved VA at four years of age and may reduce the incidence of esotropia. Aurell and Norrsell[47] found that infants who maintained more than 4.00 D of hyperopia were more likely to develop

esotropia. Clinical retrospective studies of children with high bilateral uncorrected hyperopia have also shown a connection between poorer acuity and high hyperopia. In children with 5.00 D or more, 25 to 43 per cent have acuity of 6/12 or worse[48,49] and 87 per cent have acuity worse than 6/6.[50] Poor accommodation and stereopsis have also been associated with high hyperopia.[51] It has been suggested[52] that it is hyperopic children with poorer accommodation who may develop amblyopia and, consistent with this, Schoenleber and Crouch[53] found that none of their high hyperopes who were able to co-operate for amplitude testing had sufficient accommodation to maintain a 50 per cent reserve of accommodation for extended periods of viewing.

With regards to astigmatism, researchers have sought associations between meridional amblyopia and astigmatism with mixed results, although they have shown that recognition acuity and other measures of visual function are decreased in astigmatism. The age of the child when the astigmatism is present seems to be a factor. The visual system may not be very sensitive to uncorrected astigmatism in the first year of life[54] but from one year onwards, there is evidence that uncorrected astigmatism, particularly oblique astigmatism, is associated with meridional amblyopia.[20,25,55] Dobson and colleagues[56] found no evidence of meridional amblyopia in six-month-olds up to three-year-olds with astigmatism of 2.00 D or more, although the acuity for both vertical and horizontal gratings was decreased in children with astigmatism, which may be because most of the children with astigmatism were also hyperopic. In three- to four-year-olds, 1.50 D or more of astigmatism is associated with poorer recognition acuity, such that for every dioptre increase in cylinder, there was a half-line decrease in VA.[57] In older children with 1.00 D or more of astigmatism (first corrected at the age of 4.75 to 13.5 years), a range of visual functions (grating acuity, letter acuity, vernier acuity, contrast sensitivity and steroacuity) is impaired.[58] After optical correction, there was some improvement up to one year but deficits still remained. The results of Harvey and colleagues[58] indicate that correcting astigmatism at 4.75 years or later may be too late to allow development of optimal visual function, while the results of Atkinson and colleagues[20] indicate that we should correct astigmatism of 1.00 D or more as early as two years to optimise acuity development. If, however, we were to correct the levels based on Atkinson and colleagues,[20] we might find ourselves prescribing for up to 20 to 45 per cent of the population, because according to some studies, 20 to 45 per cent of two-year-olds still have 1.00 D or more of astigmatism.[13,14,27] This would not be clinically reasonable. Thus, the suggested values for prescribing for astigmatism in Table 2 are based on the 95 per cent upper limits of the distribution of astigmatism with respect to age, in addition to the evidence that higher levels of astigmatism are associated with visual function deficits.

We have already seen that anisometropia of 3.00 D or more at one year is likely to cause amblyopia,[37] as is persisting anisometropia of 1.00 D or more. Donahue[59] showed that anisometropia after the age of three years is more likely to cause amblyopia than before that age. It also appears that different types of anisometropia might be more or less likely to cause amblyopia. In a cross-sectional study of clinic patients, Weakley[60] found that more than 1.00 D of spherical hyperopic anisometropia was associated with amblyopia and decreased steroacuity, while spherical myopic anisometropia had to be greater than 2.00 D before amblyopia occurred. Cylindrical anisometropia (either myopic or hyperopic) had to be greater than 1.50 D before amblyopia occurred. Weakly also found that the degree of amblyopia increased with the amount of anisometropia (of any kind). Dobson and colleagues[61] found somewhat similar results; amblyopia and intraocular differences of VA were associated with 1.00 D or more of hyperopic anisometropia and 2.00 to 3.00 D or more of cylindrical anisometropia. Stereoacuity seemed to be more sensitive to the presence of anisometropia; 0.50 D or more of hyperopic, myopic or cylinder anisometropia was associated with a decrease of stereoacuity.

Will prescribing spectacles improve visual function or functional vision?

By visual function, we mean psychophysical measures of the sensory capability of the visual system, such as VA or contrast sensitivity, while functional vision is used to refer to how the person as a whole is able to use vision in performing everyday tasks, which are dependent on vision.[62]

With regards to visual function, there are few randomised clinical trials that have studied the effects of a prescription in the pre-school age group. The two studies by Atkinson and colleagues[20,46] were randomised clinical trials, in which one group of nine- to 11-month-olds with hyperopia of 3.50 D or more in the most hyperopic meridian was given a partial spectacle correction and the other group (controls) was not. The prescribing protocol can be seen in Table 2, guideline 3. The incidence of strabismus and amblyopia was reduced in the children who were prescribed glasses compared with the controls in the first study but the incidence of strabismus was not reduced in the second study. They were followed until the age of four years, at which time more children in the corrected group obtained a VA of better than 6/9 than in the control group. The only other such clinical trial is that by Ingram and colleagues,[63] in which infants aged six months with +4.00 D or more of hyperopia in one meridian were randomly assigned to spectacle or no spectacle treatment. The protocol was a little unusual as cycloplegic retinoscopy was performed at one metre but a 1.75 D correction factor was subtracted. The spectacle prescription appears to have been a dioptre undercorrected in both meridians, that is, the full astigmatic correction was given. They found no impact of the spectacle correction on the incidence of strabismus, even when compliance with wear was taken into account. They found a significant difference in VA between the spectacle and non-spectacle wearers only when compliance was taken into account, with the compliant spectacle wearers having better VA. Differences between the studies are that the studies of Atkinson and colleagues[20,46] prescribed a smaller

percentage of the refraction and prescribed a little later in life than the Ingram and colleagues[63] study (nine months compared with six months). It also appears that in the Ingram and colleagues[63] study, any controls who developed strabismus during the study were prescribed treatment involving spectacles, occlusion and/or surgery.

There is clinical evidence that amblyopia due to high isometropic hyperopia responds to treatment with refractive correction,[49,50,52,53] although the time-course for improvement varies from one to several years.[50,52] Many children in these studies achieved a final VA of 6/7.5 or better.[49,52] On the other hand, the outcomes for other children were not so good. The percentage of children whose final VA with spectacle correction was 6/12 or poorer ranged from 11 to 50 per cent.[48–50,53] Surprisingly, three of these studies found that the final outcome of VA was not dependent on the age of first spectacle prescription,[49,50,52] which ranged from seven months to 12 years. To conclude, these clinical studies indicate that moderate improvements can be obtained for children who already have bilateral refractive amblyopia due to hyperopia, but do not indicate whether we can prevent amblyopia by even earlier spectacle prescription. The best current evidence for prevention is based on the randomised clinical trials of Atkinson and colleagues[20,46] and Ingram and colleagues[63] described above.

With regards to functional vision, there are studies that have shown that young children with uncorrected hyperopia perform more poorly on some tests. Atkinson and colleagues[46] followed their corrected and uncorrected hyperopic infants to the age of 5.5 years. At the age of three years, they still had 3.50 to 4.00 D of hyperopia on average. At 5.5 years, they faired more poorly on a range of visuomotor and visuocognitive tests and had poorer visual attention than the emmetropic children (although the authors note that there was no significant difference between the corrected versus the uncorrected hyperopic children). In a small study, Shankar, Evans and Bobier[64] showed that four- to seven-year-old children with more than 2.00 D of uncorrected hyperopia had poorer emergent literacy skills measured on several tests than emmetropes, although in this study the children with hyperopia performed equally well on tests of visual motor and visual perceptual skills. The fact that both Atkinson and colleagues[20,46] and Shankar, Evans and Bobier[64] found poorer performance on some but not all tests indicates that the poorer performance of the hyperopic children does not seem to be part of a general developmental delay. The results of Rosner and Rosner[65] indicate that prescribing for hyperopia greater than 2.50 D before the age of four years may reduce deficits in visual perceptual skills later in life. In a recent study, Roch-Levecq and colleagues[66] showed that to three- to five-year-olds with uncorrected hyperopia of 4.00 D or more, three year olds with 2.00 D or more of astigmatism and four- to five-year-olds with 1.50 D or more of astigmatism had poorer visuomotor skills and performance intelligence scores than a control group with lower refractive errors. Importantly, after the children with these higher ametropias were prescribed glasses, their visuomotor skills performance improved to the level of the control group in only six weeks, although it must be noted that they were not followed longer than six weeks and therefore a Hawthorne effect is almost certainly in operation. These studies do not prove a causal relationship between hyperopia and these skills, because there are likely to be many other influences, such as IQ and family background, which interact in a complex fashion. To prove a causal relationship, the impact of spectacle correction should be studied either over a longer period of time (to avoid a Hawthorne effect) or in a clinical trial. Thus, we do not have the quality of evidence that we would like regarding this question and this is an area that requires more research. Therefore, the guideline is not based on these studies alone but also on studies of risk factors for amblyopia and epidemiological studies.[14,18,25]

Will prescribing glasses interfere with the normal process of emmetropisation?

Experimental animal studies clearly show that refractive correction will influence the development of refractive error[67,68] and therefore we need to consider this possibility in humans also. The human evidence of whether a prescription for glasses has some effect on emmetropisation is equivocal and there are few randomised clinical trials that can give solid evidence in humans. In the study by Atkinson and colleagues,[46] there was no difference in the reduction of hyperopia comparing those who were fitted with a partial prescription and the controls. Ingram and colleagues[41] also found no significant difference overall. However, when they re-analysed their intervention group according to the amount of spectacle lens wear, they did find a difference—the compliant spectacles wearers emmetropised less than the non-compliant spectacle wearers or the controls. In the study by Ingram and colleagues[41] it appears that a greater percentage of the refractive error was corrected in the spectacle prescription compared with the studies by Atkinson and colleagues,[20,46] which may have caused the different results—there would have been a smaller stimulus for emmetropisation. Friedman, Neumann and Abel-Peleg[48] reported retrospective clinical data of 39 children with high levels of ametropia, who were treated with spectacle correction at one to 2.5 years (we are not told whether this was a partial or full correction). Sixty-four per cent of the hyperopic eyes, 60 per cent of the astigmatic eyes and 50 per cent of the myopic eyes showed some decrease of the ametropia up to the age of seven to 10 years. However, this was not compared with a control group that had no correction. An interesting study that may have relevance involves adult monovision contact lens wearers,[69] which showed that a refractive difference developed between the eyes. If adults are influenced by correction, we may anticipate a greater effect in young children. Therefore, with the current information, it behoves the clinician to be conservative, that is, we cannot assume that prescribing

glasses does not influence refractive development.

CHILDREN IN THE SCHOOL YEARS

During the school years, there are slightly different considerations. Emmetropisation is essentially complete by six years[13] and the most sensitive part of the critical period is over (although various aspects of vision may not be adult-like until eight years or even until the teenage years and there are different critical periods for different functions[9,70–73]). During these years, the refraction of children with higher hyperopia and with emmetropia remains unchanged, while the refraction of children with moderate hyperopia still shows a drift towards emmetropia up to nine or 10 years of age[74] and early onset myopia commences. Thus, with age, there is a slow movement of the population mean towards emmetropia and then myopia[38,39,75] and a slow increase of the range of refractive error of the population, as shown by an increase in the standard deviation.[13,38,75] From six years onwards, when early onset myopia starts,[13,74] there is also an increase in the prevalence of higher amounts of astigmatism, and in individual children, increases in astigmatism occur simultaneously with increases in myopia.[28] Thus, during these years, correction is more for function, with a consideration of symptoms and school performance.

In the school years, myopia should be corrected for function with full correction. There is no evidence that a partial correction reduces the progression of myopia.[76] In fact, undercorrection may lead to further progression of myopia.[77] There are numerous randomised clinical trials that have examined the impact of progressive lens additions on the progression of myopia.[78–81] Most have shown a small but statistically significant difference, although Edwards and colleagues[80] found no effect in a group of Hong Kong children. Leung and Brown[79] found an effect of the power of the addition, +2.00 D resulting in more myopic control than +1.50 D, and in a cross-over study, Hasebe and colleagues[78] found that earlier intervention resulted in less myopic progression. The largest and most ethnically diverse study was the Correction of Myopia Evaluation Trial (COMET).[81,82] This found that the group fitted with +2.00 D addition progressive addition lenses had less myopic progression compared with those with single vision lenses. The difference was statistically significant (0.20 D over a three-year period) but was not considered to be clinically significant.[81] A subanalysis, however, showed that myopic children with a larger lag of accommodation (greater than 0.43 for a 33 cm target, which can be measured with dynamic retinoscopy) in combination with a near esophoria gained a clinically significant benefit from progressive addition lenses (0.64 D less myopic progression over three years).[82] Similarly, those with the larger lag of accommodation plus a closer working distance or a lower baseline myopia experienced clinically a significant reduction in myopic progression (0.44 D and 0.48 D, respectively).

In school age children compared with younger children, there are fewer guidelines on what level of hyperopia should be corrected in the absence of symptoms and there are very limited current data on which to make this judgement. The following studies give some indications of when to prescribe. Mutti[83] presented data from a longitudinal study of school children. Visual acuity was poorer in the children with uncorrected hyperopia (spherical equivalent) of 2.00 D or more compared with those who had a correction. For those who wore glasses and had hyperopia of 1.00 D or more, corrected VA was a line better than uncorrected VA. In other words, uncorrected hyperopia of 1.00 D or more can impact VA. This was for distance VA measured at one point in time. Therefore, it is reasonable to assume that near acuity and acuity for sustained tasks would be more impacted. In this study, they also measured the lag of accommodation. Uncorrected hyperopia of 1.50 D or more was also associated with 2.00 D or more of accommodative lag (at a 4.00 D demand), which is a significant defocus for near work. A recent study in Australia of 12-year-old children found that those with 2.00 D or more hyperopia without glasses did less close work and reading than controls with lower refractions, while the hyperopic children with glasses reported the same amount.[84] Rosner and Rosner[85] reported that first to fifth graders with 1.50 D or more of hyperopia had poorer school achievement than other children and Williams and colleagues[86] found similar results, namely, uncorrected hyperopic children with a total of 3.00 D hyperopia in the two eyes summed had poorer performance on standardised school tests. Two older reviews of the literature concluded that hyperopia (specifically hyperopia 1.00 D or more) is associated with poor reading skills (nonspecific reading difficulty).[87,88] It is possible that it is specifically those children, who fail to accommodate for their moderate hyperopia, who are most likely to benefit from a hyperopic prescription for reading,[89] but this is an area that needs more study.[90] Anisometropia is also related to poor reading, although there is no evidence of such a relationship for astigmatism.[87] However, when children with an explicit diagnosis of specific reading disability (dyslexia)[91,92] are considered, there is little evidence of any relationship to refractive error.[93] As mentioned above, an association between performance on tests such as reading and refractive error does not prove causality. When we consider these studies together (those on VA, accommodative lag and poorer reading), there are indications that higher levels of uncorrected hyperopia may have functional impacts on vision and near work. Taking both the modal and median values of hyperopia from among these studies seems to indicate that 1.50 D or more of hyperopia should be considered for correction even in the absence of symptoms. It is clear that more studies are required to confidently answer the question of what level of hyperopia should be corrected at this age.

There is little solid evidence for or against the benefit of correcting lower levels of hyperopia. Correcting small refractive errors generally (myopia, hyperopia, astigmatism and anisometropia) in school children (for example,

0.50 D to 1.00 D for astigmatism or up to 1.50 D for hyperopia) is controversial and there are no solid studies to give guidance. Robaei and colleagues[94] considered the spectacle usage of 12-year-old children with hyperopia of less than 2.00 D or astigmatism less than 1.00 D (termed non-refractive spectacle wearers in this study) and found that 62.2 per cent used their spectacles at least sometimes. In an earlier study of six-year-old children, they found that 42.3 per cent of those with these lower refractive errors were symptomatic before but not after wearing spectacles.[95] In one of the few studies to apply different cut-off criteria to examine the improvement with a spectacle prescription, Congdon and colleagues[96] found that a cut-off of -0.75 D or less of myopia, 1.00 D or more of hyperopia and 0.75 D or more of astigmatism was effective in discriminating six- to 19-year-old children, who gained improvement in VA, although none of their criteria distinguished between the children who did or did not use their spectacles.

On this question of prescribing for low refractive errors, clinical opinion varies. Some clinicians suggest that children with smaller refractive errors (down to 0.75 D) associated with symptoms (asthenopia, difficulty with focusing, headaches) may benefit from spectacle prescription.[8,11,97,98] Other factors that would indicate a prescription for lower levels of hyperopia are reduced uncorrected vision, the presence of esophoria or esotropia (perhaps indicating a bifocal), higher than normal lags of accommodation, difficulty with close work (for example, squinting, blinking or poor attention span) or reports of suspected or diagnosed reading difficulties.[11,99] These smaller prescriptions would usually be given for part-time wear. For myopia, most clinical opinions indicate correcting the refractive error once the child reaches -1.00 D,[11,100,101] although some say a prescription can be considered at less than -0.50 D.[8] Milder and Rubin[102] state that a prescription would usually be required at less than 2.00 D.[102] Certainly, a prescription can be offered once the child starts to notice difficulty with blackboard work.[100]

With all these considerations in mind, the guidelines shown in Table 2 have been developed. They are based on the very few randomised clinical trials that have been undertaken. This is the highest level of evidence. When these are not available, the guidelines are based on epidemiological studies that give the expected age-related range of refraction and longitudinal and cross-sectional studies, including clinical studies, which link refractive error with outcomes. When none or very few of these are available, the guidelines are based on current clinical opinion and other guidelines (shown as italics in Table 2). These show when spectacle prescription would be considered. In the following section, which gives notes on the guidelines, other factors that would influence a prescribing decision are discussed.

There are some instances when spectacle correction is essential. This would include children with anisometropic amblyopia, very high refractions of any kind with reduced VA and children who are aphakic or pseudoaphakic. Children with aphakia or pseudophakia require glasses or contact lenses to correct any residual hyperopia plus a correction for near because they have no accommodation.

NOTES ON MANAGEMENT

In prescribing for higher hyperopes, apart from the level of hyperopia, factors that may give further indication of the need for intervening with a correction are reduced uncorrected vision, reduced corrected VA or stereopsis and whether there is reduced or insufficient accommodation. Accommodation could be measured with dynamic retinoscopy or by amplitude testing depending on the child's age. The clinician should consider if there is excessive lag of accommodation without a correction (in the case of dynamic retinoscopy) or if there is sufficient amplitude of accommodation to overcome the hyperopia and accommodate for a near task, allowing 50 per cent of the amplitude in reserve.[53] Clinical observation and opinion, including the author's own experience, indicate that signs and symptoms such as poor co-ordination, slower development of fine motor skills, reduced attention for near tasks, excessive activity and asthenopia, headaches or learning difficulties in older children are also indicators of the potential benefit from a prescription.[11,12,99,100] Many authors[10–12] recommend monitoring the refraction (hyperopia, myopia or astigmatism) in infants and toddlers before prescribing. Frequently unchanging or increasing refractions are associated with amblyopia.[25,32] This is unless factors such as demonstrable amblyopia indicate prescribing immediately. The other main factor, which will influence one's likelihood of prescribing for hyperopia, is the presence of heterophoria. Correction of hyperopia to optimise alignment (with a bifocal in cases of convergence excess esophoria) is a consideration.[12]

Guideline 1 (Table 2) suggests prescribing if the refraction is outside the 95% limits for a particular age. Guideline 3 (Table 2) is based on the studies of Atkinson and colleagues,[20,46] which indicate functional improvements when children with hyperopia in the least hyperopic meridian of 3.50 D or more were given a partial prescription. For the current data for white children, these guidelines are fairly similar. This is not the case for African American or Hispanic children according to the MEPED study, which shows the higher 95% limit of the spherical equivalent normal range to be greater than 3.50 D. At present, we do not know whether we should follow the guideline based on the functional improvements in English children, which would mean prescribing glasses for more than five per cent of children in the African American or Hispanic groups, or whether we should prescribe only for those who fall outside the 95% range for their ethnicity. The latter approach would indicate that in some way, these ethnic groups are more immune to the functional impact of higher hyperopia or better able to compensate with accommodation.

When prescribing for infants with hyperopia, there are several approaches that could be adopted to determine how much hyperopia to correct. We could pre-

scribe to bring the uncorrected portion just within the normal range, for example, to the 95% limit. This would leave a large stimulus for emmetropisation and therefore potentially encourage a greater amount of emmetropisation. Clinical experience suggests that children who are prescribed in this way may be more at risk of developing esotropia, although evidence from research has not confirmed this. It seems that the child's accommodation cannot overcome the very large uncorrected hyperopia but a correction that is small enough to bring them just within the normal range allows them to accommodate for the remaining hyperopia, resulting in esotropia.[102] Another approach is to prescribe to leave the uncorrected portion equal to the average for the age. This would give the child an average stimulus for emmetropisation, which may not be the optimal stimulus to emmetropisation considering their higher than normal level of hyperopia. Thus, the approach suggested here is to prescribe to leave the uncorrected portion just above the mean for the age, leaving a stimulus for emmetropisation, which is still larger than the average. For example, at one year the mean according to Mayer and colleagues[14] is approximately 1.75 D spherical equivalent (cycloplegic refraction), so the clinician might consider prescribing to leave approximately 2.00 to 2.25 D undercorrected. This is still prescribing to leave the uncorrected portion within the normal limits, as suggested by Marsh-Tootle.[11] Alternatively, the clinician could apply the Atkinson and colleagues protocol,[46] which in practice gives a similar result. If this approach of prescribing and leaving a greater than average stimulus to emmetropisation is used, the child must be monitored very frequently (for example, every month initially) and the parent warned that at the first sign of a strabismus, they should return. If that happens, the prescription should be increased to optimise ocular alignment[12,98] or to the full hyperopic prescription.[102]

In prescribing for any of these young patients, especially when a larger prescription is given, it is imperative to see the child approximately four to six weeks after the prescribing appointment. This allows time for the spectacles to be ordered and dispensed and for the child to adapt to them. At this follow-up visit, the optometrist should question the parents regarding any signs of strabismus and should carefully check for strabismus and changes in phoria, as well as measuring the VA and over-refraction.

In the pre-school years, the general rule for prescription of glasses is that while emmetropisation is active, the refractive error is undercorrected, unless other factors such as the need to treat amblyopia or strabismus or to optimise ocular alignment outweigh the need to leave a stimulus for emmetropisation. Emmetropisation may be active for astigmatism up to four to five years and possibly up to six years for spherical ametropia,[13] and even until nine to 10 years for some moderate hyperopes.[74] Also, while emmetropisation is still active, the optometrist should monitor the child frequently and maintain an undercorrection according to these guidelines. It is tempting not to decrease the prescription, when the child is functioning well and visual function is good. However to prevent any interruption to emmetropisation it would seem prudent to do this. Therefore, the optometrist should remember to advise the parent from the outset that the prescription may have to be changed frequently. If the parents understand that the clinician hopes to decrease the prescription, they are usually happier (parents are always more concerned when a prescription has to be increased).

In cases of anisometropia with amblyopia, refractive correction is the usual first management option. Full refractive correction alone often results in some improvement of VA, most of which occurs in the first four months, although some improvement may continue to occur up to one year.[103] After this four-month period of refractive correction, occlusion therapy may not be necessary in some cases and in those that do require occlusion, the improved VA after a period of spectacle wear may make compliance better.

With respect to correcting myopia in infancy, most myopia in the first year of life can be monitored. Emmetropisation is active, the visual world that is important to babies is close and the visual demands of babies do not include a need for clear distance vision. Therefore, it is only the very high refractive errors that should be corrected. The clinician should be aware that high myopia at this age is associated with prematurity, in particular with retinopathy of prematurity[14,104] and ocular or neurological conditions unless there is a family history of degenerative myopia,[11] so that a referral for an ophthalmological or neurological examination may be warranted. Very high levels of myopia are also associated with amblyopia.[105] From the age of one year, children are starting to explore their environment and take an interest in distance activities and therefore are likely to benefit from a correction, but they do not have a requirement for fully focused distance vision.[10] By reducing the prescription, some stimulus to emmetropisation is maintained.

When prescribing for school children, the author finds that the full non-cycloplegic subjective refraction for occasional or full-time wear can be considered. This means that for children with previously uncorrected high hyperopia, the prescription would be reduced from the retinoscopic result and that generally most prescriptions would be reduced compared with any cycloplegic findings to allow for tonus.

CONCLUSION

This paper has reviewed the evidence that is currently available and has attempted to bring this together to guide the clinician who works with children. There are reasonable data available regarding the natural history of refractive error development for the population as a whole and we have some knowledge of the risk factors for abnormal visual development; however, we currently lack the ability to accurately predict which children will emmetropise. There are also very few studies on the impact of spectacle prescription on the child's visual system and functional vision. Prescribing spectacles when a risk factor is present would seem to

be logical to avoid the development of amblyopia, for example, but without more longitudinal studies and clinical trials we cannot be sure whether this is the case. We can now identify reasonably well the child who is outside the limits of the normal distribution, based on the natural history and clinical data that have been reviewed here. It would be useful to have population-based data published in the format of the clinical data of Mayer and colleagues[14] for the various components of refractive error, so that a more exact idea could be determined of where a child of a particular age lies with respect to the population mean and ranges. We also need to know at exactly what age and level of ametropia we should intervene. This seems particularly problematic with astigmatism, in which effects on visual function, including meridional amblyopia, have been identified at levels of astigmatism that are quite prevalent in the population and therefore might be considered 'normal' for age. It is clear that the field of refractive development and correction is in need of further research.

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